

***OPERATION MANUAL FOR THE SEDIMENT EROSION  
RATE FLUME (SERF)  
SECOND EDITION***

**BDK75 977-09  
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**Developed for the**



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The opinions, findings, and conclusions expressed in this publication are those of the author and not necessarily those of the State of Florida Department of Transportation.

**SI (MODERN METRIC) CONVERSION FACTORS (from FHWA)**  
**APPROXIMATE CONVERSIONS TO SI UNITS**

<b>SYMBOL</b>	<b>WHEN YOU KNOW</b>	<b>MULTIPLY BY</b>	<b>TO FIND</b>	<b>SYMBOL</b>
<b>LENGTH</b>				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
<b>SYMBOL</b>	<b>WHEN YOU KNOW</b>	<b>MULTIPLY BY</b>	<b>TO FIND</b>	<b>SYMBOL</b>
<b>AREA</b>				
in <sup>2</sup>	square inches	645.2	square millimeters	mm <sup>2</sup>
ft <sup>2</sup>	square feet	0.093	square meters	m <sup>2</sup>
yd <sup>2</sup>	square yard	0.836	square meters	m <sup>2</sup>
ac	acres	0.405	hectares	ha
mi <sup>2</sup>	square miles	2.59	square kilometers	km <sup>2</sup>
<b>SYMBOL</b>	<b>WHEN YOU KNOW</b>	<b>MULTIPLY BY</b>	<b>TO FIND</b>	<b>SYMBOL</b>
<b>VOLUME</b>				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft <sup>3</sup>	cubic feet	0.028	cubic meters	m <sup>3</sup>
yd <sup>3</sup>	cubic yards	0.765	cubic meters	m <sup>3</sup>
NOTE: volumes greater than 1000 L shall be shown in m <sup>3</sup>				
<b>SYMBOL</b>	<b>WHEN YOU KNOW</b>	<b>MULTIPLY BY</b>	<b>TO FIND</b>	<b>SYMBOL</b>
<b>MASS</b>				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
<b>SYMBOL</b>	<b>WHEN YOU KNOW</b>	<b>MULTIPLY BY</b>	<b>TO FIND</b>	<b>SYMBOL</b>
<b>TEMPERATURE (exact degrees)</b>				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
<b>SYMBOL</b>	<b>WHEN YOU KNOW</b>	<b>MULTIPLY BY</b>	<b>TO FIND</b>	<b>SYMBOL</b>
<b>ILLUMINATION</b>				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m <sup>2</sup>	cd/m <sup>2</sup>
<b>SYMBOL</b>	<b>WHEN YOU KNOW</b>	<b>MULTIPLY BY</b>	<b>TO FIND</b>	<b>SYMBOL</b>
<b>FORCE and PRESSURE or STRESS</b>				
lbf	pound force	4.45	newtons	N
lbf/in <sup>2</sup>	pound force per square inch	6.89	kilopascals	kPa

## APPROXIMATE CONVERSIONS TO ENGLISH UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
AREA				
mm <sup>2</sup>	square millimeters	0.0016	square inches	in <sup>2</sup>
m <sup>2</sup>	square meters	10.764	square feet	ft <sup>2</sup>
m <sup>2</sup>	square meters	1.195	square yards	yd <sup>2</sup>
ha	hectares	2.47	acres	ac
km <sup>2</sup>	square kilometers	0.386	square miles	mi <sup>2</sup>
SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m <sup>3</sup>	cubic meters	35.314	cubic feet	ft <sup>3</sup>
m <sup>3</sup>	cubic meters	1.307	cubic yards	yd <sup>3</sup>
SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
TEMPERATURE (exact degrees)				
°C	Celsius	1.8C+32	Fahrenheit	°F
SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m <sup>2</sup>	candela/m <sup>2</sup>	0.2919	foot-Lamberts	fl
SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
FORCE and PRESSURE or STRESS				
N	newtons	0.225	pound force	lbf
kPa	kilopascals	0.145	pound force per square inch	lbf/in <sup>2</sup>

\*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.(Revised March 2003)

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# **CHAPTER 1**

## **INTRODUCTION AND DESCRIPTION**

### **1.1 Introduction**

The Sediment Erosion Rate Flume (SERF) is the second of two apparatus developed at the University of Florida for the purpose of measuring the rate at which sediments erode when subjected a water flow-induced shear stress. Development of the SERF began in the early 2000's, and it has continued through 2010. In December of 2005, the original manual for SERF testing was developed. Since then, the SERF has been enhanced and improved. This manual describes the updated version of the flume, the sediment sample preparation, and the test procedure. This manual is meant to replace the previous version of the SERF manual.

### **1.2 Sediment Erosion Rate Flume (SERF) Description**

This section describes the details of the SERF testing apparatus. Listed below are the major components of the flume and the data acquisition system followed by a detailed description of the complete apparatus assemblage.

- Two (2) 1,000 GPM Vertiflo pumps. One equipped with a GE Electronic variable frequency drive/Labview computer control and the other equipped with a simple on/off relay.
- Aluminum flume, 1.75 in. x 8 in. (4.45 cm x 20.32 cm) cross sectional area, ½ in. (15.24 cm) wall thickness, and 9 ft. (2.74 m) in length.
- Five (5) rectangular flume sections. The first and second are 1 ft. long, and the first contains a rectangular flow straightener. The third section, which is 2 ft. long, contains a series of two (2) pressure ports, a state-of-the-art shear stress sensor with a topside access hatch, and a vortex generator. Following the 2 ft. section is the 1 ft. test section. The test cylinder is inserted into the bottom of this section and an ultrasonic ranging system is mounted over top of the sample portion. Flush with the flume bottom on one side of the sample are three (3) lasers and three (3) corresponding photoelectric sensors. Two (2) more pressure taps are positioned on either side of the sample. The test section and the section with the shear stress sensor are both equipped with viewing windows for observation/recording SERF tests. Following the test section is a 4 ft. section which contains the second pressure tap and temperature probe.
- Two (2) 1 ft. long aluminum transition sections located between the round CPVC pipes and the rectangular flume (at the flume entrance and exit).
- An Elektat shear stress sensor and signal amplifier (0 Pa – 100 Pa with 4 data ranges).

- A RT5-603 six (6) ton Rite-Temp water chiller.
- A Triton-II commercial grade sand filter.
- A 1.5 hp pool pump to supplement the water chiller pump.
- Connective Plumbing. (6 in. CPVC pipe from tank to pumps, 4 in. connective pipe from pumps to flume, 4 in. discharge hose from flume to tank, 2 in. connective pipe from tank to filter, 1 in. connective pipe from filter to chiller and from chiller to tank).
- 1100 gallon stainless steel reservoir, equipped with baffles and a drain.
- SEATEK 12 element 5MHz ranging system.
- Three (3) Keyence FU-59 fiber optic lasers and corresponding photoelectric sensors, three (3) Keyence FS-V30 signal amplifiers, a Keyence CU-21A control box, and a CU-21TA control box.
- Haydon-Kerk linear actuator (stepper motor) powered by Servo Systems power drive, and controlled by National Instruments (NI) UMI-7764 motion controller/PCI-7330 stepper motor interface.
- Two (2) Omega FX2300 0.5bdi pressure transducers, +/-0.5 psi, 0.2% F.S. accuracy.
- Omega type T temperature probe.
- NI data acquisition system consisting of a PCI 6014 DAQ card and a SC-2345 signal conditioning terminal block capable of recording pressure, laser, shear stress, and temperature data.
- Watec auto-focus, color camera for real-time viewing and recording of the erosion test.
- A 4CM CPCam MPEG-4 DVR with networking capabilities for recording and remote viewing of SERF experiments.
- An Omega FPB151 paddlewheel flowmeter.
- A vortex generator.

The SERF was designed as a rectangular cross-section flume since the shape allows the flow to become fully developed quickly, and a sectioned flume permits testing of numerous sections varying in length, design, roughness, etc. which can be easily inserted into the flume for a wide variety of testing scenarios. For example, in addition to the aforementioned components, a sand injecting device was designed and built. The device consists of two (2) concentric PVC pipes. The outer, ten (10) pipe serves as a reservoir tank while inside the inner pipe a PVC feedscrew is positioned to feed sand into the flume. The sand injector is driven by a Leeson Speedmaster adjustable speed and motion controller and a 1700 rpm Sew Eurodrive motor. Due to pump breakage concerns, the sand injector was not installed, but it can be added as soon as a proper filtering mechanism is installed in the flume. It was also conceived that numerous test sections, each accepting a different sized sample diameter, could all be used in the SERF.

The testing apparatus consists mainly of the flume, an 1100 gallon reservoir, and the connective plumbing. The flume is mounted on two 5.5 ft. stands, and stiff rubber has been inserted between the stands and the flume to reduce vibration. Water is supplied to the flume from an 1100 gallon reservoir. The reservoir is equipped with a series of baffles to reduce the amount of turbulence in the tank and aid in the settling of suspended sediment. The tank is also equipped with a 2 ft. port on the top and a drain valve to allow for cleaning between tests. The piping between the tank and the two pumps is 6 in. sch. 80, CPVC, and the discharge from the pumps to the flume is carried through 4 in. sch. 80, CPVC.

The two 1,000 gpm motors are mounted on inertial bases, and the discharge end of each pump is equipped with expansion joints to inhibit movement and/or fracturing of the pipe due to pump movement or vibration. There is also a set of shut off valves at both the discharges of the tank and at the discharges of the motors which allow for increased flow control and prevent any backflow of water into the pumps. Water discharged through the pumps is carried through the 4 in. pipe, past the paddlewheel flowmeter, and enters the flume through a 1 ft. circular to rectangular transition section.

As water enters the flume, it first passes through a 1 ft. long flow straightener. This reduces any turbulence or vortices which may be present in the flow and aids in the transition to a hydraulically smooth, fully turbulent flow. The flow passes through a second 1 ft. section followed by a 2 ft. section. The vortex generator is located 6 in. from the upstream edge of the 2 ft. flume section. The vortex generator consists of a 3/8 in. aluminum bar, two (2) aluminum

plugs, and two (2) rubber o-rings. The bar is designed to induce a near-wall vortex street, while the o-rings prevent leakage and the plugs are included in case a test is to be run without the induction of upstream vortices. Approximately 1 ft. downstream from the vortex generator (18 in. from the upstream edge of the 2 ft. section) is the shear stress sensor and access hatch. The shear sensor has a removable disc that sits level with the flume bottom. This removable disc is advantageous because it can easily be replaced with other discs of the different roughnesses. The access hatch allows operators to replace the disc without removing the sensor. On either side of the sensor are two pressure taps which lead to one of the two differential pressure transducers. This allows for a comparison between the pressure drop method for shear stress measurement and actual shear stress readings from the sensor. A 1.4 in. diameter viewing window is located on the side of the flume parallel with the shear stress sensor so that real-time viewing and recording (via DVR) of shear stress tests can be conducted either via CCTV or remotely.

Once through the 2 ft. section, the flow passes through the 1 ft. sediment sample test section, which supports the test cylinder containing the sample being analyzed. The test cylinder consists of an acrylic or PVC cylinder secured by two compression plates. The top plate is mounted to the bottom of the test section of the flume, while the bottom plate is attached to the top plate through four bolts. This supports and secures the cylinder in compression, permitting sample removal without disassembling the entire test section. The top of the test section is equipped with a port through which the SEATEK ultrasonic ranging system is mounted. Along the flume bottom, three (3) 1.5 mm grooves are cut in which the fiber-optic lasers and photoelectric sensors are positioned and glued. Located on the side of the test section is another 1.4 in. diameter viewing window through which erosion results can be recorded and observed. On either side of the eroding sample, two (2) more pressure taps are attached to the second differential pressure transducer.

. The stepper motor is bolted to a variable elevation stand (mounted to the floor underneath the test section) and is positioned directly under the test cylinder. The sample is driven up by the motorized lead screw and plunger inside of the test cylinder. Once through the test section, water proceeds through a 4 ft. long duct section, and exits the flume. At the exit of the flume is a 1 ft. rectangular to circular transition, which is bolted to a 4 in. rubber hose that transports the water back to the reservoir.

### 1.3 Monitoring and Control Description

SERF tests are managed through Labview software on a computer station. This section provides an overview of the major software components, hardware components, control structures, and data acquisition techniques used for SERF testing. The following overview describes all SERF components and assumes a “complete test” or a test where erosion rates and analog signals (shear stress, pressure readings, temperature, etc.) are all measured with one another. Section 4 will discuss different testing procedures that can be conducted in the flume to differentiate between a test where erosion is measured using either the lasers or the SEATEK, analog signals (including shear stress) are measured, and critical shear stress is measured.

The SEATEK ultrasonic depth array and laser leveling system are used in conjunction with one another to keep the sample level with the bottom of the flume. The SEATEK ultrasonic array measures elevations of the sample and of the test section bed. Of the twelve transducers contained within the SEATEK, four measure the outside bed elevation and eight measure the inner bed elevation. A diagram of the ultrasonic depth array is provided in Figure 1-1.

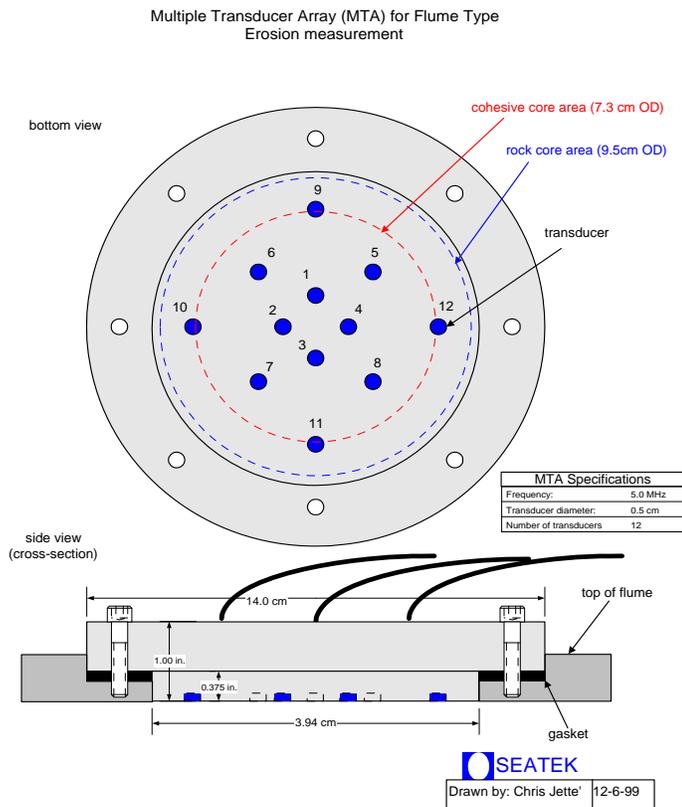


Figure 1-1. Schematic diagram of the SEATEK transducer array.

First, the correct temperature is specified to the SEATEK through a Labview feedback loop with the flume's thermocouple. This extra step insures that the SEATEK uses the correct speed of sound when it computes the time between ultrasonic ping and ultrasonic ping return. Once the SEATEK knows the correct temperature, an ultrasonic burst is sent from the SEATEK to the flume bottom. The output data from the SEATEK control is typically averaged over twenty sample readings (user defined). That is, the output value for a particular channel is the average of twenty return signals for that channel. These distances are input into a Labview program, and an average of the sample surface elevation is calculated and compared against an average of the flume bed surface elevation. If the difference is greater than 0.5 mm, the program signals the stepper motor to move the sample to where it is flush with the bed. Once completed, a new temperature is sent to the SEATEK, a new ultrasonic burst is initiated, and new ultrasonic return signals are read. If the stepper motor oversteps the desired amount, (due to erroneous SEATEK data or particle stacking), the Labview program retract the sample such that it is flush with the bed. During SEATEK data averaging, the program excludes the highest and lowest values so that chunking or blocking is taken into account. Additionally, signals from faulty transducers are removed from the data set via a user control.

The laser system (Figure 1-2) operates somewhat differently. The laser system consists of three fiber optic lasers and three corresponding photoelectric sensors. The lasers and sensors are located within grooves along the flume bottom such that the top of the fiber optic lines to the lasers/sensors are level with the flume bottom. The photoelectric sensors read whether or not light is shining across the top of the sample. If the sensors can see their corresponding laser, it must mean that a portion of the sample has eroded. If two of the three sensors (the middle laser and either of the two edge lasers) can see their corresponding photoelectric sensor, a 14 V output signal is sent from the laser control boxes to the SC-2345. This in turn sends a signal to the Labview interface that tells the motor to advance. The photoelectric sensors will read a light signal if half of their diameter and half the laser diameter is uncovered. In other words, the resolution of the laser system is 0.75 mm. Once the laser system indicates that a sample should move upward, it is advanced in 0.75 mm steps. Then, the Labview interface checks to see if the lasers are uncovered, and if not, the sample is advanced again. Because both the laser and the motor signal are analog, this advancement procedure occurs very quickly. While the SEATEK derives its strength from using the depth deviation to advance a sample a certain amount, the

lasers' strength is that the advancement loop is much faster because data from the SEATEK is digital.

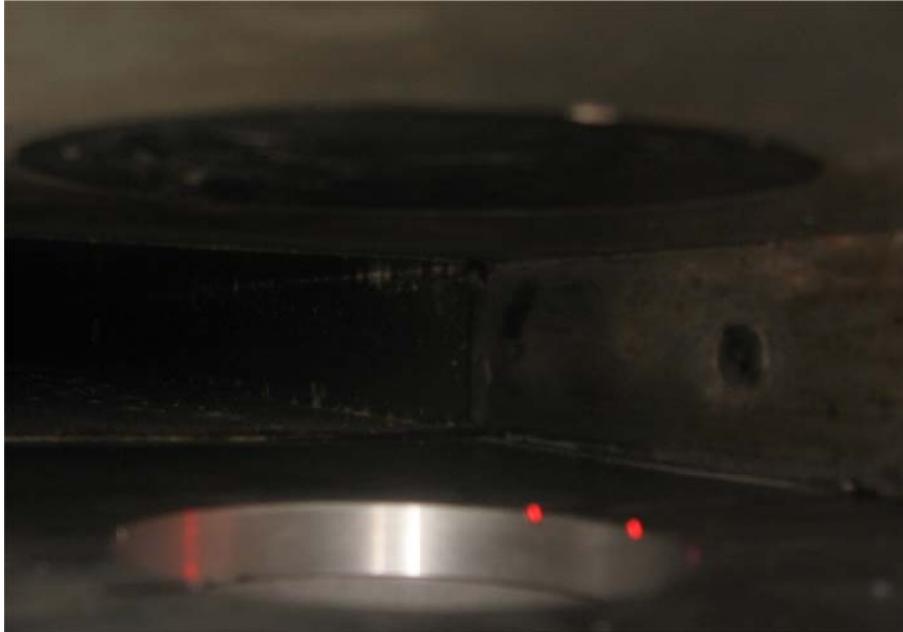


Figure 1-2. Laser Leveling System

After each motor-SEATEK-laser iteration, sample position (based on both steps and distance) and a timestamp are recorded. A second timer runs in conjunction with this first series. The second timer begins at the beginning of each test and resets itself based on a user-specified analog burst input. For example, during a 24-hour test, it probably is not necessary to record an average flow speed or average shear stress every ten minutes. Rather, it is often more useful to record a raw analog signal at a high frequency at a specified time interval (for example, every 10 minutes) so that spectral analysis can be conducted. Based on the second timer's reset parameter, a high frequency analog burst is recorded at this return interval. During this burst, pressure transducer data, flow data, raw temperature signal, and shear stress data are recorded.

While the experiment is underway, a camera positioned at the test section window and the shear stress test window displays the erosion process and shear stress test as they progress. This is viewed via the second computer monitor in the control office. Data is recorded via the MPEG4 DVR. Although the program is capable of running continuously without input from the user, there is still need for human control to ensure proper testing. In particular, if large chunks of sediment break off from the sample, and the sample consequentially protrudes into the flow, the test should be stopped and restarted. The ability to have each test backed up on video is a

very useful advantage. This allows for future researchers or designers to see exactly how a certain material erodes under the specified conditions.

The two pumps used for the erosion rate and critical shear stress testing are each controlled separately by the lab technician running the test. If a “soft” sample, such as a soft clay or sand, is being tested, the use of only one pump is required. Whereas in the past, the variable frequency drive pump is used, currently all pump controls are driven through the Labview interface. The full range of the frequency drive pump is 60 Hz, and the incremental steps may be set as low as 0.01 Hz. For “hard” samples such as rock or stiff clay, both pumps may be used. First the variable speed pump is slowly brought up to full speed. Once it begins operating at 60 Hz, the variable speed motor is shut down and the on/off pump is started. The variable speed motor is then slowly stepped up until the desired velocity and shear stress is achieved. Currently, there is no software input for the non-variable speed pump; rather, the hardwire switch still must be used manually.

