

Procedure for Replacing the HET Structure Azimuth Limit Switches

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1. Purpose

This procedure serves to document the work required to replace the structure azimuth limit switches after an incident on July 22, 2004 (see PR1268). The motivation for this document came about due to the necessity of replacing this switch after it was inadvertently pulled out of its mount on the structure pintle bearing. The techniques and information learned are documented here.

2. Scope

This document is limited to the physical replacement of the limit switch, reconnecting wires to the appropriate terminals and adjusting each of the 7 micro switches in the limit switch assembly so that each is triggered appropriately when the telescope is in the correct azimuth.

3. Applicable Documents

4. Required Equipment/Personnel

- soldering iron and solder
- 5/32 " ball end allen tool
- small slotted screwdriver
- multi-meter, voltage and ohms
- 4 people required, 1 in the pintle bearing area to control structure azimuth with the pendant, 1 in the pintle bearing area to adjust the limit switches, 1 person to monitor and reinsert azimuth limit pin, 1 person to monitor the computer terminal in the control room to advise when certain limit positions have been reached.

5. Procedure

The procedure will consist of 1) removing the old limit switch, 2) unsoldering the old limit switch, 3) measuring the current set points of all 7 micro switches, 4) transferring the measured set points of the old limit switches to the new limit switch, 5) resoldering the new limit switch in place, 6) reattaching the new limit switch to the 80:1 step down gearing, 7) fine tuning the limit switch set points as a function of telescope azimuth. The 7 micro switches are monitored by the azimuth computer. Each of the 7 switches are actuated at a different telescope azimuth. The actuation of each provides an indication to the azimuth computer as to the absolute position of the telescope, independent of the encoders. Table 1 below shows the 7 different micro switches and how the azimuth computer responds to each.

Table 1. List of the 7 azimuth limits and the system response to each. Also description of the software limits

Limit Switch	Function
Cable Wrap (CW)	Indicates which side of the cable wrap that the azimuth is located. Provides a CW/CCW indication on the computer monitor
CW Velocity Limit (CWVL)	Indicates a region of azimuth travel in which the manlift may interfere. Structure computer responds by limiting azimuth rotation speed. Currently disabled.
CW Prelimit (CWPL)	When activated computer responds by permitting motion away from CW limit, but not motion towards limit.
CW Final Limit (CWL)	When activated, computer responds by prohibiting further motion in either CW or CCW direction. Motors must be moved manually or limit switches jumpered
CCW Velocity Limit (CCWVL)	Indicates a region of azimuth travel in which the manlift may interfere. Structure computer responds by limiting azimuth rotation speed. Currently disabled.
CCW Prelimit (CCWPL)	When activated computer responds by permitting motion away from CCW limit, but not motion towards limit.
CCW Final Limit (CCWL)	When activated, computer responds by prohibiting further motion in either CW or CCW direction. Motors must be moved manually or limit switches jumpered
CW Software Limit	When activated, does not allow any computer controlled motion in the CW direction. Hand paddle can still move in CW direction
CCW Software Limit	When activated, does not allow any computer controlled motion in the CCW direction. Hand paddle can still move in CCW direction

5.1. Remove Old Limit Switch

On the night of July 22, 2004, a power cable fell through the structure grating and caught the end of the 7 pole rotary limit switch shown in Figure 1. The shaft of the limit switch was pulled out of its receptacle resulting in bent shaft on the limit switch, also seen in Figure 1. This first step of the replacement process, remove old switch, was brutally performed.