Before each test, the temperature control system must be initiated. Without the temperature control system, during longer tests or a series of back-to-back shorter tests, operators should expect a temperature rise of approximately 2°C per hour. Over the course of several hours, this temperature rise may be significant and may damage equipment. To initiate the temperature control system, first the Triton II sand filter must be primed. Then, the water chiller and the supplemental pump are turned on. The water chiller should be run continuously during all tests.

# **CHAPTER 2**

## **PROCEDURE FOR OPERATION**

### **2.1 Introduction**

When conducting a test, there are three possible things that can be tested, and each of these three tests has its own procedure:

1. Shear stress for a specified sample.
2. Critical shear stress for a specified sample.
3. Erosion rate for a specified sample.

Please note that although it is possible to measure shear stresses and erosion rates at the same time (the computer code has been developed), it may be inaccurate. Shear stresses should only be measured concurrently with erosion rates when a flat disk is installed in the shear stress sensor or when a sample is smooth enough to be considered “flat.” Generally, if median size of eroding elements is expected to be greater than 0.5 mm, an eroding section is not considered “flat” and it probably will affect the velocity profile downstream from it. Because of the positioning of the shear sensor, this disturbance in velocity profile will probably affect the erosion rate of the sample. If/when it becomes possible to measure velocity profiles in the SERF, it may be possible to justify measuring shear stress and erosion rates at the same time, but until that happens, the eroding material should not be considered to be “flat.” Procedure for the testing erosion rate includes a section on concurrently measuring shear stress, but keep this disclaimer in mind when running future tests.

### **2.2 Preliminary Procedure for Tests**

Before any of the three categories of tests are set up, a few preliminary steps need to be completed. First, the SERF operator needs to decide what conditions are going to be run.

#### **2.2.1 Vortex Generator**

To install/remove the vortex generator, the following procedure needs to be conducted:

1. If vortex bar is already installed and it needs to be removed, push the bar through the flume and install the vortex generator plugs.
2. If the vortex bar needs to be installed, remove the vortex generator plugs from the SERF, and slide the bar into the flume. Make sure the O-rings remain on (they prevent leakage).

### 2.2.2 Temperature Control and Filtering

To insure temperature control during tests, the temperature control-filter system needs to be turned on, but first it needs to be primed. To do this:

1. Open the air release valve on the filter (Figure 2-1).



Figure 2-1. Air Release Valve on Sand Filter

2. Open the PVC release valve in the filter-chiller system (Figure 2-2).



Figure 2-2. PVC release valve for Chiller-Filter System

3. Push the plunger on the PVC slide valve down (Figure 2-3). This causes the filter to run in reverse and fills it with water.



Figure 2-3. Slide Valve in the Down Position

4. Turn on the pool pump using the white switch that is circled in Figure 2-4:



Figure 2-4. Pool Pump Switch

5. When water begins to shoot out of the air release valve, close the air release valve.
6. Turn the pool pump off.
7. Pull the slide valve up to the “filter” position (Figure 2-5). Turn to lock it into place.



Figure 2-5. PVC Slide Valve in the Up Position

8. Turn the pool pump back on. The filter is now primed and running. Pressure in the filter should be approximately 25 psi. If pressure is much higher than 25 psi, the filter needs to be backwashed. To backwash the filter, fill the reservoir tank with water and run the filter

in reverse until approximately 700 gallons of water remain in the reservoir tank. Make sure the PVC valve in (2) is open. If it remains closed, a pipe will burst because pressure inside the filter-chiller system will build. This may irreparably damage the water chiller. Once drainage water is clear, the filter has been properly backwashed. Then, refill the reservoir tank and resume with instructions below.

9. Turn on the water chiller (Figure 2-6). Pressure in the system should drop to approximately 20 psi. Now, water is being cooled and filtered.



Figure 2-6. On Switch for Water Chiller

10. Turn the thermostat on the back side of the water chiller to the desired temperature (Figure 2-7).



Figure 2-7. Position of Thermostat on Water Chiller

11. The temperature control-filter system is now working. Leave this system on during tests.

## 2.3 Stand-Alone Shear Stress Test

During a shear stress test, the goal is to find how the roughness of a soil or rock sample affects the wall shear stresses along its face. Please note that a shear stress test on an existing sample will disturb it; this is a disadvantage to the testing method, but at present, there is no way to accurately measure shear stress and avoid this. If multiple Shelby tubes are taken, it may be advantageous to dry one, sieve it, mix thoroughly (assuming uniformity) and use the procedures for conducting a synthetic test. If gradation is present, each graded section could be dried and mixed separately to produce multiple test discs using the synthetic method. These procedures assume a uniform sample. The procedure for a shear stress test is as follows:

1. Prepare the test disk. Because the shear sensor has a removable circular disk (Figure 2-8), this disk can be replaced with a disk of the appropriate roughness for use in shear stress testing.



Figure 3-8. Example of Removable Test Disc (Flat Disc Shown)

- a. For a synthetic sample, disk preparation:
  - i. A uniformly, evenly mixed batch of aggregate used to make the sample synthetic sample should be set aside.
  - ii. A 50 mm acrylic disk should be coated with epoxy. Experience has shown that JB Weld two-part epoxy (Figure 2-9) works the most effectively. Be sure to spread the epoxy evenly and level.



Figure 2-9. JB Weld Epoxy in its Package

- iii. Press the epoxy coated disk onto a random portion of the aggregate so that the disk coats with sediment particles.
- iv. Multiple disks should be prepared to ensure that a true random sampling form the aggregate is achieved.



Figure 2-10. Three Newly Prepared Test Discs (Three Different Aggregate Distributions Shown)

- b. For a non-synthetic non-rock sample, disk preparation is similar
  - i. A 50 mm acrylic disk should be coated with epoxy.
  - ii. Press the epoxy coated disk onto the top of the Shelby tube so that aggregate from the Shelby tube sample coats the disk.
  - iii. If multiple Shelby tubes are collected, multiple disks should be prepared.
- c. For a rock core, disk preparation is the most complicated.
  - i. A sliver of the top of the rock core needs to be cut from it. The sliver must remain intact and it must be no more than 1cm thick. The sliver must be flat on both its top and the bottom.

- ii. The rock core sliver needs to be carefully epoxied to a 50mm plastic disk.
  - iii. A hole needs to be carefully drilled through its center, and the entire rock core sliver-disc apparatus needs to be milled to 50 mm in diameter.
2. Open the shear stress sensor's access hatch (Figure 2-11) and remove the existing plastic disc. Attach the newly prepared disk using the screw through the center of the disc (Figure 2-12).



Figure 2-11. Shear Stress Sensor Access Hatch



Figure 2-12. Attachment of Newly Prepared Disk to Shear Sensor (Flat Disc Shown)

3. Close the SERF access hatch by using an Allen wrench to tighten the 8 hex-screws on top of the flume. Make sure the black rubber gasket is between the access hatch cap and the top of the flume. **DO NOT OVER-TIGHTEN**. The screw threads that attach the access hatch to the flume are drilled directly into the aluminum and if they are over-tightened, they will strip.
  4. Check the shear sensor access window for pollution. Often, particles get stuck in the wet section of the shear sensor, and they can block the space between the Servo magnet and the Hall Sensor.

5. If the wet section of the shear sensor is polluted, remove the Plexiglass window and clean it. If not, proceed to step 6.
6. Calibrate the shear stress sensor.
  - a. Zero the sensor using the knobs (1) and (2) as shown in Figure 2-13. The coarse adjustment knob is knob (2) and the find adjustment knob is knob (1). When the sensor is properly zeroed, the ammeter on the front of the amplifier should read 0.

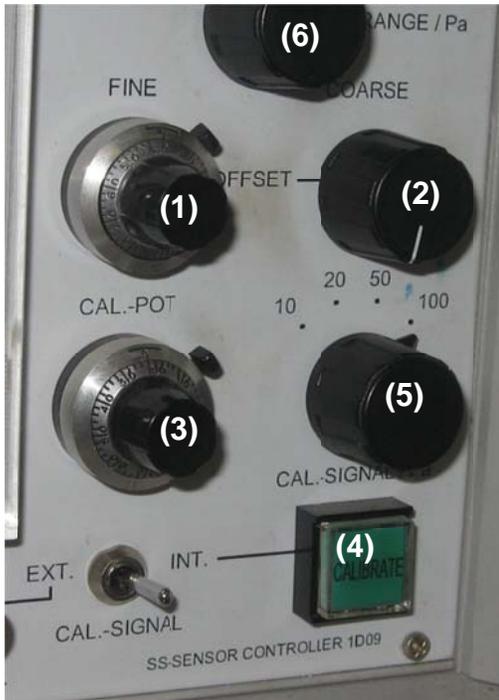


Figure 2-13. Knobs on SS Sensor Amplifier

- b. Press and hold the CAL button on the shear stress sensor (4). This sends a voltage to the calibration solenoid based on the position of knob (5), which causes the deflection solenoid to react. Turn knob (3) such that the ammeter on the amplifier deflects to the corresponding correct stress reading. For example, if knob (5) is turned to 50, the corresponding stress read on the ammeter should be 50 Pa. Release the CAL button (4). Repeat for several values of (5) to make sure the sensor is working. Note that the shear sensor runs at 4 different ranges: 10 Pa, 20 Pa, 50 Pa, and 100 Pa. To set the range of the sensor, turn knob (6). Keep in mind that if the range is set to anything less than 100 Pa, a calibration voltage of 100 Pa will rail the instrument. Likewise, if the range is 20 Pa a calibration voltage of 50 Pa will do the same thing. When the range goes below 100 Pa, the scale on the ammeter adjusts accordingly. Therefore, a calibration voltage of 50 Pa when the range is on 50 Pa will still deflect the ammeter to full deflection (this is correct and it is how the instrument was designed).

- Turn on the computer in the SERF control room and start the vi labeled Flume Control No Motor. The shortcut for this vi is located on the desktop in a folder called “Flume Shortcuts.” If the correct vi has been opened, its front panel should look like Figure 2-18.

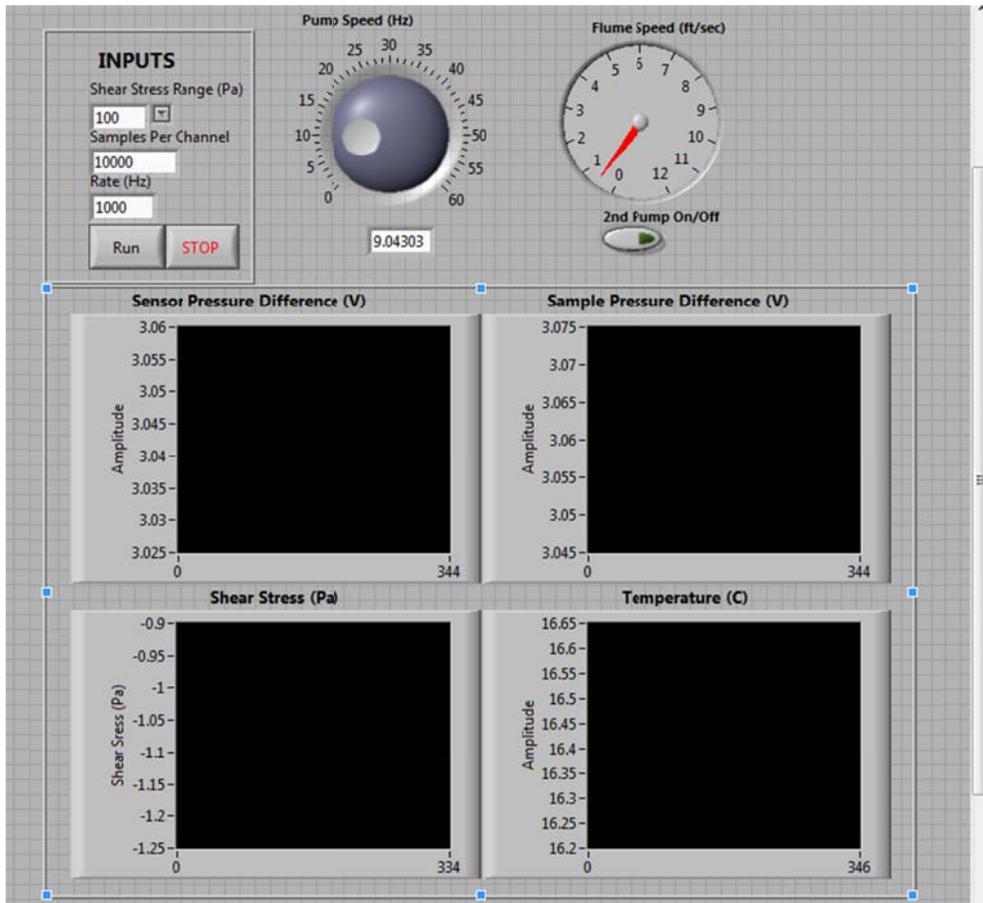


Figure 2-18. Shear Stress Test Front Panel in Labview

- Make sure that the data range in the Labview program matches the data range on the shear stress sensor amplifier (Figure 2-19)

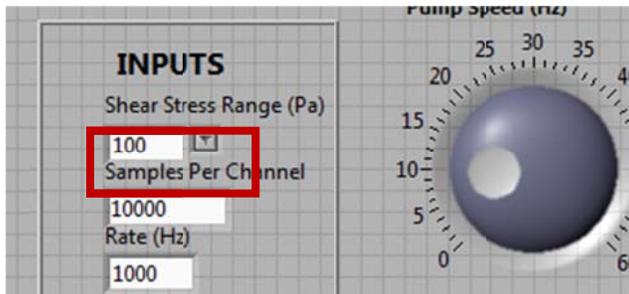


Figure 2-19. Data Range on the Shear Stress Amplifier

- Turn the pump on and make sure that the digital display reads “remote.” Press forward on the digital pump readout (this initializes the pump).

10. Press start in Labview, and the Labview program should ask where to save the data file. Files are saved as .dat files to allow for easy Matlab data analysis.
11. Press record on the DVR.
12. Adjust the pump speed to approximately 20 Hz. This will start a flow of water through the flume and pressurize it. Anything less than 20 Hz is not high enough to overcome the head differential between the flume and the reservoir tank. Allow the flume to run for a few seconds until bubbles in the flume are eliminated.
13. If pressure transducers are to be used during the shear test, next they need to be “bled.” To bleed a pressure transducer, unplug both tubes from the flume to the transducer. Make sure to unplug the downstream tube first. The transducers are designed to tolerate over pressurization on the positive side only. Because the flume should be running at approximately 20 Hz, when the tubes are unplugged, water should be going into them. Lightly tap on the tubes to eliminate bubbles from them. When bubbles have been eliminated, plug the tubes back into the sensor. Plug the upstream side in first this time, then the downstream side.
14. While bleeding the sensors, real-time graphs should have begun to be generated in the Labview program. As far as data collection goes, these graphs are meaningless. They were included in the program for the user to get a broad idea of shear stress/pressure conditions, but they are sampled at a much lower frequency than data collection.
15. Now, everything is ready for data collection. Bring the pump to the desired flow speed. Give the system a few seconds to stabilize. Stabilization is achieved when the shear sensor begins to display a somewhat consistent shear stress from the graphs.
16. When conditions have stabilized, press the “RUN” button in Labview. This will stop the generation of the graphs (but this is OK) for a length of time that is dependent on the Sampling Rate Parameter (default is 1 kHz) and the Number of Samples Parameter (default is 10,000). Both these values can be changed as the Labview program runs to allow for different sampling frequencies and different sampling lengths. A long sampling length though means lots of computer memory. Anything over 15,000 data points should not be used because the computer does not have enough RAM to support this (the computer only has 3.5 GB).
17. When the graphs start moving again, data collection has been completed. Bring the pump to the next desired flow rate, wait for it to stabilize, hit the run button to collect data, repeat.
18. Repeat for flow rates that are to be investigated.
19. When testing is done, gradually bring the pump speed down to zero. For example, if a pump frequency of 30 Hz was used for the test, bring the pump down to 25 Hz, let it run for 5 seconds, then bring it to 20 Hz, let it run for 5 seconds, etc. the way to 0 Hz pump frequency. This gradual velocity reduction allows the shear sensor to “catch up” with changing flow conditions and can help prevent breakage to the instrument.

20. The test may now be repeated, or a new sample disk may be installed. It is recommended to repeat each test at least three times and to recalibrate the shear sensor after every test. Before removing the access hatch to install a new sample, make sure the valves on the pressure transducer are closed. When the access hatch is removed, water rushes from the flume into the reservoir because of the pressure differential created by exposing the flume to air. If the pressure transducer valves are open, there is a significant risk of breaking one or both of the transducers.
21. Go to the saved .dat files and perform data analysis. The most effective method for data analysis is Matlab, and there are several Matlab algorithms written in the G:\analysis folder that average samples over the entire sampling domain, perform spectral analyses, plot graphs of the results, etc. Excel can be used, but every data run has 10,000+ data points per flow rate and an Excel analysis will be arduous. SERF operators are encouraged to learn Matlab.

## 2.4 Critical Shear Stress Test in SERF

Shear stress tests should be conducted first on any sample batch so that a correlation can be developed between flow rate and shear stress. Once a shear stress analysis has been completed, a critical shear stress test may be performed:

1. Make sure that a flat disk has been installed in the shear stress sensor. Alternatively, the entire shear sensor may be removed and the shear sensor plug (Figure 2-20) can be installed in its place.
2. To remove the shear sensor, loosen ONLY the hex screw on the sensor flange (Figure 2-20).



Figure 2-20. Hex Screw to Loosen for Shear Sensor Removal

3. Once the hex screw loosened, carefully pull and twist the sensor to release the shear sensor from its blue Loctite bond.

4. Coat the sensor plug (Figure 2-21) with blue Loctite, and slide it into the sensor hole. Make sure the plug is level with the flume bottom.



Figure 2-21. Shear Stress Sensor Plug

5. Retighten the hex screw.
6. If the sensor plug is not installed, the shear sensor still needs to be turned on during shear stress tests. The magnets in the sensor help to prevent the sensor disc from moving, and turning the sensor on will help to prevent damage to the sensor and help to prevent flow disturbances in the SERF.
7. Load the test section of rock core, Shelby tube, or synthetic material into the piston-cylinder apparatus (Figure 2-22). Grease the piston-cylinder's O-rings with a silicon grease.



Figure 2-22. Piston-Cylinder for SERF

8. Attach the piston to the Servo motor's feedscrew using a screw.
9. Raise the Servo motor (which is now attached to the piston and the cylinder) into the SERF's sample hole. Make sure to put an O-ring around the top of the cylinder to prevent leakage. If using an opaque piston, also make sure that the ridges on the top of the cylinder provide a clear line of sight for the lasers (Figure 2-23).



Figure 2-23. Close-up of Ridges on Top of Cylinder.

10. Attach the four threaded rods around the cylinder to the bottom of the SERF.
11. Tighten the compression coupling around the bottom of the test cylinder through the threaded rods. **DO NOT OVER TIGHTEN AS IT WILL CAUSE THE TEST CYLINDER TO CRACK.** If leaks develop, the compression screws can be retightened. When installed, the apparatus should look like Figure 2-24:

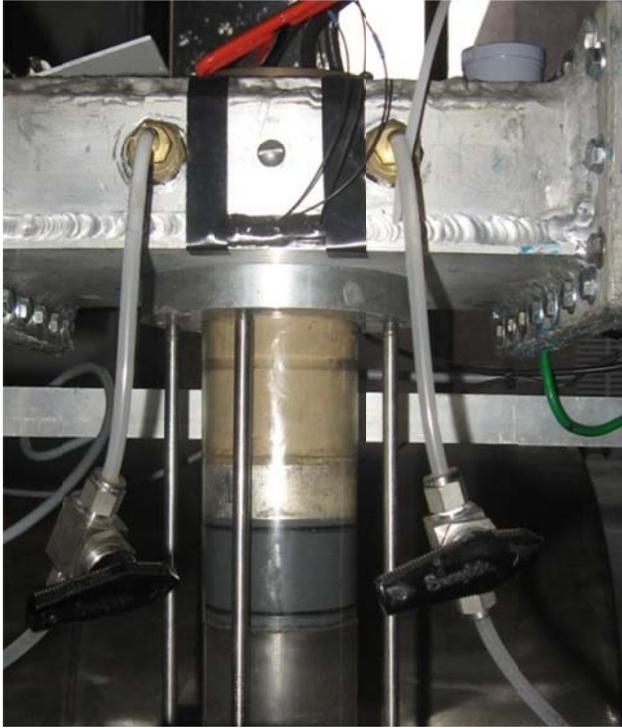


Figure 2-24. Piston-Cylinder with Sample Installed (Note, Figure 2-22 shows a PVC Cylinder while this Figure Shows a Clear Acrylic Cylinder).