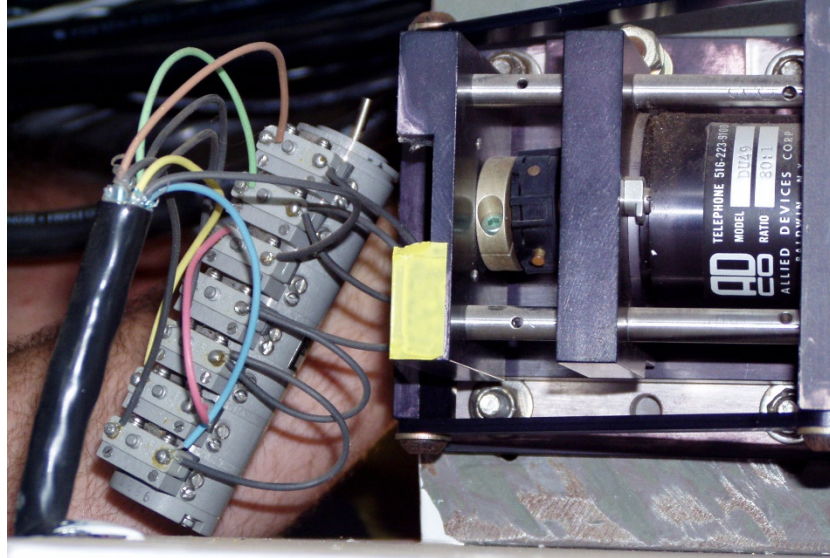


Figure 1. Photograph showing the 7 pole rotary limit switch, next to the flexible coupling to the 80:1 gear reducer. The other side (right, off edge of photo) of the gear reducer has a 54 tooth gear that couples to a rotating 2160 tooth gear on the rotating part of the telescope structure.

In order to properly remove the limit switch, it must be unbolted from the front of the housing as shown in Figure 2. Three slotted screws in a 120° circle must be loosened. Each screw holds a metal tab that fits a slot in the front of the limit switch assembly. As the screws are loosened, the metal tabs can be swung clear of the limit switch slot. The

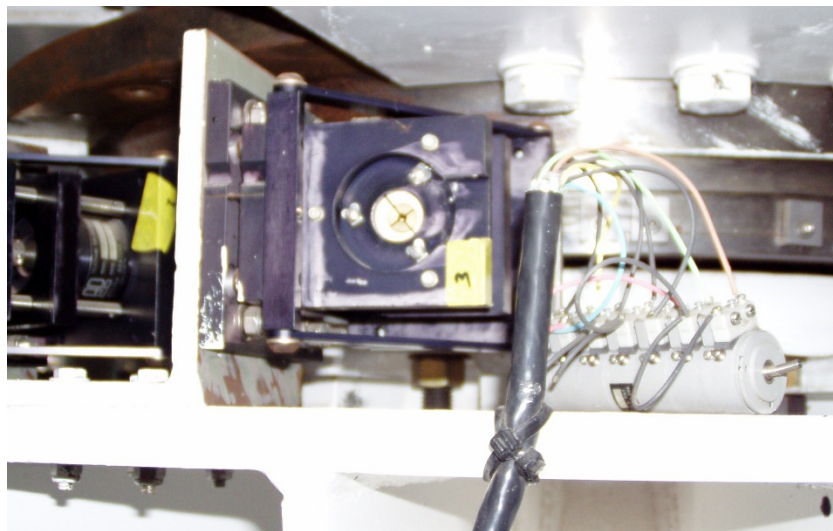


Figure 2. Photograph of the face of the flexible coupler that accept the rotary limit switch.

shaft of the limit switch must be loosened from the flexible coupling. The allen head screw seen on the copper ring of the flexible couple in Figure 1 above must be loosened to permit the shaft to be pulled free.

5.2. Desolder Old Limit Switch

Once removed, the old limit switch must be desoldered from its connections. Schematically, the limits switch is shown in Figure 3 below. The limit switch assembly is manufactured by Precision Mechanisms Corporation, model #CS-402-7. When soldering or desoldering wires to the terminals, the manufacturer states that the soldering iron should be set to 550°F and held to the solder terminal for not more than 10 seconds.

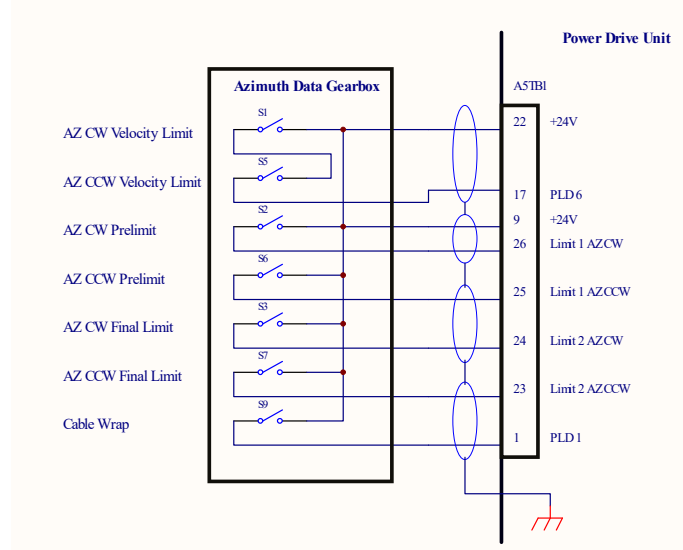


Figure 3. Schematic of the limit switch connection. The azimuth data gearbox is the limit switch located at the pintle bearing. The power drive unit is located with the azimuth control system in the Upper Electrical Room.