12. If lasers are to be used, turn on the lasers by clicking the “on” button on the surge protector shown in Figure 2-25:



Figure 2-25. Surge Protector to Turn on Lasers

13. Open the program labeled “Motor Mover.” The front panel is shown in Figure 2-26:

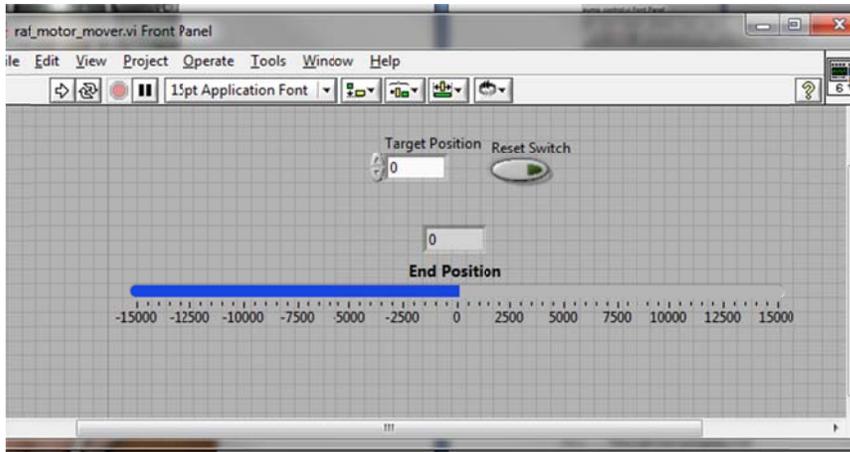


Figure 2-26. Front Panel of Motor Mover Program

14. Flip the input switch on the VGA-BNC adapter so that the right monitor of the control program is looking into the flume. Tune to channel 2 on the DVR to see the eroding test section.
15. Turn on the motor by flipping the switch on the black box below the laser amplifiers and start the motor mover program. Click start on the Motor Mover program.
16. Move the motor up in small increments until the control boxed from the lasers indicate that they are blocked. The control boxes will “click” when they are blocked and the lights on the amplifiers will switch off. A “small increment” is approximately 500 steps in the motor mover program. **DO NOT MOVE THE MOTOR MORE THAN 5,000 STEPS AT A TIME.** It will cause the motor’s gears to grind and may cause the motor to break.
17. Once the control boxes have clicked and the lasers indicate that the sample is level with the flume bottom, verify that the flume is level visually by looking at the right monitor on the SERF computer. If the sample is level, proceed. If not, re-level.
18. Open the program labeled “Pump Control” from the “Flume Control Shortcuts” folder on the desktop Press the start button. The front panel is shown in Figure 2-27:

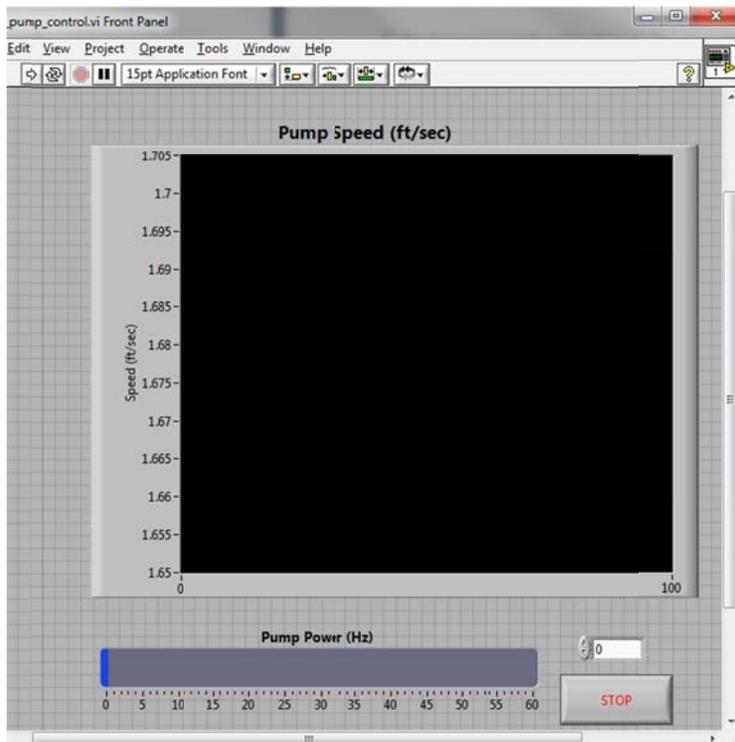


Figure 2-27. Front Panel of Pump Control Program

19. Click Start the pump at approximately 20 Hz to pressurize the flume. If dealing with a highly erodible material, this can be rather tricky. The flume will need to be pressurized, then the motor will need to re-level the sample using the same procedure outlined in (11).
20. Bring the pump down to a slow flow speed (approximately 5 Hz).
21. Press record on the DVR.
22. Slowly increase the pump speed in small increments (approximately 0.25 Hz) and watch the right monitor. Look for any particle motion along the bed.
23. When incipient motion is detected, stop the pump and record the flow rate. The critical velocity for the material just tested is now known.
24. Use correlations developed in shear stress testing to convert critical flume velocity to critical flume shear stress. Now, the critical shear stress for the material is known and the critical shear stress test has been completed.
25. Repeat the critical shear stress test at least three times for each material.

## 2.5 Erosion Rate Test

The erosion rate test is the most complicated test that can be conducted in the SERF. To reiterate, until velocity profiles can be measured in the flume, shear stress tests and erosion rate tests should be conducted independently. Once velocity profiles can be measured, it may be possible to justify running both sets of tests concurrently, but until then, it is believed that placing a rough sample upstream from an eroding sample will affect the hydrodynamics downstream from the rough sample and alter the measured erosion rate of the bed material. To conduct the erosion rate test:

1. Load a sample into the piston-cylinder using the same steps for a critical shear test.
2. Install the flat disc into the shear stress sensor, or install the shear sensor plug. If the sensor is to remain in the flume, follow plug installation steps from the critical shear stress test.
3. Turn on the motor.
4. Turn on the lasers and level the sample using the same techniques used for an erosion rate test. Note that by default the lasers use “and” logic to advance the sample. If an operator feels that “or” logic is more appropriate, refer to Chapter 3 for guidelines on how to change this.
5. Open the pump control program.
6. Fill and pressurize the flume. If pressure drops are to be measured, bleed the pressure transducers using the same method used for a critical shear stress test.
7. Stop the pump. If shear stresses are to be measured, calibrate the shear sensor using the same method used for a shear stress test.
8. Turn the pump on a low flow rate (~5 Hz). This will help to push bubbles away from the SEATEK during SEATEK calibration. If the SEATEK is not to be used, skip steps 9-15 and go straight to step 16.
9. Open TeraTerminal. TeraTerminal is sort of like a Windows 7 version of HyperTerminal. The TeraTerminal shortcut is on the Windows 7 control bar at the bottom of the screen, next to the Labview 2009 shortcut (Figure 2-28).

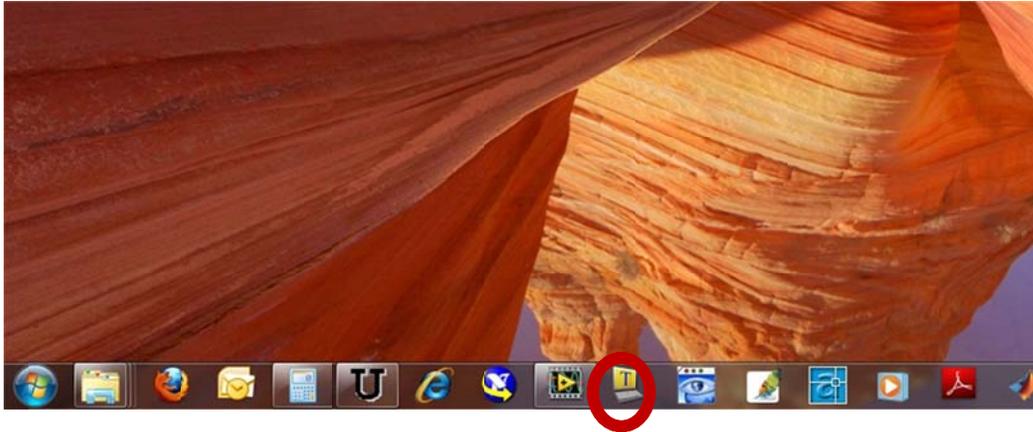


Figure 2-28. TeraTerminal Icon (Circled in Red)

10. In TeraTerminal, click the option to read from the Serial Port.
11. Turn on the SEATEK. In TeraTerminal, output should read MTAS V3.12S Input Command [? For help].
12. Pressing “?” will give a list of SEATEK commands. The important parameters to change in the SEATEK are temperature (TE), maximum transducer depth (MA), threshold voltage (V), and number of sample runs (N).
13. First, change the temperature to the correct temperature. For example, to change the temperature to 21°C, type “TE 21” and Enter.
14. Next, press “P” to ping the SEATEK sensors. If the depth readings that are returned are around 4.92 cm, the SEATEK is working properly. If not, play with the “MA” and “V” commands until the proper depths are being returned. There are 12 crystals in the SEATEK array – 8 within the sample’s area and 4 along its outside. The crystals that are most important are the first 8 as they measure the sample position. The outside 4 crystals measure the depth to the solid flume bottom (4.92 cm). Please note that when this project began, crystal #2, crystal #5, crystal #6, and crystal #10 were damaged; as of 2007, they were not working properly (this will be addressed in Labview).
15. Keep pinging the crystals after each “MA” and “V” command to determine if they are working properly.
16. Once it the crystals are working properly, set up a data run to confirm that the crystals can read multiple results correctly. Take at least twenty readings by executing the following commands:
  - a. N 20; Enter
  - b. D; Enter

17. Exit TeraTerminal. The serial port on any computer can only communicate with one program at a time, and if TeraTerminal is left open, Labview will not read from the Serial port because TeraTerminal already is doing so.
18. Open the Labview vi entitled “Flume Control With Motor (With Temperature Patch).” Its front panel should look like Figure 2-29.

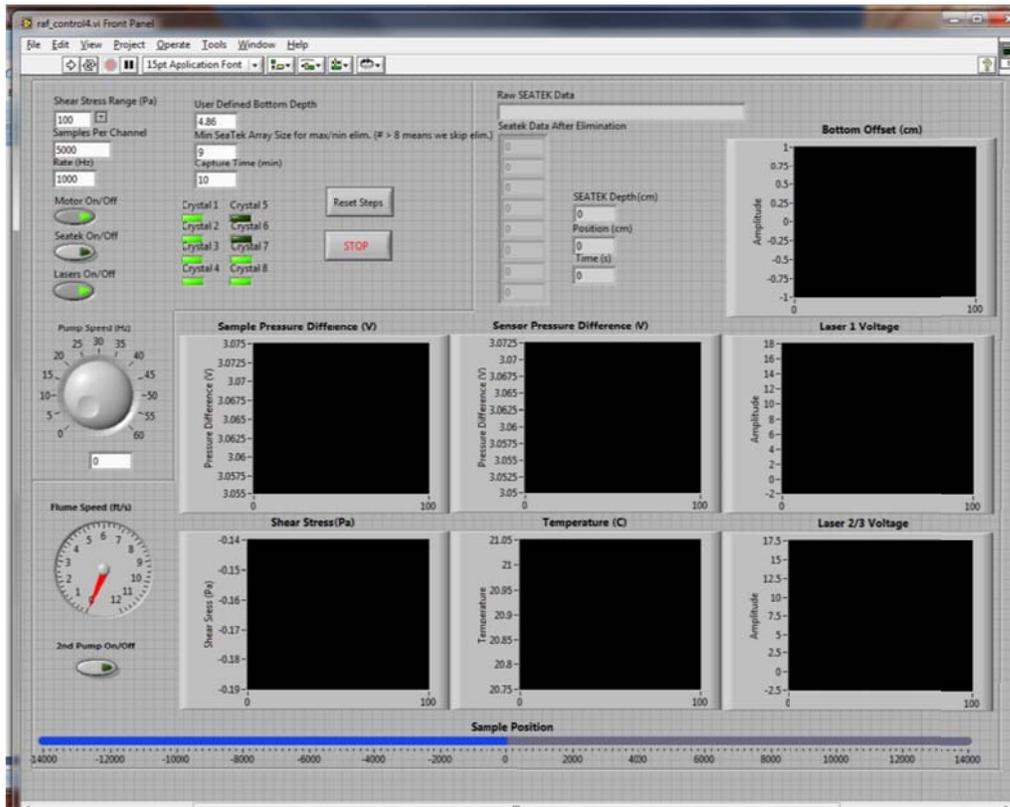


Figure 2-29. Flume Control with Motor Front Panel

19. If the SEATEK is not to be used, turn it off using the switch on the control panel.
20. If the lasers are not to be used, turn them off using the switch on the control panel.
21. Assuming the SEATEK is to be used, from the TeraTerminal procedures, turn off the crystals that are not working properly by clicking on the green LED lights on the Labview front panel. Note that crystals 8-12 are not listed. The malfunctioning crystal, crystal #10 is automatically eliminated from consideration during data processing (Chapter 3).
22. Make sure the motor is turned on in the front panel.
23. Press start on the Labview program. Two output files will be generated – one for analog signals (shear stress, pressure, temperature, flume speed, time) and the other for digital data (time, number of steps, motor position). Save these files in the appropriate directory.
24. Move the pump control to the desired flow speed.

25. Press record on the DVR.
26. The test should now be running. Keep an eye on it for approximately 20 minutes to make sure everything is working properly. If a crystal begins to malfunction, it can be turned off in the middle of a data run. If the SEATEK overall or the lasers begin to malfunction or give nonsensical results (for example, the SEATEK when some clays are used), they can be turned off as well.
27. If two pumps are to be used during the test, turn on the “2<sup>nd</sup> Pump” switch. This will insure that the correct velocities are recorded in the analog output file.
28. If analog signals are to be recorded (shear stress and pressure drop), the program will run much like it did for shear stress tests. Water will flow through the flume, graphs will generate on the front panel, and every specified time step (the default is 10 minutes, but this can be changed – see Chapter 3), the graphs will freeze and analog output files will be written at the specified frequency.
29. If analog signals are not to be recorded, skip step 28. Motor position will be recorded every time the program goes through its loop (Chapter 3) in the digital output file.
30. Allow the SERF to run for the specified length of time. It should be monitored during operation to insure that nothing malfunctions, but once it has been set up, it should work properly.

## **2.6 Remote SERF Operation**

In any SERF test, it is now possible to control the flume remotely if required hard switches have been turned on. This is especially useful in monitoring erosion-rate tests because erosion rate tests often need to run for 24 hours or more. Tests do not need to be constantly monitored, but they do require someone to look at them from time to time to make sure they are running correctly. Remote operation also useful for changing flow parameters during a test. If one of these scheduled modifications needs to be made late at night or early in the morning, remote operation is convenient.

The worst thing that can happen during a SERF test is the motor can malfunction due to bad readings from the SEATEK or lasers. Sometimes, the motor may retract such that the piston pulls out of the test cylinder. If this happens, the lab can flood. Other times, the motor may advance uncontrollably and cause the sample to be pushed up to the top of the flume. If either of these things happens, the test needs to be stopped, the source of error needs to be assessed and addressed so that nothing malfunctions again. Software limit switches have been installed in

MAX (Measurement and Automation Explorer), and the lab has yet to flood, but there is no hard-wired method installed to prevent uncontrolled advancement/retraction. Therefore, operators need to be conscious of this risk. Although most bugs from operation have been worked out, operators are still encouraged to monitor testing as much as possible.

### **2.6.1 Remote Visual Inspection**

The easiest way to monitor a SERF test is visually. Two cameras look at the important parts of the flume (the eroding test section and the shear stress sensor), and visual data from these cameras is useful at determining whether or not a test is running correctly. A third camera is set up to monitor the entire lab from above so that a remote operator can have even more information with how a test is going in the device.

Visual inspection is conducted by using the DVR because the DVR has networking capabilities. To see what is being recorded in the DVR and to control the DVR remotely, the following procedure should be followed:

1. Initiate a Virtual Private Network (VPN) connection with the UF network. The DVR and SERF can only be accessed through a VPN because when remote operation was set up, there were concerns about providing security for it. The VPN allows for security options that are not possible through a normal network connection. To set up a VPN connection for the first time, follow the UF guidelines for VPN. They can be accessed at [http://net-services.ufl.edu/provided\\_services/vpn/vpn-install.html](http://net-services.ufl.edu/provided_services/vpn/vpn-install.html).
2. Open Microsoft Internet Explorer. Remote operation of the DVR will not work with Mozilla Firefox. This technique has not been tested with Apple Safari or Google Chrome, but it may work.
3. In the address bar of Internet Explorer, type the static IP address for the DVR – <http://10.5.72.138>. Press Enter.
4. A popup will appear that asks for a username and password. The username is “admin” and the password is also “admin.”
5. A window should appear that looks like Figure 2-30. If this window is generated, remote operation has been initialized properly and the DVR can be viewed and operated from Internet Explorer.



Figure 2-30. Remote DVR Panel

## 2.6.2 Remote Labview Operation

If after visual inspection, an operator realizes that a test needs to be shut down or if an operator wishes to monitor data collection and Labview operation remotely, the SERF computer has also been configured to do this. The following procedure is used for remote control of the computer:

1. Initialize a VPN connection to the UF network.
2. Open Windows Remote Desktop Software. This capability is standard in Windows XP, Windows Vista, and Windows 7. Once open, the remote desktop software looks like Figure 2-31.



Figure 2-31. Windows Remote Desktop Software

3. Go back to the remote desktop connection software. Next to “Computer,” type the name of the computer. The computer’s name is “KEYWEST.”
4. Press connect.
5. The computer will ask for a username and password. Type the correct username and password for the computer.
6. Remote desktop connection is now complete. The computer is now being controlled remotely. While remote control is taking place, the computer will lock itself.
- 7.

## 2.7 Data Analysis

The methods used to reduce the data output from the data acquisition program are briefly presented, although SERF operators are encouraged to read FDOT Report *Enhancement to FDOT’s Sediment Erosion Rate Flume (SERF) Device and a Study of Erosion Rates of Rock, Sand, and Clay Mixtures using FDOT’s Rotating Erosion Test Apparatus (RETA) and SERF Instruments* for a more detailed data analysis description.

## 2.7.1 Analog Signal Results

Generally, analog signal results are most important during a shear stress test. Analog signals of particular interest are readings from the shear stress sensor and readings from the pressure transducers. Before averages are to be computed, a spectral analysis is important to insure that unusual vibrations/fluctuations are not manifesting themselves in the pressure transducer or shear stress sensor signal.

To perform a spectral analysis, the following Matlab script (basicSPT.m) is useful:

```
function [freq,SPT]=basicSpt(allTS,dt,fbounds,Nft)
    hfNft=round(Nft/2); Nft=2*hfNft;
    freq=(0:hfNft-1)/dt/Nft;
    kmask=find(freq>=fbounds(1) & freq<=fbounds(2)); freq=freq(kmask);
    SPT=[];
    for kpt=1:length(allTS(1,:))
        TS=detrend(allTS(:,kpt)); [Nts,Npt]=size(TS);
        DOF=floor(Nts/hfNft-1);
        kseq=zeros(2*hfNft,DOF);
        for k=1:DOF, kseq(:,k)=((k-1)*hfNft+1:(k+1)*hfNft)'; end
        Han=hanning(2*hfNft); nHan=Han./sqrt(sum(Han.^2)/length(Han));
        TF=fft(detrend(TS(kseq).*(nHan*ones(1,DOF))));
        spt=2*mean((TF.*conj(TF)),2)/Nft*dt;
        spt=spt(1:hfNft);spt=spt(kmask);
    SPT=[SPT,spt(:)];
end
```

This script was used extensively for spectral analysis in the aforementioned FDOT report. This script performs a fast fourier transform and computes the spectral density for a signal defined by *allTS*, where *dt* is the sampling rate, *fbounds* is the upper and lower computed frequency limit, and *Nft* is the number of records in a sequence. For details on running Matlab and incorporating this script with a dataset, operators are encouraged to consult any number of Matlab tutorials available online regarding using functions in Matlab.

If unusual spectral data is present in a signal, it is possible to filter the dataset using Matlab. Matlab offers a number of filtering options. For example, to use a 4<sup>th</sup> order Butterworth filter, the following syntax should be used in Matlab:

```
f = 1000;
cutoff = [4/(f/2) 23/(f/2)];
order = 4;
[B,A] = butter(order,cutoff,'bandpass');
pse_filt = filter(B,A,pse_dm);
pse_filt_avg = mean(pse_filt);
```

In this code sequence, the signal that is filtered is called *pse\_filt*, and the filter mechanism is a bandpass filter with upper and lower limits defined by *f* and *cutoff*.

To use either the filtering script or the spectral analysis script, return data from the Labview program must be rearranged. Labview returns a series of numbers in a .dat file that corresponds to the sampling frequency and sampling rate. For example, if 10 analog bursts are taken at a sampling rate of 1000 Hz, Labview will generate a 1x10,000 (10\*1000) number array in its .dat file. To rearrange this array to a more usable format such as a 10x1000 array, Matlab's *reshape* command should be used.

Once spectral analysis and filtering has been completed, Matlab's averaging command, *mean(X)*, and Matlab's plot command, *plot(X,Y, 'properties')* should be used to present data. Because of the length of Labview output files, SERF operators should not use MS Excel because Excel often has difficulty dealing with arrays with several thousand entries. Rearrangement from Labview to a matrix-style Excel-style array would also be difficult and require the use of several Visual Basic (VB) Excel scripts. Since the Matlab code for analysis has already been developed, operators are encouraged to use this instead.

### **2.7.2 Critical Shear Stress**

Critical shear stress data analysis should follow analysis of shear stress tests. Once shear stress data analysis has been completed, operators should be left with a pump frequency vs. shear stress relationship (for a given sample roughness). Based on previous tests, this frequency vs. stress curve usually corresponds to a power-law distribution. Using Matlab's *Ezyfit* toolbox, a best-fit least-squares regression line should be fit to the data. Then, using this line, an approximate shear stress can be computed from the corresponding flow rate where incipient motion was observed. *Ezyfit* is not a standard Matlab toolbox; rather it is a free extension available at <<http://www.fast.u-psud.fr/ezyfit/>>. For instructions on installing the toolbox in a version of Matlab where it has not been previously been used, consult the website in the above link.

### **2.7.3 Erosion Rate Test**

In the past, erosion rate in the SERF was measured by simply subtracting piston start position from piston end position and dividing by the total length of the test. While this method

will provide an average erosion rate, it will not produce instantaneous erosion rates. When certain samples are tested (for example, sand-clay mixtures), they often respond such that localized portions of a sample erode much more slowly than other portions of the sample. These localized differential erosion rates need to be captured because they are significant.

The best method then for estimating erosion rate from SERF data is to plot a sample position vs. time graph using Matlab. Then, *Ezfit* can be used to fit a least-squares best-fit regression line to the data. The slope of this line is the average erosion rate. If the sample position vs. time graph shows a nearly constant slope as determined by a  $R^2$  value close to 1.0, then nearly uniform erosion was probably observed during the test. If however the position vs. time curve is not linear, then non-uniform erosion occurred. When non-uniform erosion occurs, data manipulation may be necessary to define an erosion rate. For example, during some sand-clay tests, relatively hard portions of the sand-clay mixtures eroded slowly while relatively loose portions eroded relatively quickly. Data should be “cut” so that hard sample portions are plotted with other hard portions and weak portions are plotted with weak portions.

Because this “cut” technique is somewhat subjective, the best technique for this procedure is to manually determine where erosion rate changed. For example, a SERF operator may use a cutoff erosion differential, compute the slope of the position vs. time curve as a step-wise function, and use this cutoff value to define where to cut data from relatively fast erosion to relatively slow erosion. Then, these fast and slow sample position vs. time curves can be plotted against one another to find an average erosion rate.

Once erosion rate and shear stress are defined, a plot should be made where erosion rate is presented as a function of shear stress. Often, erosion rate can be defined as a function of shear stress differential such that:

$$E = M(\tau_b - \tau_c) \quad (2-1)$$

where  $E$  is the erosion rate,  $M$  is a material-specific erosion rate constant,  $\tau_b$  is the bed shear stress, and  $\tau_c$  is the critical shear stress. Using this equation, erosion rate vs. shear stress results can be conveniently non-dimensionalized such that  $E/(M*\tau_c)$  is plotted against  $\tau_b/\tau_c$

## **CHAPTER 3**

# **SERF EROSION RATE PROGRAMS**

### **3.1 Test Program History**

SERF programs have gone through a three generation progression – first in 2004, then with in 2006, and finally the 2010 third-generation programs. The basic purposes of two of these programs have not changed much over the years. Generally, a motor mover and a primary control exist. The motor mover has served as a stand-alone program to move the stepper motor up and down when loading a sample into the device. Secondly, the motor mover is used as a sub-vi component in the primary control program. The primary control program is to be used to run erosion-rate tests.

From 2004 to 2006, the basic principle of the SERF control programs did not change, nor did their structure. The algorithm for the control programs was:

1. Read SEATEK signals
2. Read analog (pressure transducer and thermocouple) signals
3. Move the motor
4. Write SEATEK and averaged analog data to a file

In the 2004 original programs, SEATEK data, which takes a second or two to read, was recorded in the computer memory. Then, analog data, whose timing is based on sampling frequency and sampling time, was saved into the computer memory. Next, analog data was averaged over the sampling time domain, and an average analog signal was recorded along with a massaged SEATEK signal (the 2004 and 2006 versions used different methods for this). At the end of a loop through the program, a user was left with a depth reading, a sample position reading, an average pressure transducer reading, and an average temperature reading.

The problem with this algorithm is that it is slow and CPU intensive. Allowing the computer to keep high amounts of analog and digital information in memory, perform computations on it, etc. caused a loop to take several seconds. When erosion rates were high this meant that by the time the motor should have moved again, its updated position was already out of date. The other issue was that at no point in the algorithm was a raw analog signal ever

captured. Rather, it was averaged over the sampling time domain. This meant that any spectral analysis from an analog signal was impossible.

In 2006, the control programs were improved to address the sample updating issues by using improved computational techniques. The 2004 program originally eliminated zeros from the SEATEK number string (which are caused by false depth readings) by using an “eliminate zeros from string” command. The 2006 version changed this to an “eliminate zeros from array” command, which is faster. The 2006 version also tried to improve the SEATEK depth average by programming a rather rudimentary module where individual crystals from the 8-crystal inner SEATEK array could be turned off. A module was also added to the 2006 program in his program that eliminated the maximum and minimum SEATEK reading from the depth average so that a more representative average depth was computed.

During longer-duration tests, erosion rates are slow. This gave 2006 programmers the opportunity to add a second SEATEK average depth component to his program. This component differentiated between “rock” erosion programs and “normal” erosion programs via this additional SEATEK depth module. During a “rock” test, the SEATEK took a secondary depth reading before the motor was allowed to move. If secondary SEATEK reading did not correspond to the first reading, programmers assumed that one of the readings must have been in error. The motor was only allowed to move when both back-to-back SEATEK readings indicated that movement was necessary.

To speed up the 2006 programs further, operators realized that reading shear stress from a pressure difference was difficult. The only other analog signal in the 2006 version of the programs besides pressure readings was temperature from the thermocouple. This reading was not a critical component in the overall system. Therefore, two programs called “slim” programs where analog signal capturing was eliminated were designed. As a result of this, the SEATEK-motor loop sped up a little bit more and the used a little bit less CPU power. When this was completed, operators were left with five programs – the motor mover, a rock program, a slim rock program, a normal program, and a slim normal program.

### **3.2 2010 Test Programs**

The 2006 programs were a welcome improvement to SERF control, but parts of them were still rather elementary, and although some timing elements were incorporated in them, there was

more work that could be done. In 2010, the lasers were added to the SERF, and because of this addition, dual-layer SEATEK control could be eliminated. The lasers are a precise enough check for SEATEK data without the dual-layered system. This eliminated the need for rock programs. To allow for “slimmish” designs, buttons and case structures were added to the overall normal program so that different components could be turned on or off. The “slim” concept was reversed such that a program was written to capture only analog signals; this program is to be used for shear stress tests.

Currently, there are four updated computer programs that can be used to control the SERF:

1. Pump Control
2. Motor Mover
3. SERF Control No Motor
4. SERF Control Full

Programs are found in the G:\SERF\_control\_new directory on the SERF computer. Generally, programs begin with the three-letter extension “raf” because they were written by Raf Crowley and starting programs with the same three-letter extension was an easy way to differentiate them from other programs. A program in Labview is also generally called a “vi” (pronounced vee-eye). In this discussion, the terms “program” and “vi” will be used interchangeably.

### **3.3 Pump Control**

The pump control program is a brand-new SERF control program. Previously, pump controls were coordinated with the digital display drive in the control room (Figure 3-1).



Figure 3-1. SERF Digital Control Display

A logical step in SERF development was to computerize the primary SERF pump. Although when running on two pumps the SERF's second pump still needs to be run manually, computerizing the variable speed pump gives more computer control than before. To connect the pumps to the computer, a set of wires simply needed to be added from the pump control box to the computer's SC-2345 analog reader/writer.

One common improvement that was made to the first and second generation of SERF programs was the incorporation of timing using flat sequence structures. This theme will be discussed throughout the SERF computer discussion. In 2004 and 2006, tick-count timers were used to coordinate analog vs. digital signal readings instead of flat sequence structures. The addition of the pump forced analog signals to be read and written at different times during each loop through the program. As such, flat sequence structures were appropriate. The pump control program is simply a two-phase analog input/output program. During the first phase of the program, the correct pump voltage is written to the pump. During the second phase of the program, the return voltage from the pump is read which shows actual pump frequency. Additionally, an analog signal is read from the paddwheel flowmeter. Flow speed is recorded in m/s. The pump control's front panel is shown in Figure 3-2 while the pump control's block diagram is shown in Figure 3-3.

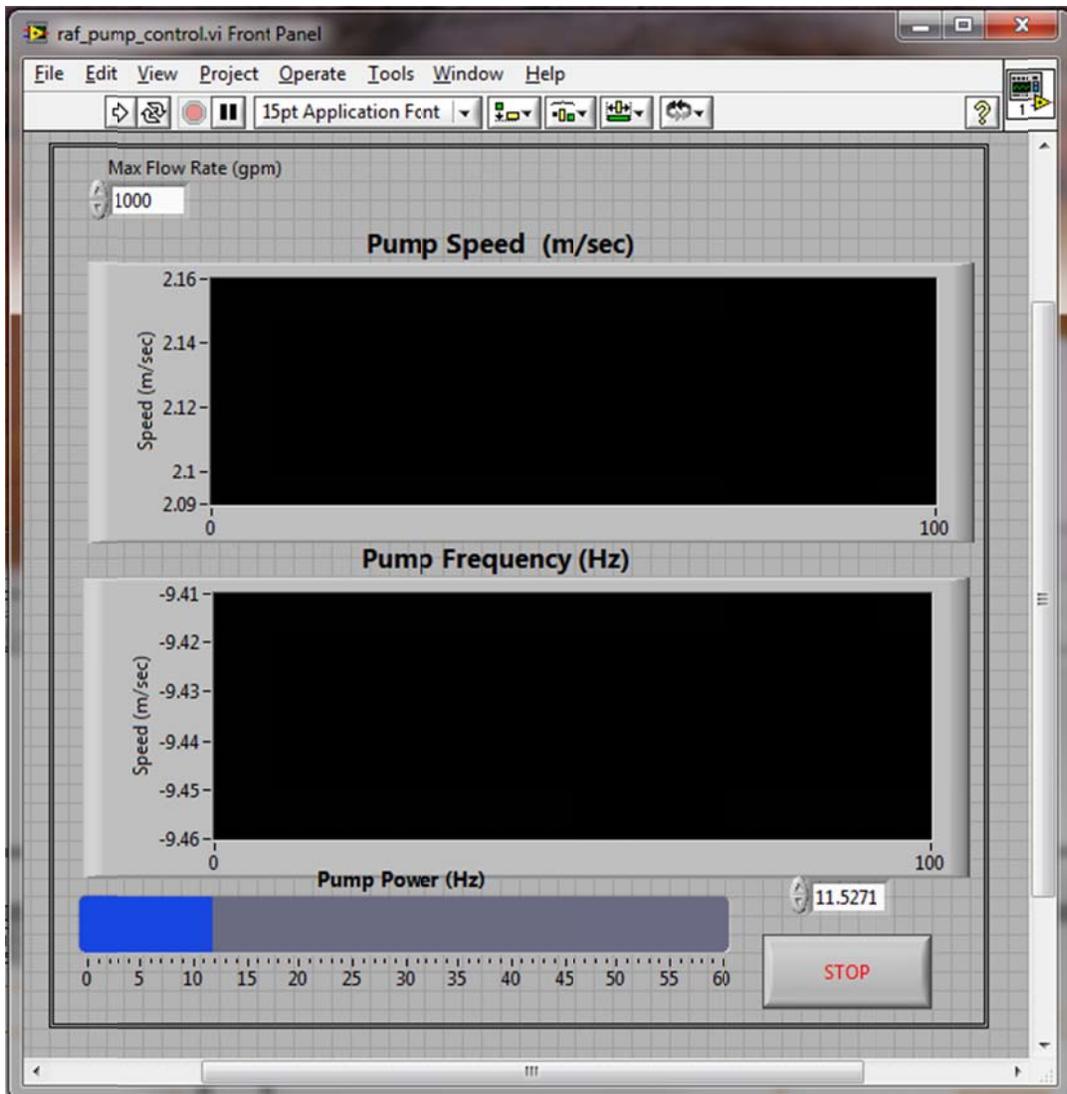


Figure 3-2. Pump Control Program Front Panel



### 3.2.1 Block Diagram Explanation

First, the rate at which velocity and actual pump frequency are to be read is specified. Since this program is designed to read, then write, then repeat, there is no need to take more than one analog reading at a time. As such, the sampling rate does not matter; default is set to 100 Hz, although any number greater than or equal to 1 will work. Next, the pump output channel and velocity output channel from the SC-2345 are specified. As wired, actual pump frequency is read from SCC1Mod2/ai0 and the flowmeter velocity is read from SCC1Mod5/ai1.

Next, the program moves into the first phase of the two-phase flat sequence structure. During the first phase of the program, a check is run to see if the STOP button has been pressed; if it has, the “True” case sends a 10V signal to the pump. This stops water flow, and it also kills the program. If the “False” case is read, then the appropriate user-specified input voltage is sent to the pump via the three DAQ-mx commands. The DAQ-mx sequence is as follows:

1. SC-2345 channel where data is to be written is specified.
2. Voltage is output from SC-2345 to the pump.
3. DAQ-mx task is cleared.

Voltage is calibrated such that the user inputs frequency in the front panel. If someone wanted to change this, it would be easy to change the calibration to allow for a velocity or volumetric flow rate instead. SERF operators were moving from a using the manual digital display control which only has a frequency output. Familiarity with using frequency for the pump input is why another parameter was not used instead.

During the second phase of the flat sequence structure, the computer is told which channels on the SC-2345 are to be read. One similarity between the current generation of SERF programs and the previous programs is the use of a sub-vi to initiate the DAQ-mx data reading sequence ([a] in Figure 3-3). The block diagram for the pump sub-vi (raf\_DAQ\_pump\_output.vi) is shown in Figure 3-4:

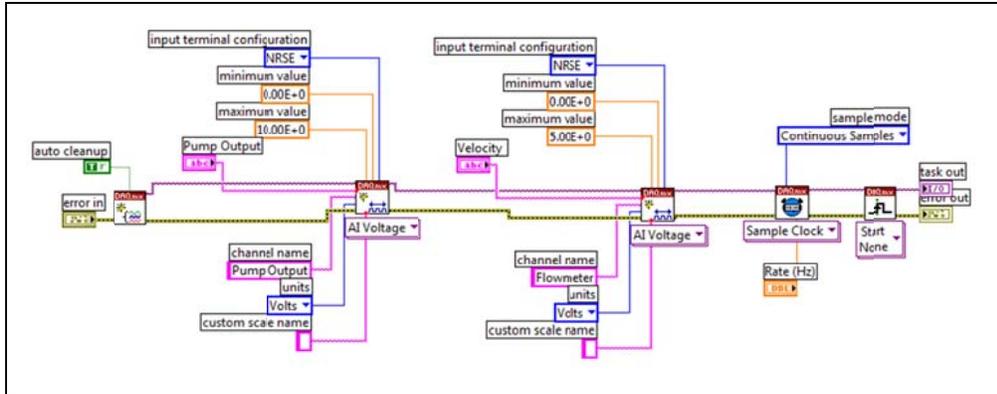


Figure 3-4. Analog Reader Sub-vi (raf\_DAQ\_pump\_output.vi)

The structure of this sub-vi is the same as the 2004 and 2006 version. The algorithm is as follows:

1. Create the DAQ-mx task
2. Specify the first channel to read.
3. Specify the second channel to read (more channels can be added if necessary).
4. Use a sample clock to input the correct sampling rate.

Output from the sub-vi is sent back to the pump control block diagram. Then, a new DAQ-mx task is started to read everything from the channels that were specified in the sub-vi. Finally, the signal is split between so that the velocity signal and the actual pump frequency signal are isolated from one another. Lastly, the signals are calibrated so that instead of a voltage output, a velocity or pump frequency output is given.

The wait timer, [b] is a new addition to SERF control programs. Previous programmers did not realize that this simple addition frees up computer memory. Generally, addition of a wait timer in a Labview program in between each loop is considered good programming practice. This component should not be removed from any of the new SERF computer programs. Once the while loop waits the specified number of seconds (10 ms in this case), the loop repeats. The block diagram's loop will continue to repeat until the user pushes the large stop button on the front panel.

### 3.2.2 Front Panel Operation

To operate the pump control, press the Labview start button on the top of the program. Then, press “FWD” on the digital pump display to initialize the pump. Failure to press “FWD” will not allow the pump to run, and this is a common error. Move the slider on the front panel to the desired pump frequency or alternatively input the pump frequency in the number box. The pump should start moving water through the flume and real-time frequency and velocity graphs should be generated. The max flow rate button should not be changed from 1000 gpm unless the setting on the flowmeter is also changed. The max flow rate in this box corresponds to the data range coming from the flowmeter (Figure 3-5).



Figure 3-5. View from Top of Flowmeter Showing Data Range. See flowmeter’s operating manual for directions on how to change it settings.

### 3.3 Motor Mover

The motor mover is the one SERF component that has hardly changed over the years. In 2010, Labview components were updated from Labview 7.1 to Labview 2009. Some of the old motor mover commands have changed since the 7.1 version of Labview, but overall the program remains the same. The changes result from slightly different syntax requirements between

Labview 2009 and Labview 7.1. A screenshot of the Motor Mover's front panel is shown in Figure 3-6 while a screenshot of its block diagram is shown in Figure 3-7.

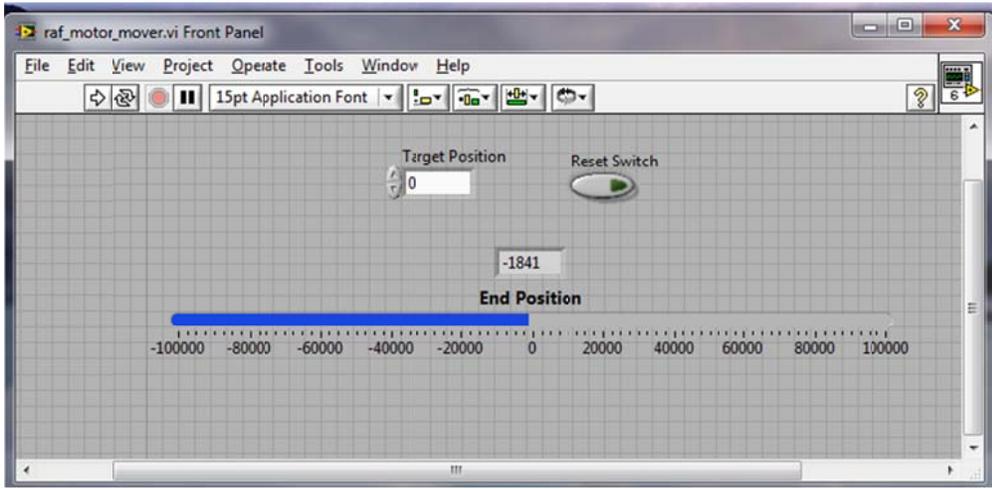


Figure 3-6. Motor Mover Front Panel

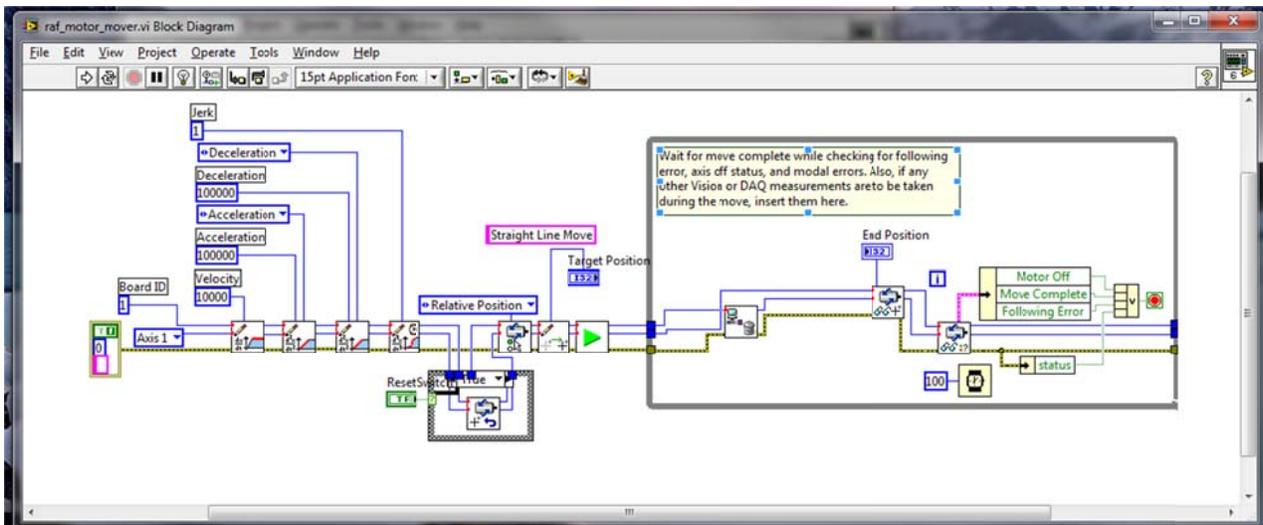


Figure 3-7. Motor Mover Block Diagram (raf\_motor\_mover.vi)

### 3.3.1 Block Diagram Discussion

The algorithm for the motor mover is as follows:

1. Specify the movement axis. For the stepper motor, only one axis, Axis 1, moves.
2. Specify the Board ID. Board ID corresponds to the slot in which the motion controller (a National Instruments PCI 7330 Card) is plugged in the control computer. With the current SERF setup, the PCI 7330 is plugged into Slot #1.