Figure 4 is a diagram of the location of the 7 individual limit switches within the overall switch mechanism. The color code of the wire is also shown. The black wires are distinguished from one another a numbering scheme seen in the figure.

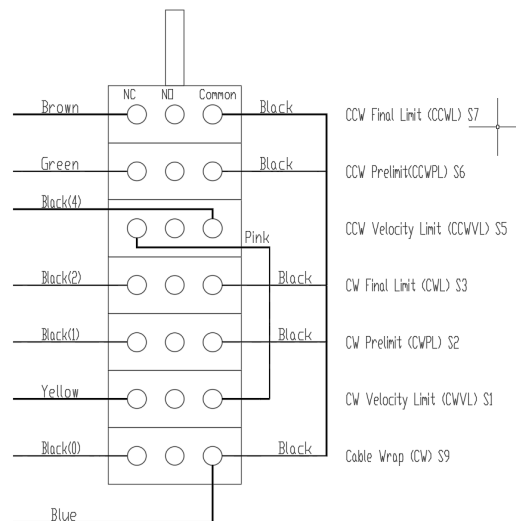


Figure 4. Diagram showing the location of the individual limit switches and the color code of the wiring within the limit switch assembly.

5.3. Measure the location of old switch actuation

In order to simplify the adjustment of the new limit switch, it is advisable to record the positions of the 7 current (old) limit switches. These positions can then be transferred to the new set of limit switches. The back of the rotary switch assembly, away from the shaft contains a slotted shaft that rotates within a set of markings each set at 30° intervals. Using a fine slotted screw driver one is able to rotate the shaft to an accuracy of 15° degrees, about midway between the set of 30° marks.

Each of the 7 individual micro switches must be measured independently. An ohm meter, preferably with an audible short indicator, is connected between the common and the N.C. connection of the switch to be measured. Rotating the slotted shaft clockwise, the shaft position is noted for those points at which the normally closed contacts open and then close. The position is noted to within 15°. Care should be taken to use the correct (marked with red) end of the slotted shaft to indicate the angular position. This procedure is repeated for all 7 micro switches. The positions recorded for the incident of July 22 2004 are seen in Table 2. The angular position is measured in hours of the clock. Twelve o'clock is located away from the location of the micro switch electrical terminals.

Table 2. Angular (hours of the clock) location of the on and off switch points for each of the 7 azimuth limit switches.

Limit	On (Open)Location	Off (Closed)Location
CW	1:00	6:30
CWVL	12:15	10:30
CWPL	11:45	9:45
CWL	12:00	9:45
CCWVL	1:15	12:00
CCWPL	1:30	12:15
CCWL	1:15	11:00

5.4. Adjust new limit switch to match old limit switch location

The position of the old limit switches recorded in Table 2 must be transferred to the new limit switch. Two adjustment screws, A and B, are adjustable for each limit switch. Next to each adjustment screw is a set screw to fix the position of each. Each adjustment screw is labeled on the end cap of the limit switch assembly on the end opposite the shaft. Precision Mechanisms Corporation publishes a set of instructions on the adjustments. From our experiences on July 22, 2004, Table 3 was created. This table shows which adjustment screw controls the Off (Closed switch) or the On (Open switch) transition point of the limit switch as the shaft is rotated clockwise as viewed from the end opposite the shaft.

Table 3. List of adjustment screws that control the On and Off transitions for the 7 Azimuth limit switches when shaft is turned clockwise.

Limit	Adjustment Screw for On Control	Adjustment Screw for Off Control
CW	A	B
CWVL	B	A
CWPL	B	A
CWL	B	A
CCWVL	B	A
CCWPL	B	A
CCWL	B	A

5.5. Resolder new limit Switch

Using the diagrams shown in Figure 4, resolder the wires to the new limit switch. Follow the manufacturer’s recommendation, using a 550°F soldering iron, not holding the tip to the terminal for more than 10 seconds.

5.6. Reattach new limit switch

The procedure for attaching the new limit switch is the opposite of that for the removal. Referring to Figure 2, place the shaft of the limit switch assembly into the flexible coupling. One by one, reinsert the slotted screws on the face of the mount. After each is inserted, turn the metal tab on the screw so that it engages the slot on the front edge of the limit switch assembly. After all screws are inserted and the metal tab on each engages the limit switch, tighten all 3 screws. Finally, tighten the hex head screw to firmly couple the limit switch shaft to the flexible coupling.