3. Specify the velocity, acceleration, deceleration, and jerk quantities. None of these should be changed.
4. Read the current motor position. The default is for the motor to start at 0 when the Motor Mover program is first run. If the user wants to reset its overall position, press the reset switch on the front panel and press start.
5. Read relative vs. absolute position. The current setting as shown is relative position. This should not be changed.
6. Set the target position.
7. Initiate movement.
8. Continually move the motor and monitor movement for errors.
9. Stop movement when target position is reached.

### **3.3.2 Front Panel Discussion**

First, input the target position in steps. One centimeter equals 7874 steps. Then, press start. The motor should move. Press the reset switch and press start to move the computer position back to zero. The End Position Indicator should return the motor's position every time the program is run. The program will stop automatically when the final position is reached.

### **3.4 SERF Control No Motor**

As discussed in Chapter 2, shear stress tests should be run independently from erosion rate tests until a velocity profiler can be installed in the SERF. The Full Version of the control program can be used to conduct a shear stress test by turning off several of the buttons, but another stand-alone program was written as well to be used for shear stress tests. The stand-alone program is the same as the first few steps of the full version of the control program, but there is much less clutter on its front panel – thereby making it a little bit easier to operate. A screenshot of the front panel for SERF Control No Motor is shown in Figure 3-8 while a screenshot of its block diagram is presented in Figure 3-9.

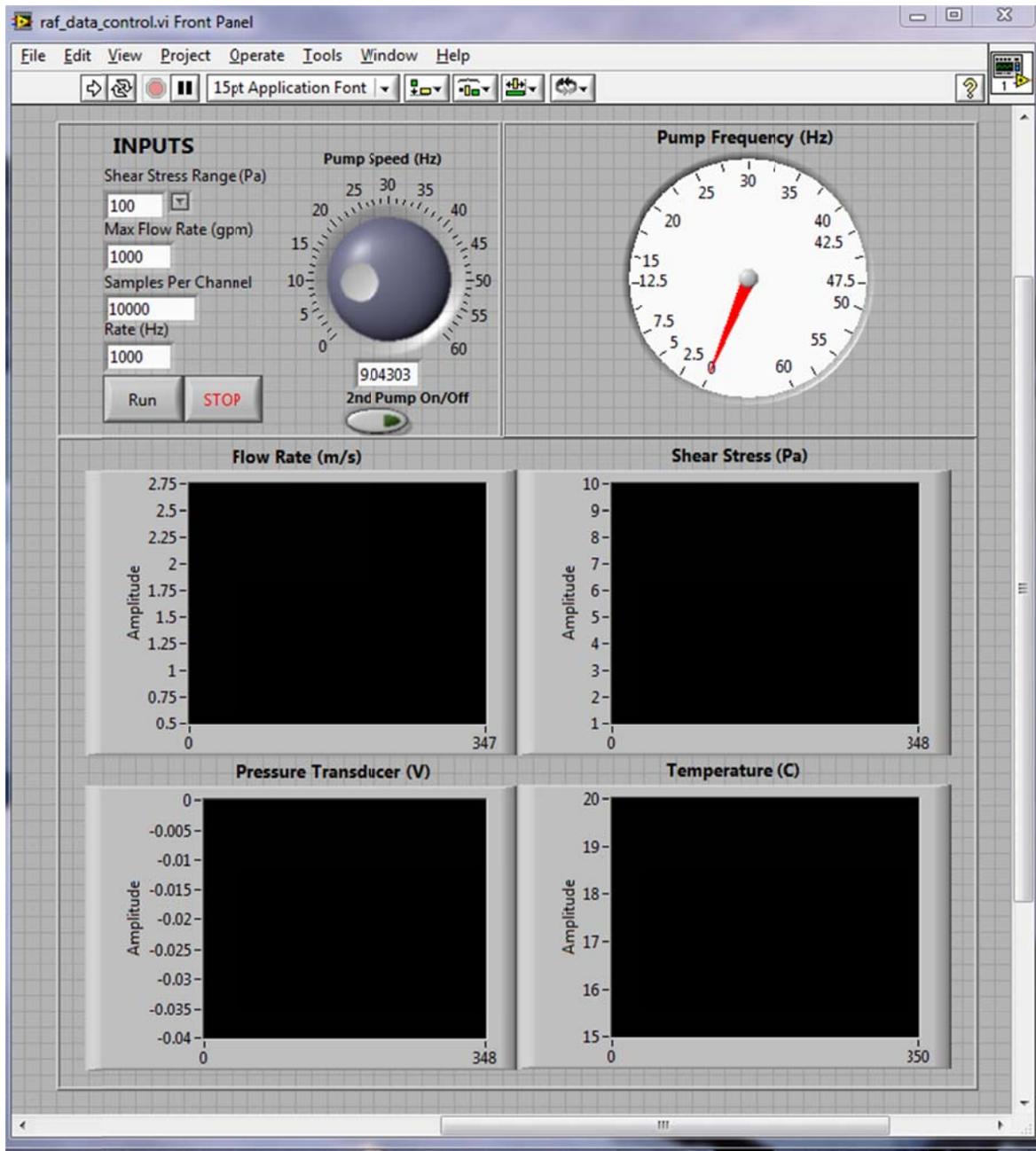


Figure 3-8. SERF Control No Motor Front Panel

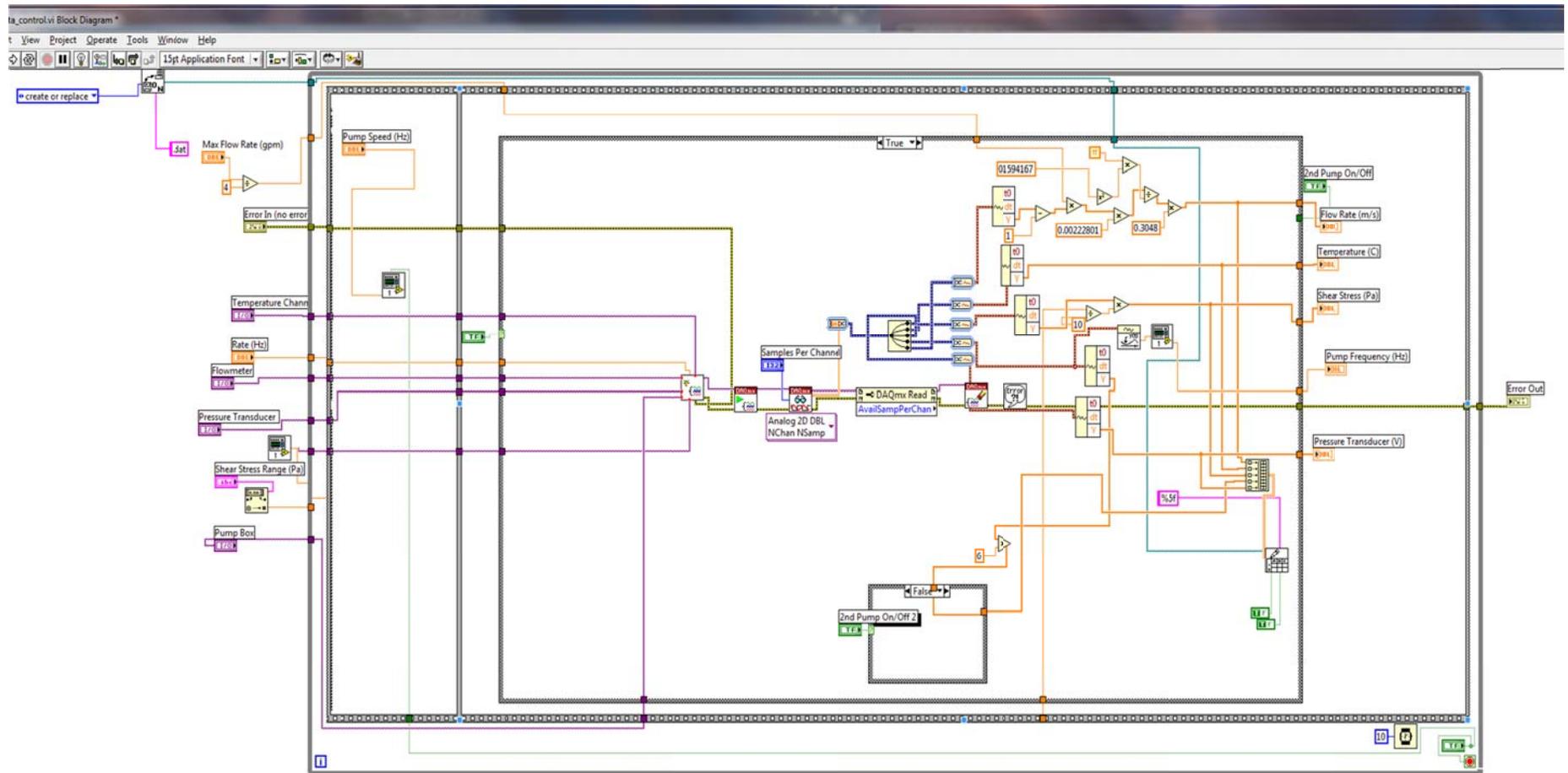


Figure 3-9. Block Diagram for SERF Control No Motor (raf\_data\_control.vi)

### 3.4.1 Block Diagram Discussion

The block diagram for SERF Control No Motor is similar to the pump control program. Both vi's are a two-phase flat sequence structure.

#### 3.4.1.1 SC-2345 Channels

First, SC-2345 channels are specified. Figure 3-10 zooms in on this portion of the algorithm. Following Figure 3-10 is a list of the way everything is currently wired in the SC-2345.

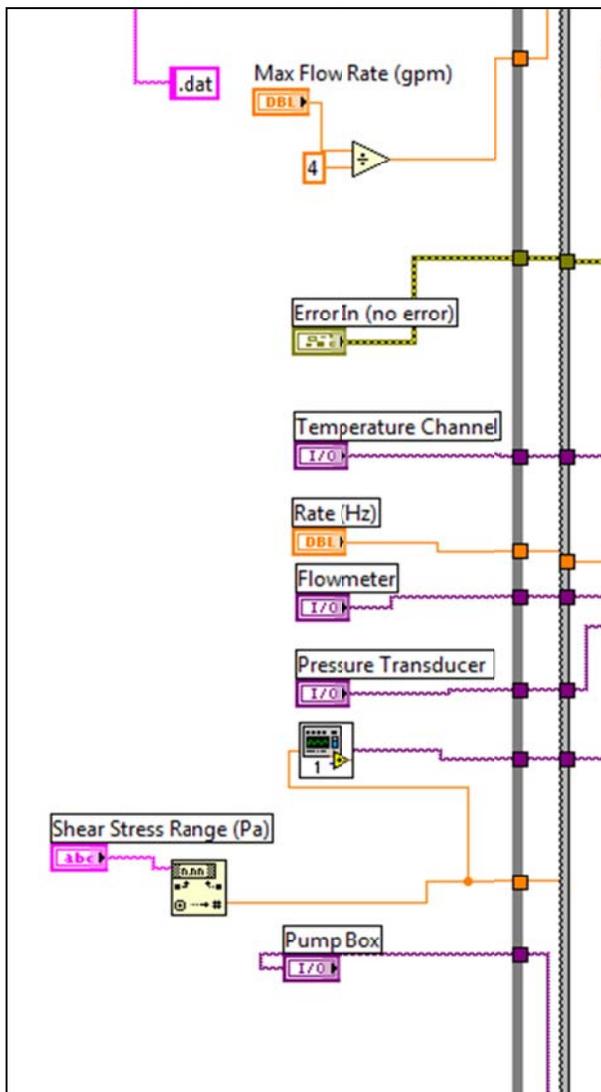


Figure 3-10. Zoom-in on SC-2345 Channels.

1. Thermocouple (Temperature Channel): SCC1Mod1/ai0

2. Flowmeter: SCC1Mod5/ai1
3. Pressure Transducer: SCC1Mod5/ai0
4. Actual Pump Frequency (Pump Box): SCC1Mod2/ai0

To explain the shear stress sensor's wiring, the sub-vi in Figure 3-10 needs to be explained. A screenshot of this sub-vi is shown in Figure 3-11:

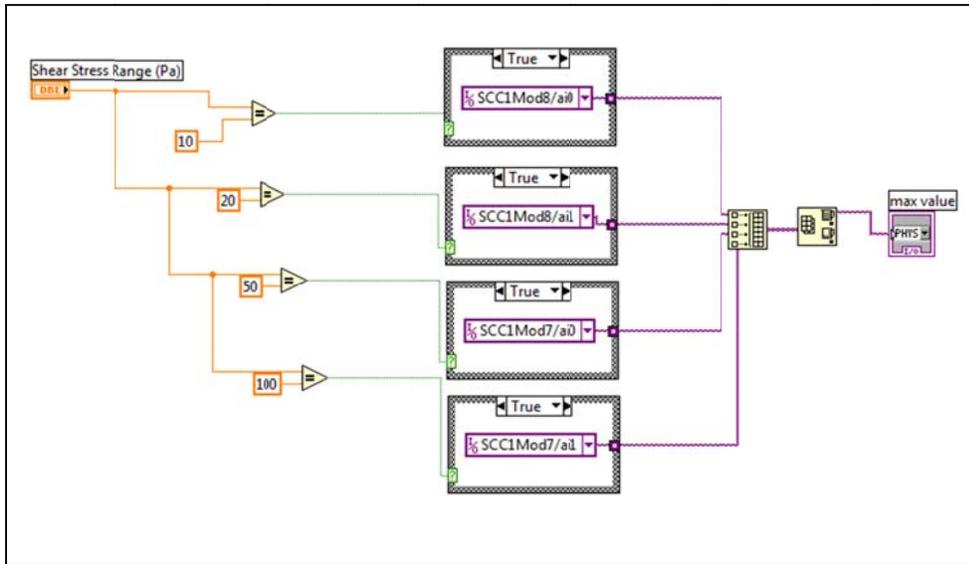


Figure 3-11. Shear Stress Calibration Sub-vi (raf\_shear\_module.vi)

On the front panel for the SERF Control No Motor Program, one of the inputs is for the shear stress sensor's range. Recall from Chapter 4 that range can be adjusted on the shear stress sensor's amplifier so that more accurate readings can be obtained at lower shear stresses. Like the flowmeter with the pump control program, the range from the instrument must equal the range in the Labview program. Four wires come from the shear stress sensor; each wire corresponds to a different output range. The sub-vi shown in Figure 3-11 takes the user input range and compares it with the possibilities from the from the shear stress sensor – 10 Pa, 20 Pa, 50 Pa, and 100 Pa. Then, an array is built with three zero values. The last value in this array corresponds to an actual channel in the SC-2345 based on the results from the four case structures shown in the figure. The array max/min command returns the maximum value from this array so that the computer knows which channel is the correct channel from which to read during shear stress tests.

In addition to specifying which SC modules are to be read, the vi also asks where the user wants to save data. In general programs were written so that .dat files were generated. This

makes Matlab analysis the easiest. The .dat extension can be changed to .xls for an Excel file or .txt for a text file.

### 3.4.1.2 Pump Input

The next step in this program uses the first part of the pump control program as a sub-vi. The user specifies a pump frequency, the pump program is run, and the pump begins. A screenshot of this sub-vi is shown in Figure 3-12.

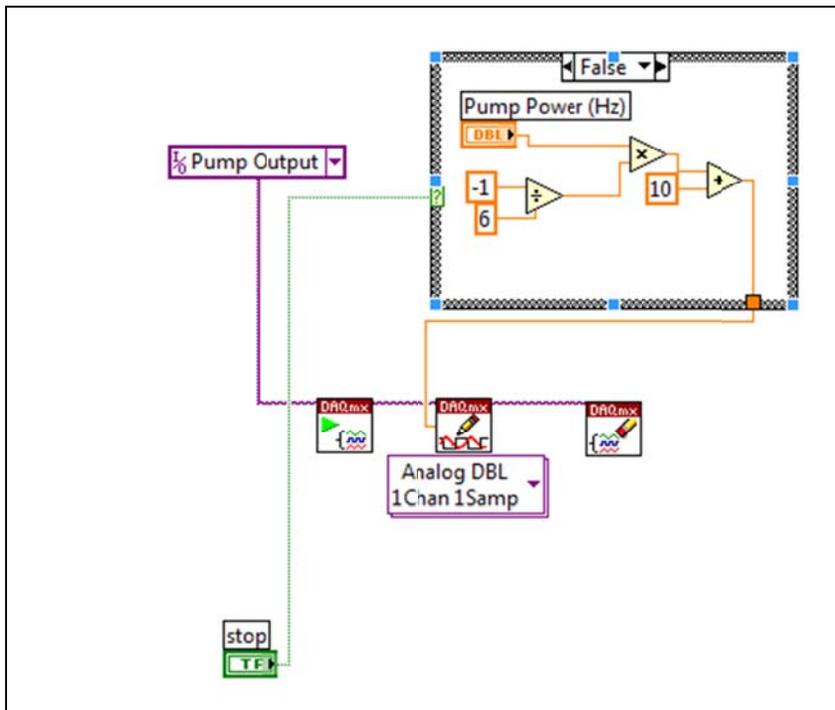


Figure 3-12. Sub-vi Showing First Portion of Pump Control Program (raf\_pump\_on.vi)

### 3,4.1.3 Analog Output

The last step in the SERF Control No Motor is also the same as it is with the pump control program except that five analog signals are taken instead of two. The only thing that changes between these two programs is that the analog reader in the second half of the case structure now has five channels. In the base program, the analog signal is now split five times instead of two (Figure 3-13 and Figure 3-14).

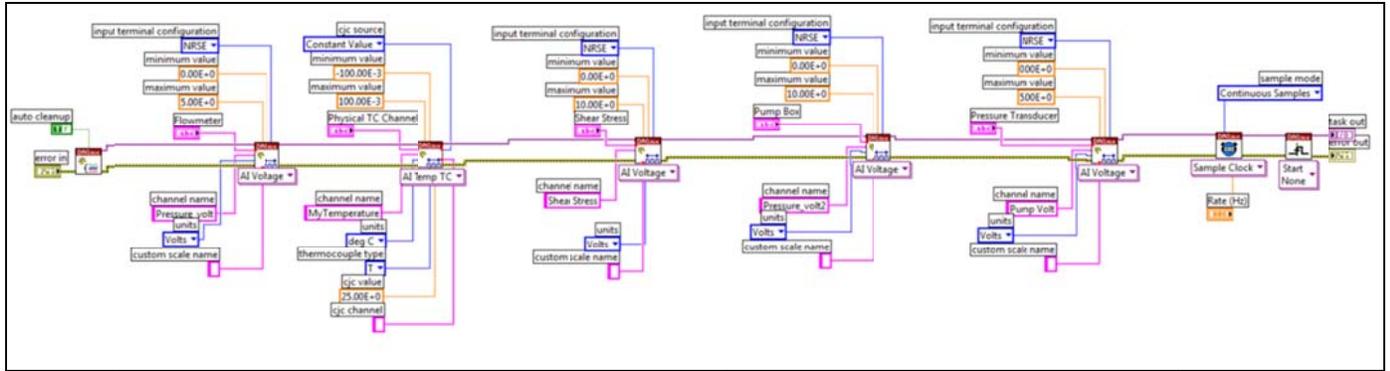


Figure 3-13. Analog Reader for SERF Control No Motor (raf\_DAQ\_no\_motor.vi)

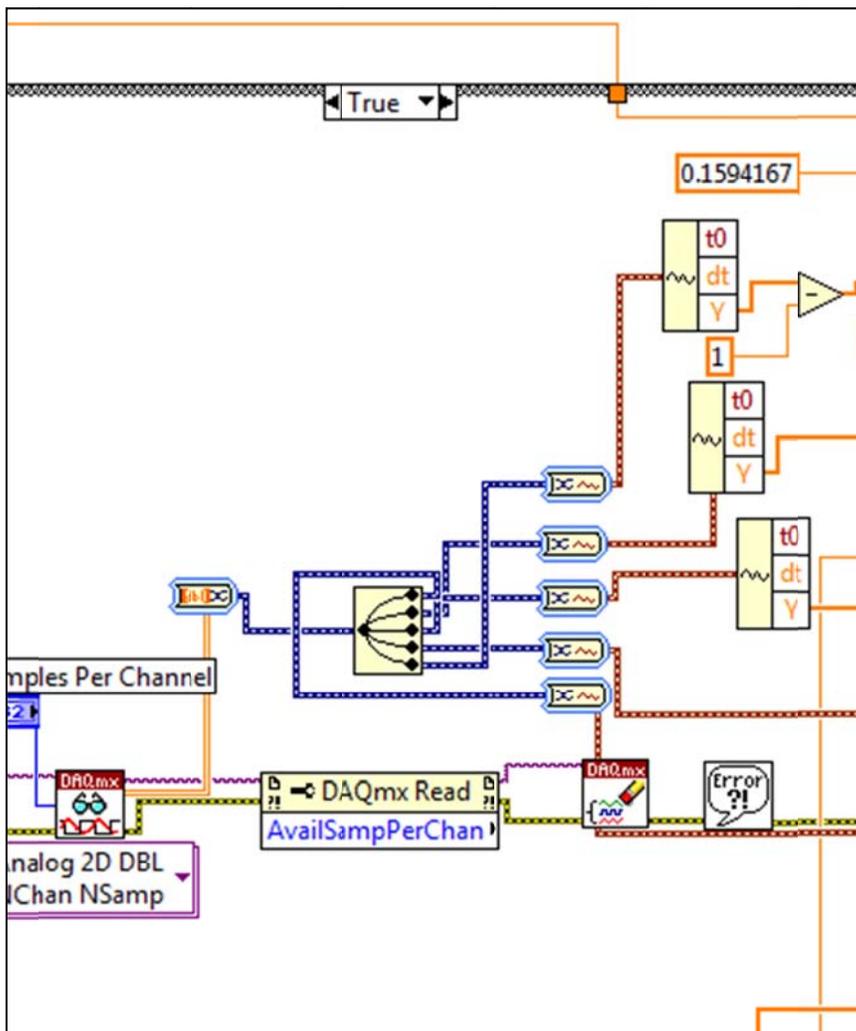


Figure 3-14. Five Signal Split in Pump Control No Motor

The case structure surrounding the analog-read portion of the base vi is to allow for manual data acquisition. During a shear stress test, a SERF operator specifies a flow rate, waits for flow

to stabilize, and collects data. Then, he or she presses “Run” in the base vi and data is collected. The “true” case for the case structure corresponds to when the “Run” button is pressed while the “false” case corresponds to when no button is pressed.

As the base vi runs, real-time graphs are generated because of this true-false sequence. During “false” execution, analog signals are sampled one time through the loop, and the results are plotted immediately. During “true” execution, raw data is sampled at the specified sampling rate according to the Samples Per Channel input parameter. Then, this data sequence is written to the appropriate .dat file. This portion of the program is much different than previous versions. Previous programs both captured an analog block of data every time through the Labview loop, averaged it, and wrote the average to the output file. The acquisition of raw data allows for more advanced data analysis.

### **3.4.2 Front Panel Operation**

To operate raf\_data\_control.vi:

1. Specify the shear stress range using the drop down menu.
2. Specify the maximum flow rate being used in the flowmeter.
3. Specify the number of samples per analog channel.
4. Specify the sampling rate in Hz.
5. Press the Labview “Run” button
6. Initialize the Pump by pressing “FWD”
7. Bring the pump to the desired flow speed using either the computerized pump dial or the number input below the pump dial.
8. When flow speed and shear stress have leveled out, press “Run” to record a burst of raw data. Data time can be computed by  $t = N/f$  where  $N$  is the number of samples per channel and  $f$  is the sampling frequency.
9. When data is taken, the real-time graphs on the front panel will freeze. When data is done being taken, the graphs will resume moving. If this happens, it means the program is working as designed.

### 3.5 SERF Control Full (Temperature Patch)

The latest edition of the full version of the SERF control program incorporates a feedback loop between the thermocouple and the SEATEK, or a temperature patch (hence the program's name). The full version of the program is the most complicated program written for the device and it uses portions of the other programs.

Figure 3-15 shows a screenshot of front panel for the full version of the SERF control computer program. Figure 3-16 shows a screenshot of the program's block diagram:

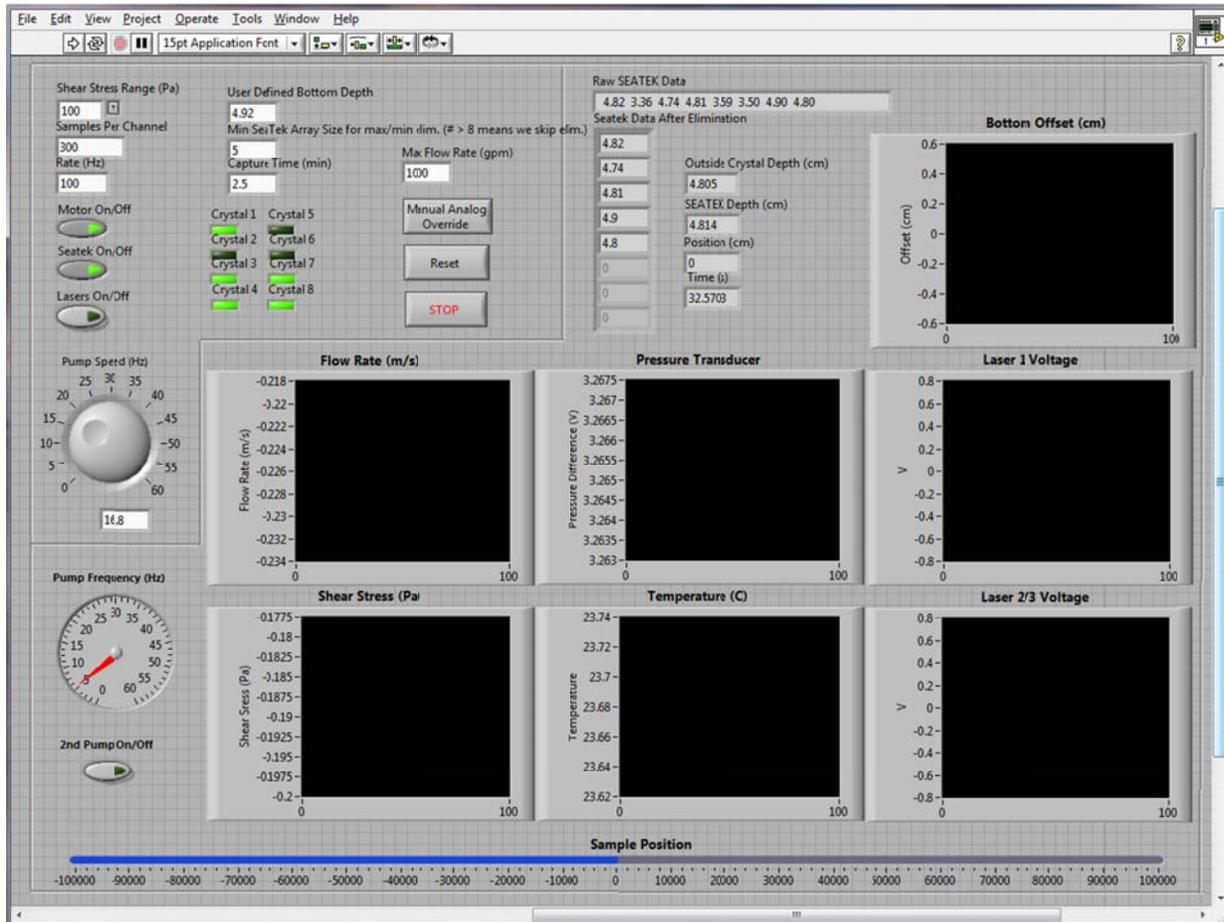


Figure 3-15. Front Panel for SERF Control With Motor and Temp Patch (raf\_control5.vi)

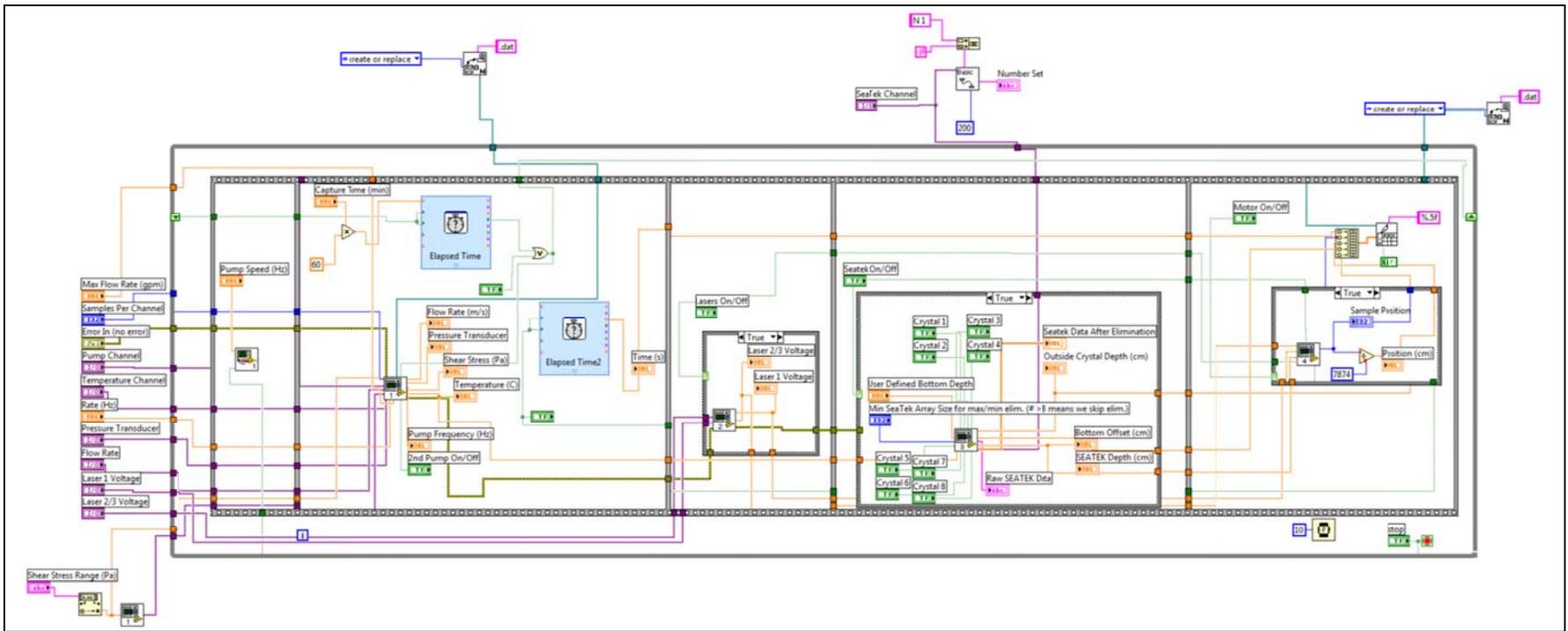


Figure 3-16. Block Diagram for SERF Control With Motor (raf\_control5.vi)

### 3.5.1 SERF Control Full Block Diagram Discussion

Like the other SERF control programs, the full control program is a multi-phased flat sequence structure. The following is a discussion of its components.

#### 3.5.1.1 Pre-Input Sequence

As with other analog SERF programs, the first step in the full version of the control program is to specify input channels for analog devices. This step is the same as it was for the control program without the motor except that the lasers' input channels also must be specified. As wired right now, the lasers are run through SCC1Mod6/ai0 and SCC1Mod6/ai1. Although there are three lasers installed in the device, they are hard-wired in an "or" logic sequence. This will be discussed in Section 3.5.1.6, but for now, it is sufficient to say that there are only two sets of wires coming from the laser system.

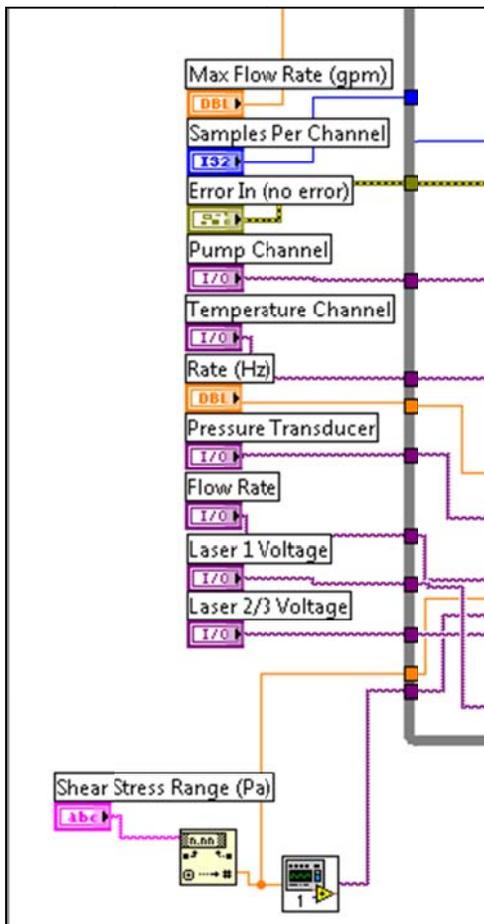


Figure 3-17. Analog Input Channels for raf\_control5.vi

The unique pre-input element to the full version of the control program is a serial port read-write sequence (Figure 3-18).

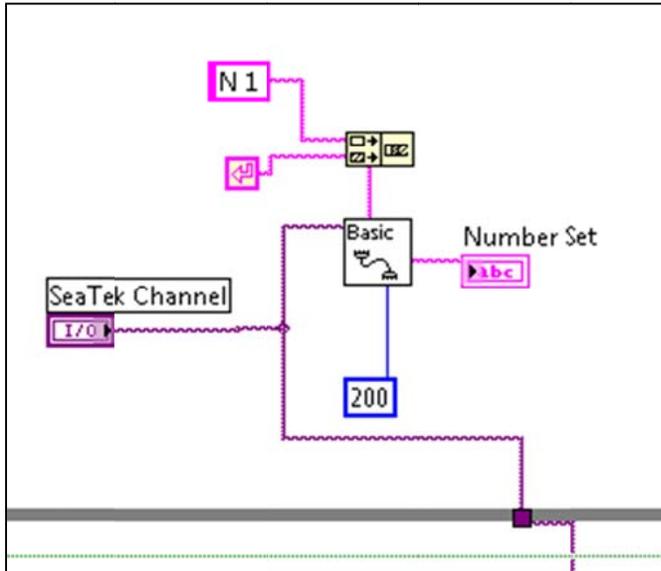


Figure 3-18. Initial Read-Write Sequence Between for SEATEK Serial Port (SEATEK\_integrate.vi)

The sub-vi in Figure 3-18 was taken verbatim from the NI examples folder and should not be changed. The sub-vi sends a “N 1; Enter” command to the SEATEK, waits for 200 ms, and then reveals an optional output that shows that the number of samples to be taken per SEATEK burst is indeed one. Previous SERF testing procedures called for a user to open a HyperTerminal session, specify the number of samples to be taken during a test, and start a data run. When a SEATEK data run is started, the SEATEK pings each of its crystals at 5 MHz, takes an average over 1 s, and then outputs its result. The SEATEK “N” command corresponds to the number of times this pinging-averaging is to repeat itself. Once a SEATEK data run is started, output data will continue to be generated until the number of bursts from the SEATEK equals N. When a data run is started, new input parameters cannot be added to the SEATEK until N is met. For the temperature patch to function properly, the SEATEK’s input temperature needs to be updated continuously. Put another way, after each 5 MHz SEATEK burst-average, the SEATEK needs to know that it should stop taking data and wait for a new temperature command. Inputting the “N 1” command as the SEATEK is initialized guarantees that this will occur properly.

### 3.5.1.2 Pump Input

Like the SERF control program without the motor, the next step is to specify the correct flow rate (frequency) to the primary control pump. As before, raf\_pump\_on.vi is used (Figure 3-19).

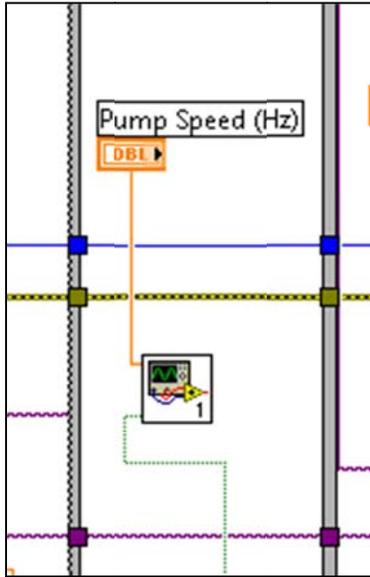


Figure 3-19. First Phase of Five-Phase Flat Sequence Structure Showing the Pump Input Controller (raf\_pump\_on.vi)

### 3.5.1.3 Analog Output

Once the correct input frequency is given to the pump, the next step as before is to read analog signals coming from the shear stress sensor, the thermocouple, the pressure transducer, the pump frequency indicator, and the flowmeter (Figure 3-20).

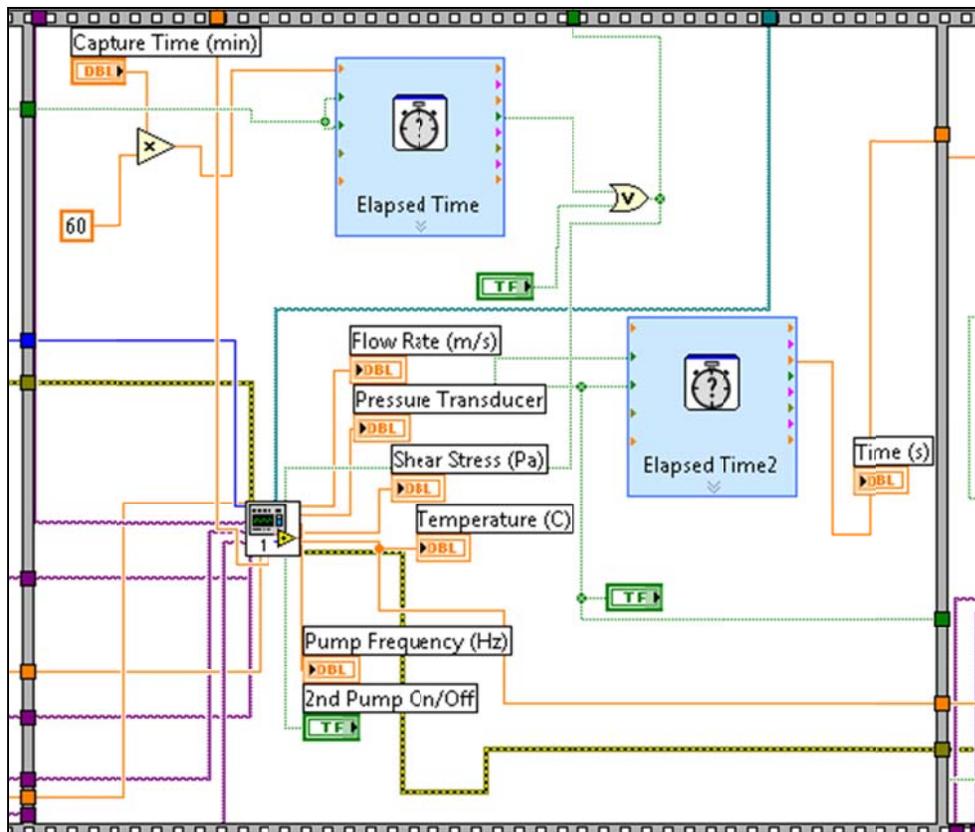


Figure 3-20. Second Phase of Five-Phase Flat Sequence Structure Showing the Analog Output Module. Sub-vi is called raf\_control\_step1-1.vi.