5.7. Fine Tune the new Limit switch location

The limit switch is coupled to the structure azimuth through gearing. The structure azimuth has a 2160 toothed gear that rotates with the structure. A 54 tooth gear interfaces to the azimuth gear for a 40:1 amplification of rotation. An 80:1 gear reducer transfers the motion of the 54 tooth gear to the shaft of the limit switch assembly. The entire gear train reduces the azimuth/limit switch rotation by a 2:1 ratio. For every 360° of rotation of the structure, the rotary limit switch turns 180°. Since we are only able to identify 15° of motion when initially setting the limit switch positions, there is a 30° uncertainty for the switch actuation. This is the reason for adjusting the limit switches once they are engaged with the structure.

We did not have the original azimuth positions for each of the limit switches so we decided upon the most logical settings. 1) The azimuth position at which the lanyard was pulled was measured for both CW and CCW rotation. This represents the extreme physical limit for rotation in azimuth. Engaging these switches trips the breaker that powers the azimuth rotation motors. 2) We know the CW and CCW software limits based on a warning provided by the computer as the structure rotates. 3) The angular difference between the physical end of travel and the software limits was divided into

thirds. The Final limit for both CW and CCW travel is placed one third of this angle away for the physical end of travel (lanyard pull). The Prelimit for both CW and CCW travel is placed two thirds of this angle away from the physical end of travel. . 4) The Cable Wrap (CW) switch should engage at 0° to indicate which side of rotation that the cable wrap was located. 5) Since the both CW and CCW velocity limit switches were not used, the azimuth for both of these switches was moved beyond the final limit azimuth. In order to properly set each limit switch, a multi-meter was placed across the common and N.C. contacts. When not asserted, the voltage across these two points would read 0. When asserted, this limit switch would open and the multi-meter would read 24 V. The adjustment technique suggested by the limit switch manufacturer was used. Table 3 was also used to quickly determine which adjustment screw to use.

Based on this logic, the telescope was moved in azimuth to the correct position and the appropriate limit switch adjusted. Once each was adjusted, the azimuth was moved away from the limit in question and then moved back to accurately record the actual azimuth at which each limit was actuated. Once the Prelimit was actuated, it was necessary to jumper the appropriate CW or CCW limit switch in order to permit motion beyond this point enabling us to actuate the CW and CCW final limit switches. Once this switch was actuated, it also required jumpering in order to move off these limits. Table 4 below shows the desired and actual azimuth positions for each of the limits switches. Figure 5 Below shows this same information diagrammatically.

Table 4. Calculated and measured azimuth positions for each of the limit switches. Also shown are the software limits.

Limit	Calculated Azimuth	Measured Azimuth
CW	0°	6.7° CW
Software CWL	N/A	180° CW
CWPL	185° CW	183.9° CW
CWL	190° CW	189.9° CW
CWVL	>190° CW	164° CW
Software CCWL	N/A	90° CCW
CCWPL	81° CCW	82.1° CCW
CCWL	73° CCW	72.9° CCW
CCWVL	<73° CCW	<73° CCW

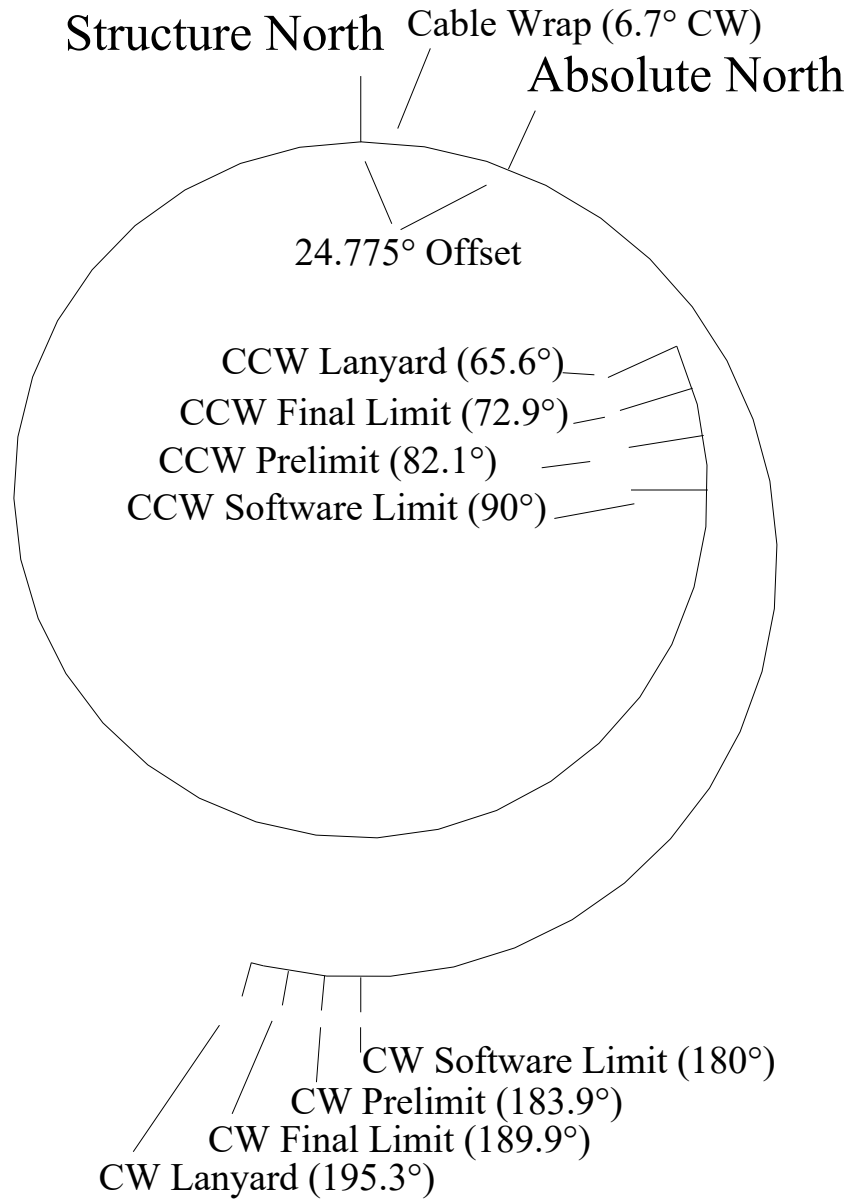


Figure 5. Schematic view showing full 490° of rotation (CW to CCW lanyard) and the location of the azimuth limits as adjusted. All angles are given in the structure coordinate system.

Addendum, August 23, 2019

This addendum serves several purposes:

- 1) **Update the tables and text** to provide more clarity as to the procedures and actions required to replace the structure limit switch
- 2) **Add additional procedures** for completeness
- 3) **Update the actual azimuth locations** for the various limits that have changed do to the replacement of the limit switch

Update Tables and Text

Table 2 shown below are the preadjustment locations of all 7 switches. These positions have been updated to a finer precision. This precision is available when the adjustment is made using a magnifying glass.

Table 2 (updated). Angular (hours of the clock) location of the on and off switch points for each of the 7 azimuth limit switches.

Limit	On (Open)Location	Off (Closed)Location
CW	1:00	6:30
CWVL	12:15	10:30
CWPL	11:45	9:45
CWL	12:00	9:45
CCWVL	1:15	12:00
CCWPL	1:30	12:15
CCWL	1:15	11:00

Included here as supplement to table two is a graphic indication the settings for the 7 switches. This graphic shows the points at which the NC-Com pins on the switch will show open and closed. As a reference, a photo is included of the back of the limit switch cluster. The photo shows the 12 positions of the hour of the clock that is used by indicate switch position.