This step is similar to the no motor SERF control program. The difference between this step and the similar step in the no motor control program is that during the full version of the program, two timers have been added. Recall that with previous vi's, analog signals were read and averaged every time the motor made a step. The problem with this is that a complete raw signal was not recovered. A better method is to set up a timed “analog burst” at a specified interval (top timer). Based on the user’s “capture time” an analog burst will be taken every time the timer hits the “capture time” interval. The second timer keeps track of total time; it corresponds to motor position readings so that a user can get a motor position vs. time output signal. If an operator wanted to go back to the old way of capturing data, the capture time, sampling rate, and samples per channel could be adjusted accordingly. For example, if a user wanted to capture data every time the program made its way through its loop (as it did before) at 1 kHz, number of samples would be set to 1000 and capture time would be set to 0.1667.

The “Manual Analog Override” button functions the same way as the “Run” button in the version of this program without the motor. If the user turns off the motor, the lasers, and the

SEATEK buttons on the front panel, the full version of the program will skip the last three phases of the five-phase flat sequence structure, and the program will effectively run the same as the version of the program without the motor. The sub-vi shown in Figure 3-20 is similar enough to the SERF Control No Motor code that it does not need to be shown here.

### 3.5.1.4 Laser Input

The third phase of the five-phase flat sequence structure is to read the voltage signal from the lasers (Figure 3-21).

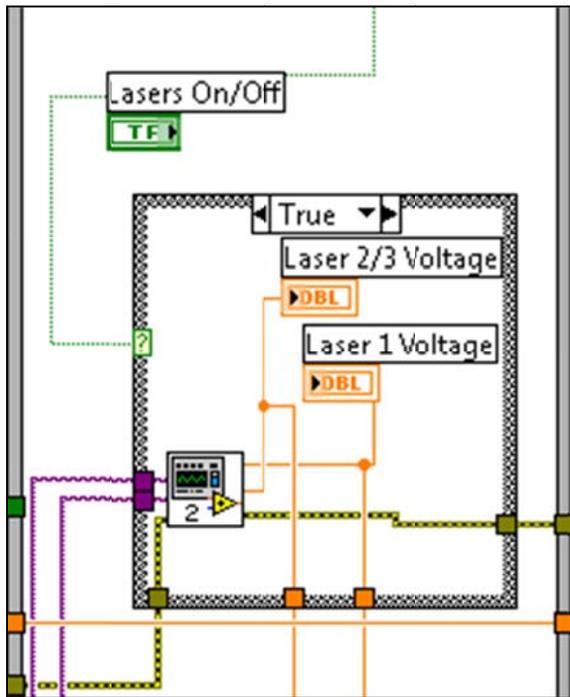


Figure 3-21. Third Phase of Five-Phase Flat Sequence Structure Showing the Laser Output Module (raf\_control\_step2.vi)

Although the laser output signal is also just another analog signal, there should not be a need to capture or sustain an analog burst. Output from the lasers is simply a +10 V reading if the lasers' photoelectric sensor picks up a light signal or a 0 V reading if the sensors do not pick up a light signal. Because there was no need to pick up a raw laser signal, this element from the program was conducted separately. This phase was also programmed separately so that the lasers could be turned off easily using the front panel. The sub-vi in this phase of the program is shown in Figure 3-22. It should be obvious from its structure that this sub-vi functions like the



Unique to this SEATEK output module compared with previous versions of the control program is a series of buttons for each of the eight inner SEATEK crystals. The 2006 programs set up the groundwork for a system where individual crystals could be turned off, but using his program was not intuitive and required block-diagram input. The buttons shown in Figure 3-23 simply require a true/false input; if the button is pressed, the crystal runs and if not, the crystal is turned off. The SEATEK sub-vi, raf\_control\_step3.vi is shown in Figure 3-24:

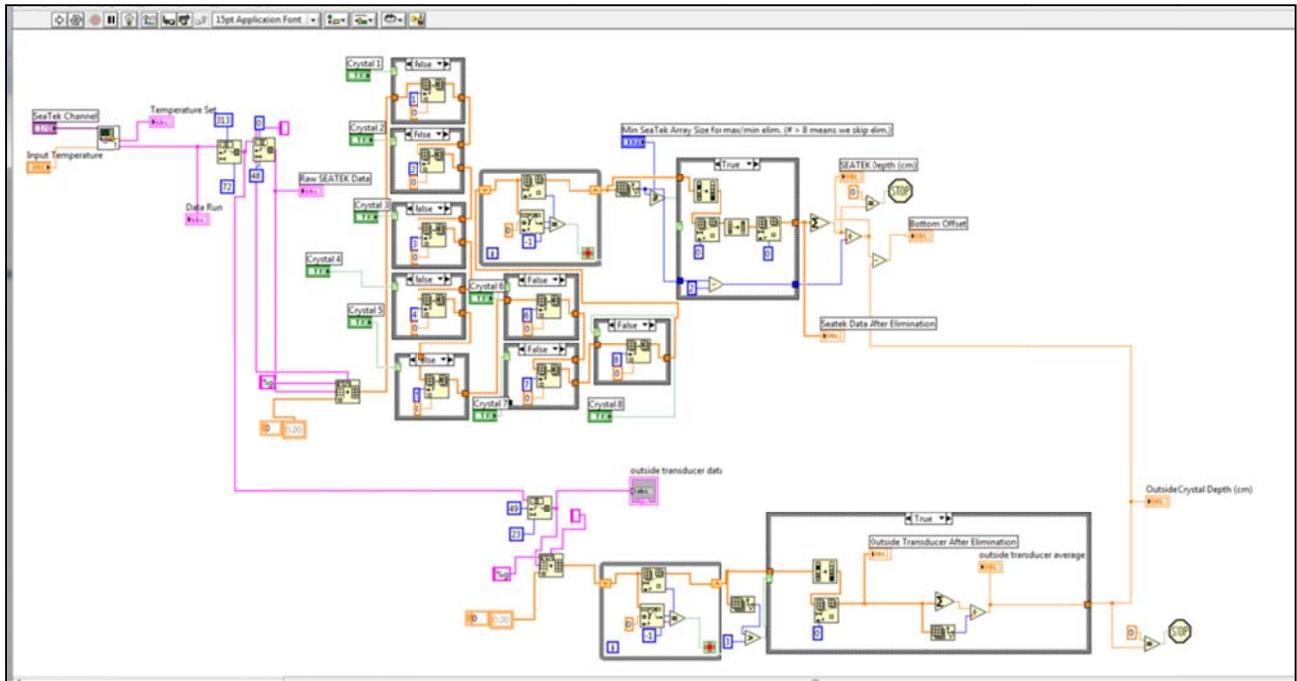


Figure 3-24. Block Diagram for raf\_control\_step3.vi

Much of raf\_control\_step3.vi is the same as previous code. The difference between this vi and the previous generations of programs is that this vi has a temperature patch. The patch reads writes temperature data to the SEATEK just before every SEATEK depth reading. When raf\_control\_step3 is run, first the SEATEK channel is specified. The SEATEK channel corresponds to the control computer's serial port – labeled SerialPort in MAX (National Instruments Measurement and Automation Explorer). Once the computer knows the correct serial port, signals are sent from the Labview program to the Serial Port. The Input Temperature control in raf\_control\_step3.vi comes from the analog signals read during the third phase of the flat sequence structure. Once the input temperature is known, the following two block diagrams are executed (as a Stacked Sequence Structure):

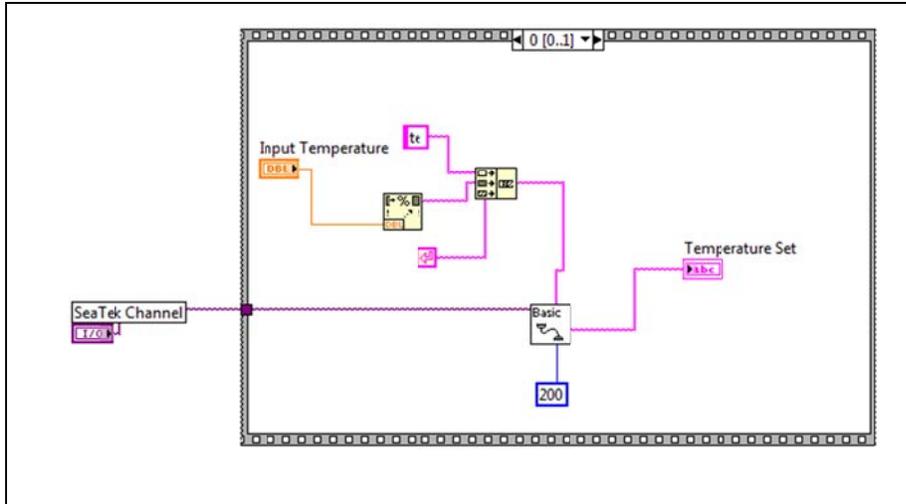


Figure 3-25. First Element in Temperature Patch Stacked Sequence Structure

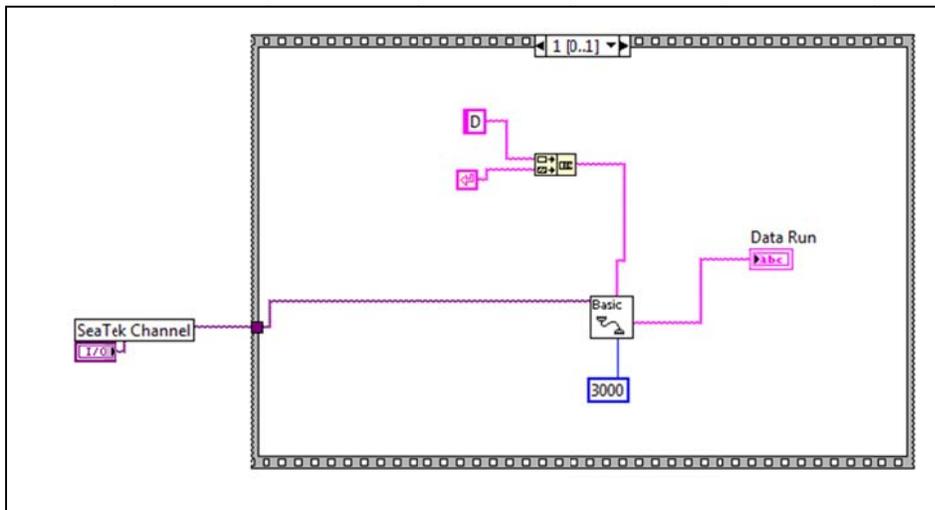


Figure 3-26. Second Element in Temperature Patch Stacked Sequence Structure

This stacked sequence performs the following algorithm:

1. Input temperature is converted to a string so that it can be written to the SEATEK
2. The command “TE XX Enter” is input to the serial port where XX corresponds to the input temperature in degrees Celsius.
3. The Serial Port waits for 200 ms.
4. The command “D Enter” is written to the serial port. This tells the SEATEK to begin a data run. Because the data run was capped at one analog burst from the previous “N 1” command, one set of numbers will be returned from the SEATEK.
5. The program waits 3000 ms. This is approximately the amount of time it takes the SEATEK to initialize a data run.

6. After 3000 ms, Labview reads the SEATEK return data from the serial port.

The disadvantage to this algorithm is the 3000 ms wait time. Before, operators began a data run corresponding to the amount of time for an erosion test. Then, they would read SEATEK data as it was written to the serial port. As soon as this happened, the depth data was recorded. The temperature patch, because of its 3200 ms wait time (which is required and should not be changed) sacrifices a certain amount of speed for accuracy.

Some quick mathematics can be used to show why the temperature patch should be effective. The speed of sound in water is temperature dependent such that a change of one degree Celsius corresponds to approximately a change in sound speed of approximately 3.1 m/s. Although the water chiller can hold water temperature steady with approximately 2 degrees Celsius accuracy, this uncertainty could correspond to as much as 12.4 m/s in speed of sound uncertainty. As originally conceived, devices like the SEATEK are generally used under field conditions – where temperatures do not vary drastically and where +/- a few centimeters of depth accuracy is acceptable. Because of the SERF's sensitivity requirements for motor advancement (0.5 mm), a few centimeters of depth accuracy is unacceptable. Programmers in 2006 realized this; hence his inclusion of the user-defined depth parameter in his generation of programs. Although quantitatively tests were not conducted to determine average SEATEK error with and without the temperature patch, qualitatively, it was clear that as soon as the temperature patch was designed the user-defined depth parameter was no longer necessary. Therefore, the SEATEK program went back to using the four outside crystals to define the fixed distance from the top to bottom of the flume (Figure 3-27 or the bottom portion of the full block diagram).

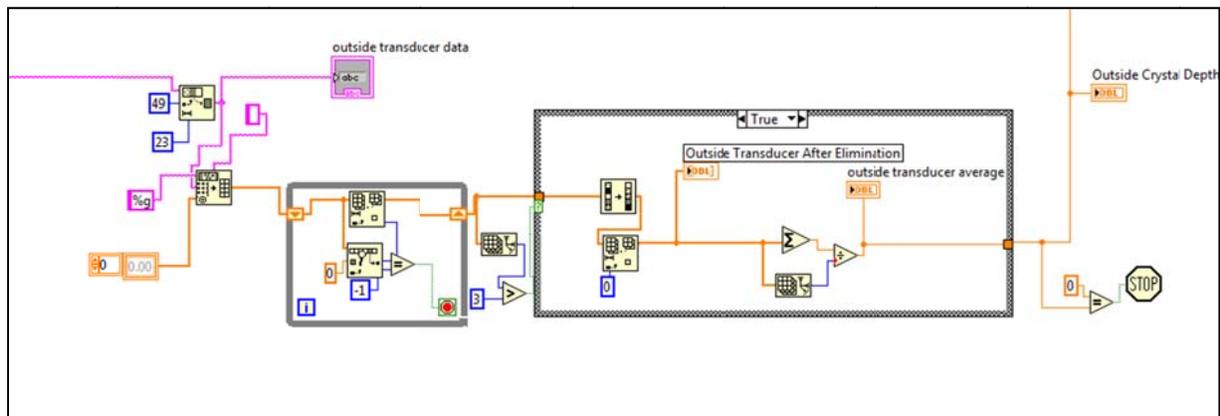


Figure 3-27. Outside Crystal Depth Algorithm

Unfortunately one of the outside crystals was damaged when this project began and was not working. The malfunctioning crystal consistently returns a low reading. For example, if bottom depth should be 4.92 cm, actual depth reading from the malfunctioning crystal holds steady at approximately 3.30 cm. To combat this problem, this crystal is automatically eliminated by eliminating the minimum value from the array of readings from the SEATEK. If somehow the entire SEATEK reading gets botched, a case structure is included with a user-defined bottom depth parameter so that this value will be used instead. A botched reading is defined when one of the outside crystals returns a value of 0.00. Readings of 0.00 from the SEATEK are given when there is an error with the device.

After the temperature patch, the top half of raf\_control\_step3.vi is similar to the 2006 version of the program. Once SEATEK data is read and converted to an array, there is an option to turn any of the inner crystals on or off. When a crystal is turned off, the number in the corresponding 1x8 array is replaced with a zero (Figure 3-27).

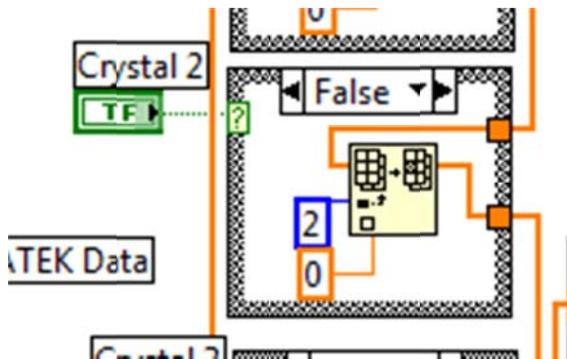


Figure 3-27. Example of a Crystal-Off Module with Crystal 2 Shown

The 2006 program's method was to simply remove the element completely, but zero-replacement is easier to understand, and after the crystal-checking algorithm, a zero-checker is included anyway. The purpose of the zero-checker originally was to check for SEATEK errors. Now, not only does it check for errors, but it also checks for zeroes corresponding to crystals that were turned off by the user (Figure 3-28).

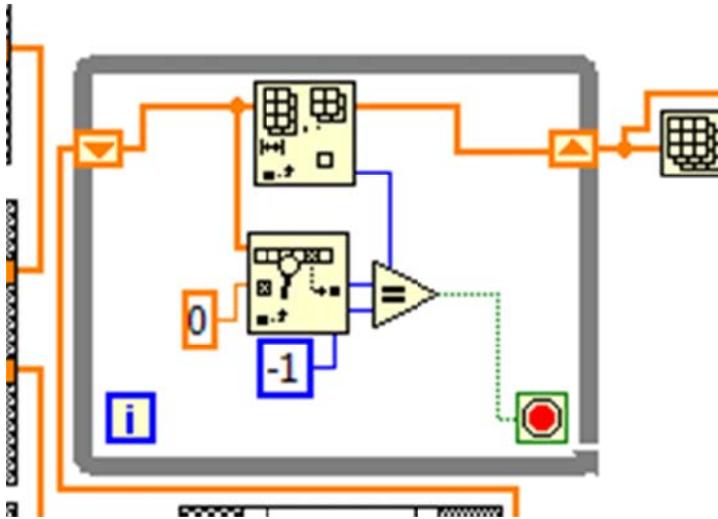


Figure 3-28. SEATEK zero-checker. Algorithm is the same as the 2006 version

After the zero-checker, a 2006-style maximum and minimum procedure is used (Figure 3-29). The max/min eliminator only functions if an array size is long enough. For example, if two crystals are malfunctioning, the maximum array that can be expected from the SEATEK is a 1x6 matrix. Suppose three SEATEK readings were in error and they returned a 0.00 value. Under these conditions, the maximum array to be expected would now be 1x3. If the “Max SEATEK Array Size for max/min elim.” parameter is set to a number greater than 3, the max/min elimination will be skipped altogether. The user specifies the minimum array size under which a max/min elimination is considered acceptable.

Lastly, results are averaged and compared with results from the outside SEATEK crystals. The STOP vi is a safety where if the SEATEK returns a string of zeros, (this happens rarely), the whole program will stop. This is important because if this safety did not exist, the motor could advance uncontrollably. This would push the sample against the top of the flume and cause the sample to rub against the SEATEK crystals. This would scratch the SEATEK’s crystals. This mechanism is probably why so many of the SEATEK crystals currently do not work. The raf\_control\_step3.vi sub-vi returns a bottom offset, outside crystal depth, a raw SEATEK string, and SEATEK data after data manipulation to the base program.

### 3.5.1.6 Motor Advancement

The motor advancement phase is the last portion of the SERF control program (Figure 3-29).

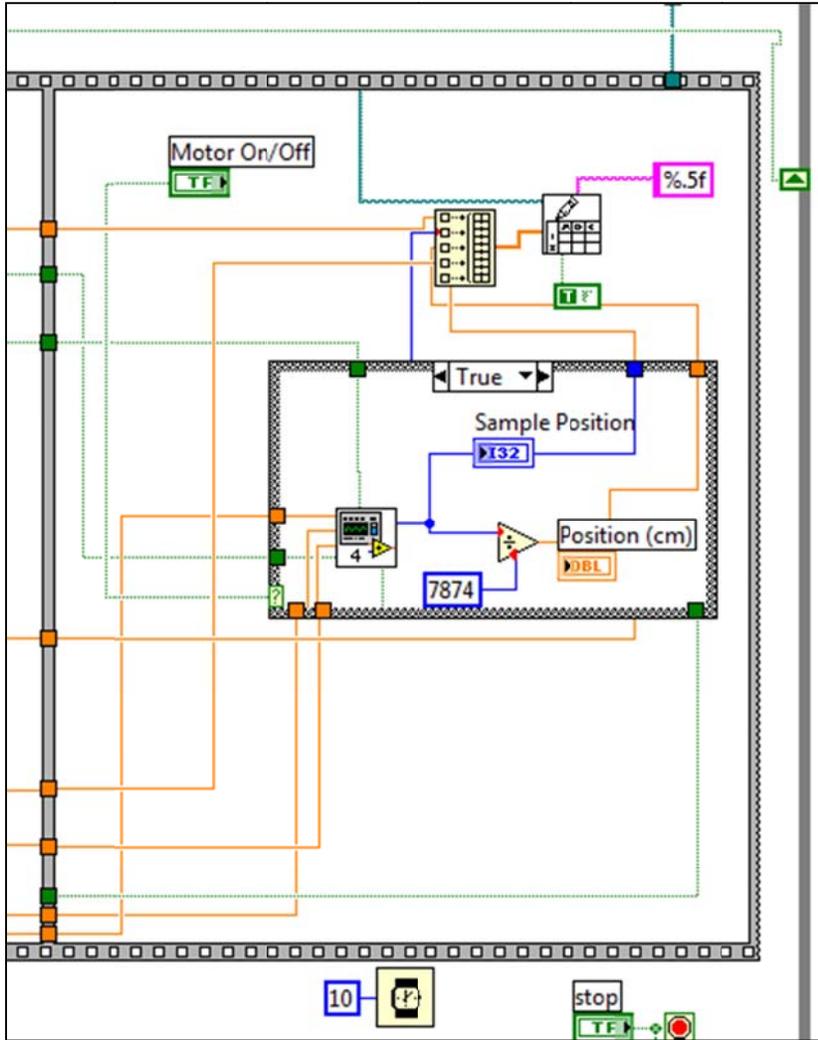


Figure 3-29. Fifth Phase of Five-Phase Flat Sequence Structure Showing the Motor Movement Module

In the base portion of the program, SEATEK depth and laser output are fed into a sub-vi called `raf_control_step4.vi` (Figure 3-30). The output from this sub-vi is sample position in steps.

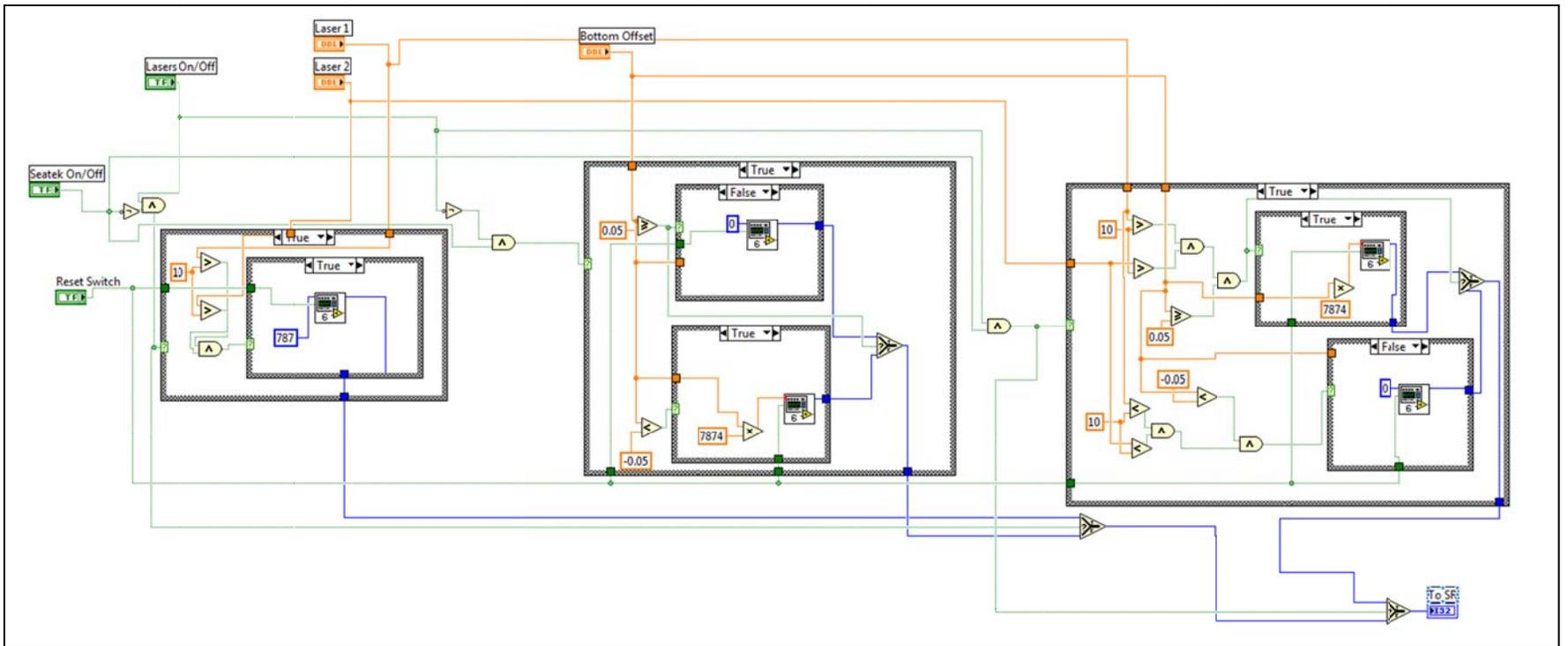


Figure 3-30. Block Diagram for raf\_control\_step4.vi

There are three case structures programmed in this sequence shown in Figure C.5.17:

1. Far left case structure corresponds to when the flume is run with the lasers only.
2. Middle case structure corresponds to when the flume is run with the SEATEK only.
3. Far right case structure corresponds to when the flume is run with the SEATEK and lasers in a redundant system.

In the case where the lasers are used exclusively, the lasers return a positive voltage only if their corresponding photoelectric sensor picks up light. When the photoelectric sensor picks up light, a voltage of  $\sim +16$  V is returned; in the program a comparison voltage of + 10 V is used, although this number is arbitrary. Recall that two lasers are wired to one control box such that they respond via “or” logic – i.e. a voltage will be returned if either of their photoelectric sensors picks up light. Experience with the SERF has shown that generally samples erode back-to-front or front-to-back. It is rare to see a sample stay intact in its center while exhibiting high erosion rates in the back and the front. This is why the outside lasers were chosen for the “or” logic, while the middle laser was wired by itself. When either of these outside lasers plus the middle laser are uncovered, the sample advances. Although it would have been better to wire lasers independently with one another, this would have been more expensive, and funding was not available for it. This solution was the most effective alternative.

In the case where the SEATEK is used by itself, depth data from the base program is written to `raf_control_step4.vi`. If the bottom offset distance is greater than 0.5 mm, the sample advances. If the bottom offset distance is less than -0.5 mm, the sample retracts. The retraction allows for a constant depth-check. If the sample has advanced too much (which happens sometimes), the retraction allows for a correction to be made.

In the case where the SEATEK and the lasers are used together, the retraction algorithm does not change from the case where the SEATEK is used by itself. The weakness of the lasers is that they do not provide any retraction information should the sample advance too far into the flume. In the advancement case, an “and logic” sequence is programmed where laser output plus SEATEK output are both needed to trigger movement. In every case, the sub-vi that controls movement is the same `raf_motor_mover.vi` describe in Section 3.5.3.

### 3.5.1.7 Data Writing

Data writing is somewhat different in this program than it was in the previous versions. Previously, data was written to one data file. Now, because analog bursts are taken to recover the original analog signal, two output files need to be generated – one for analog data and the other for piston position data. The analog burst data is written during the analog phase of the flat sequence structure while the depth data is written after the motor advances.

### 3.5.2 Using the Front Panel

The front panel improvements to the full version of the SERF control program are significant because for the first time ever, a user has touch-of-the-finger control on any of the device's components. The front panel is much more user-friendly than it was in the past. Although using the front panel should be self-explanatory, the following is an example of how to use it:

1. Specify shear stress range (if shear stress readings are to be taken), sampling frequency, number of samples per channel, capture time, and the minimum SEATEK size to be used for max/min elimination.
2. Turn off any malfunctioning SEATEK crystals (if the SEATEK is to be used).
3. Decide what kind of data run is to be used. Options include:
  - a. Analog capture only using Manual Analog Override
  - b. Erosion test
  - c. With Lasers only
  - d. With SEATEK only
  - e. With both lasers and SEATEK
4. Specify flow rate.
5. Press “FWD” on the pump's digital control.
6. Press the “RUN” button.
7. The program will ask where to save the two .dat files. Specify the directory.
  - The SERF should run until the “STOP” button is pressed.

## **CHAPTER 4 TROUBLESHOOTING**

This section presents solutions to problems that may occur while operating the SERF. The problems listed have at some point been encountered, and knowledge of how to handle these situations is very valuable. If there are other problems encountered in the SERF, solutions to these problems should be added to this section.

### **4.1 Water Leaking at the Test Cylinder**

Unfortunately, leaks are frustrating problems that usually require unexpected additional time and effort to solve. Leaks can either occur from the outside of the test cylinder or at the plunger. Leaks outside of the cylinder are much easier to stop than leaks at the plunger.

To stop a leak at the outside of the cylinder, the solution is usually to tighten the screws on the bottom compression plate with a wrench. Eventually, the leak should stop. If, however, leaks still occur, the o-ring in the top compression plate will need to be replaced. This requires that the operator drain the flume, lower the plunger to the edge of the cylinder, remove the lead screw-plunger pin, and remove the test cylinder. Remove and the o-ring in the upper compression plate and install a new, greased o-ring. Reload the cylinder, and no further leaks should occur.

Leaks at the plunger are due to damaged o-rings due to over use. To stop a leak at the plunger, the flume must be drained, the cylinder removed as described in the previous paragraph, and the plunger should be removed from the cylinder. Replace the bad o-rings on the plunger with two cleaned and greased o-rings. Reload the plunger and the cylinder into the SERF, and no further leaks should occur.

### **4.2 Stepper Motor**

When running any LabVIEW program that sends commands to the stepper motor, the stepper motor may move the lead screw at a very slow pace. This usually occurs after the computer has been reset.

To correct this problem, first close all LabVIEW programs. Open the program on the Desktop labeled “Measurement and Automation Explorer” or otherwise known as MAX. On the folder list to the left, expand the following folders in order: My System, Devices and Interfaces, PCI-7330, Default Valuemotion Stepper. Click on the Default Valuemotion Stepper folder, and in the panel to the right, change the selection from Custom to Open loop stepper, and click Apply. In the folder list on the left, now click on Axis Configuration and select “active low”. Click on the folder called Axis Settings, and select “active high polarity”. Click Apply and Initialize. Close out MAX, and the stepper motor should now function properly.

If the Labview controls indicate that the stepper motor is in a reset state, it means that due to a computer update/restart, the PCI-7330 needs to be reinitialized. To reinitialize the motor, close all Labview programs and open MAX. Click initialize (same button indicated in previous paragraph) and close MAX. The stepper motor should now function properly.

### **4.3 Erosion Rate Program not Receiving Valid SEATEK Data**

When running an erosion rate program and either no data or invalid data appears in the SEATEK window, the program is not receiving readable data from the SEATEK. This is usually due to not closing TeraTerminal out before opening any LabVIEW programs. To correct this problem, make sure that the SEATEK unit is turned on, then close all LabVIEW applications. Close TeraTerminal. Re-open Labview. The SEATEK should now function properly.

### **4.4 Invalid Pressure Sensor Data**

Although the need for extensive pressure transducer tests has been reduced because of the shear stress sensor, it may be valuable to continue to use the transducers for verification purposes during a smooth-wall shear stress test. If the user suspects that data sent from the pressure transducer is incorrect, this may be due to either a clog in the tube connecting the flume to the pressure transducer, the presence of a trapped air bubble at the transducer or in the line, or due to damage to the pressure transducer.

Sediment clogs may be removed by disconnecting the tube from the valve and using a wire or unwound paper clip to dislodge the blockage. Also, shaking or flicking the tube will be

required to remove all sediment. Once water flows easily again, re-establish the connection to the valve and shake the tube to remove any introduced air bubbles.

Most often, trapped air bubbles are the reason for invalid pressure readings. Air bubbles will probably be trapped at the tubes with side tap connections. As the tubes make a horizontal connection into the flume wall, air bubbles will often lodge here. To remove the bubbles, slowly lift the tubing above the flume so the air bubbles trapped inside are pulled out from the wall, rapidly pull down the tubing, and repeat. This will force the air bubbles to shoot back into the wall of the flume, where they may be picked up by the flow inside the flume and carried away. Air bubbles trapped in the transducer require removing the pressure transducer from its seat and turning the transducer around to encourage air to escape up the pressure line and into the flume.

To determine if a pressure transducer is damaged, MAX can be opened to display direct pressure sensor signals. If moving the pressure tube lines does not affect the output, the sensor is damaged.

#### **4.5 Air bubbles Entering the Flume through Pressure Taps**

As a sample is being tested in the flume and observed on the second monitor, air bubbles may be observed entering from the side taps into the flow. This normally is evident when there is no flow in the flume. This may occur because the side-tap fitting or tube fitting need tightening. Air bubbles in the flow or around the fittings will result in incorrect pressure and readings.

If tightening the tube fitting with a wrench does not solve the problem, the flume should be drained and the wall fitting should be removed with a wrench. The threaded end should be dried and wrapped sufficiently with clean Teflon tape, and the fitting should be replaced into the flume. If air bubbles are observed traveling through the flow on the monitor and originate from an unknown location, the other fittings may need to be checked.

#### **4.6 Shear Stress Sensor Problems**

The shear stress sensor is very temperamental and the source of most problems in the SERF. Because of the high sensitivity of the device, this is to be expected, although problems with the shear stress sensor can be frustrating. Generally, operators will become aware of a shear

stress sensor problem if the device fails to calibrate properly. If this occurs, there must be something wrong with the mechanical setup of the device. These mechanical issues are common, and they must be addressed before a shear stress test can commence. If the shear stress sensor will not calibrate properly:

1. The most common mechanical issue with the shear sensor is pollution (see step 5). First, recheck to make sure the gap between the Servo magnet and the Hall Sensor is present. If not, re-clean and recalibrate.
2. If the gap between magnet and sensor is present, the next most common mechanical issue is the connection between the deflection magnet and the platform. Open the round upstream access hatch on the left side of the sensor as the sensor is observed from the middle of Reed Lab (Figure 2-14).



Figure 4-1. Round Access Hatch on Shear Sensor

3. When looking into the round hole in the sensor, there should be a small gap between the magnet battery and the solenoid. When the connection slips, an illustration as shown in Figure 4-2 is what will be seen instead.

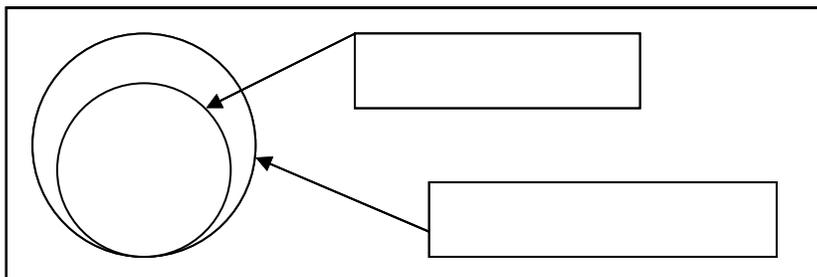


Figure 4-2. Schematic of a Slipped Brass Rod Connection

4. If it looks as though the magnet battery is rubbing against the deflection solenoid as shown in this figure, loosen the screw shown in Figure 4-3 and reposition the brass rod so that there is an air gap present between the deflection solenoid and the magnet battery.

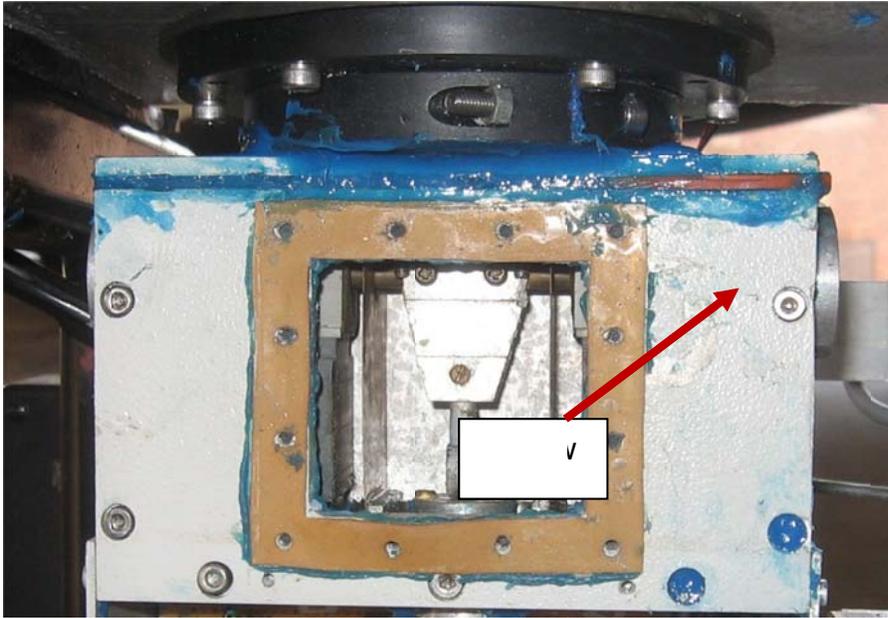


Figure 4-3. Screw holding brass rod to platform.

5. Try to recalibrate the sensor. If it still does not work, remove the brass rod and magnet battery completely and check to make sure the connection between the magnet and the brass rod is not broken (it often breaks). Reattach using a two-part plastic super glue. **DO NOT USE METAL EPOXY SUCH AS JB WELD. IT WILL CAUSE AN ERROR IN THE SOLENOID BECAUSE JB WELD IS MAGNETIC.**
6. If the sensor will still not calibrate, repeat steps i. – v. with the calibration solenoid (although this breaks much less often).
7. This should fix the sensor. The only other possible explanation could be that the leaf springs have become permanently deformed and they need to be replaced (contact Raf Crowley for procedure on how to do that) or water has leaked into the dry portion of the sensor.
8. If leakage is suspected at any time when using the shear sensor, open the panel exposing the electronics (Figure 4-4), **UNPLUG THE SENSOR**, and assess the damage. The sensor may need to be resealed and/or IC's may need to be replaced. Usually though, if the sensor is given time to dry out, it will begin working again.

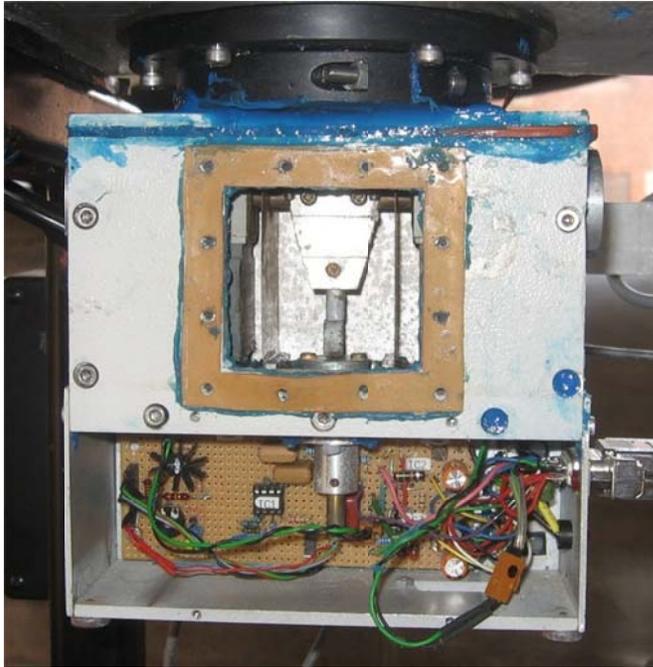


Figure 4-4. Exposed Electronics in “Dry” Portion of Sensor

## 4.7 Flume Display

Display problems with the secondary monitor/DVR system are usually caused by a lack of understanding on how to properly use the system. The secondary monitor (the monitor on the right side of the desk in the control room) is connected a BNC-VGA switch so that it can be used with either the control computer or the DVR system. To switch from one display input to another (for example from the DVR to the PC), press the input button until the display on the right monitor reads “VGA.” To switch back from PC to DVR, press the input button on the switch until it reads “CVBS.” The S-Video jack on the switch is not used, and therefore, will display a blank screen.

To stop recording with the DVR, the controls are somewhat buried in the DVR controls. This is because the DVR is designed to be used as a security system and its manufacturers did not want an operator to accidentally turn off recording. To stop recording a data run, press “Menu” on the DVR. Type the password; by default, the password is 0000. Then, using the arrows on the DVR front panel, move the highlight window to “Record” and finally “Manually Recording.” Under manual recording it should say “Enable.” Click over to it and press up. It should now say “Disable.” Pressing Menu again will end the recording session.

To back up DVR files on the hard drive, the remote interface (2.6.1) is used. This is usually not necessary however since the DVR is equipped with a 500 Gb hard drive. The primary reason to copy files to the PC is for video manipulation. For video manipulation, several programs may be used. Currently, VirtualDub is used. For instructions on using this file, please consult its manufacturer's website (<<http://www.virtualdub.org/>>).

#### **4.8 Other SERF Problems**

Other problems in the SERF are much less common, and they will not be discussed further. If a problem comes up that a novice operator cannot solve, Raf Crowley should be contacted ([raf.crowley@gmail.com](mailto:raf.crowley@gmail.com)) so that he can help to troubleshoot. If future operators suspect a problem with the shear stress sensor, Hans Prechtel should be contacted ([elekt@aon.at](mailto:elekt@aon.at)).