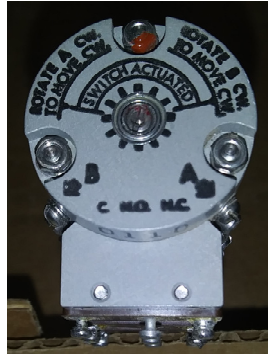
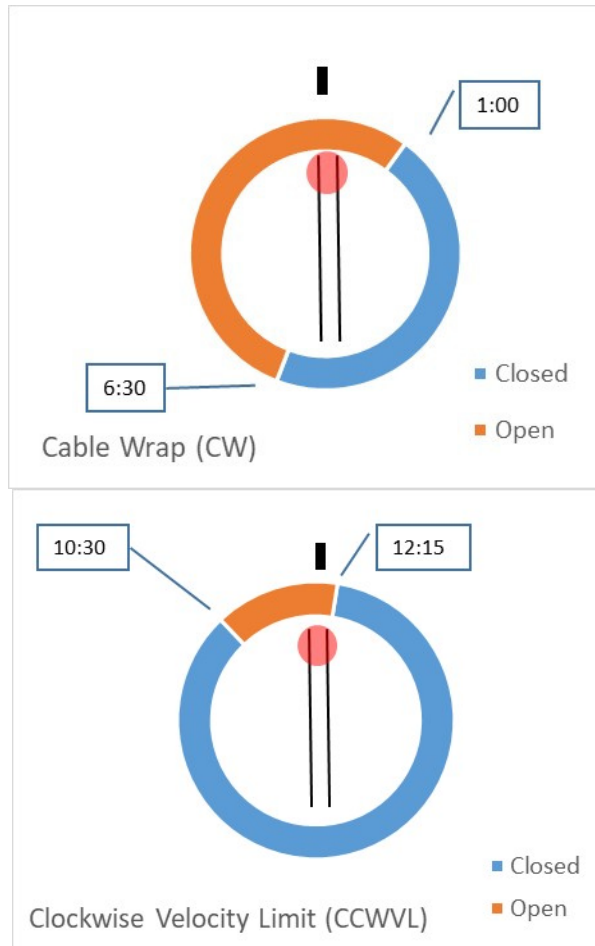
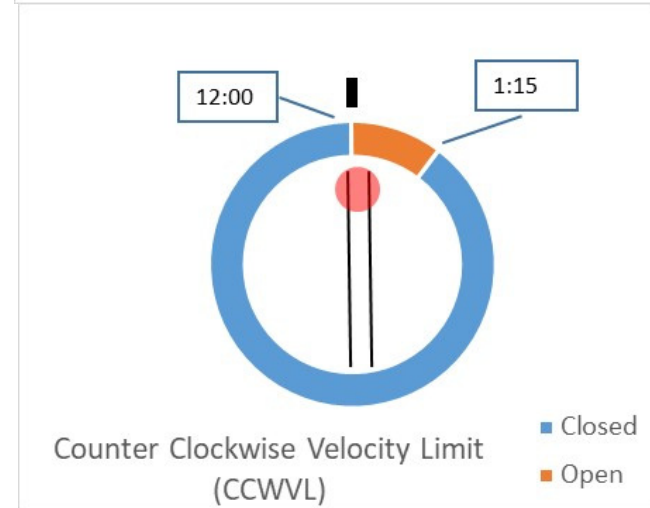
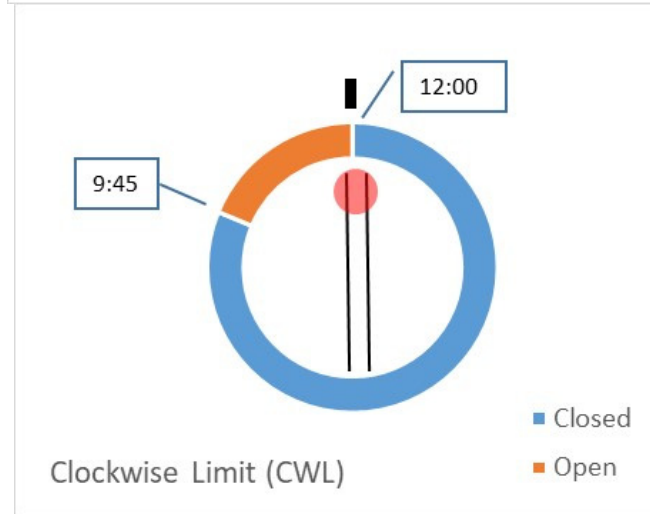
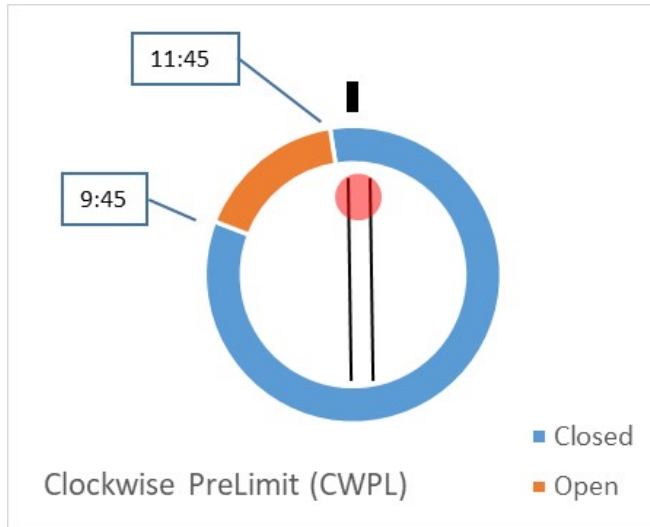
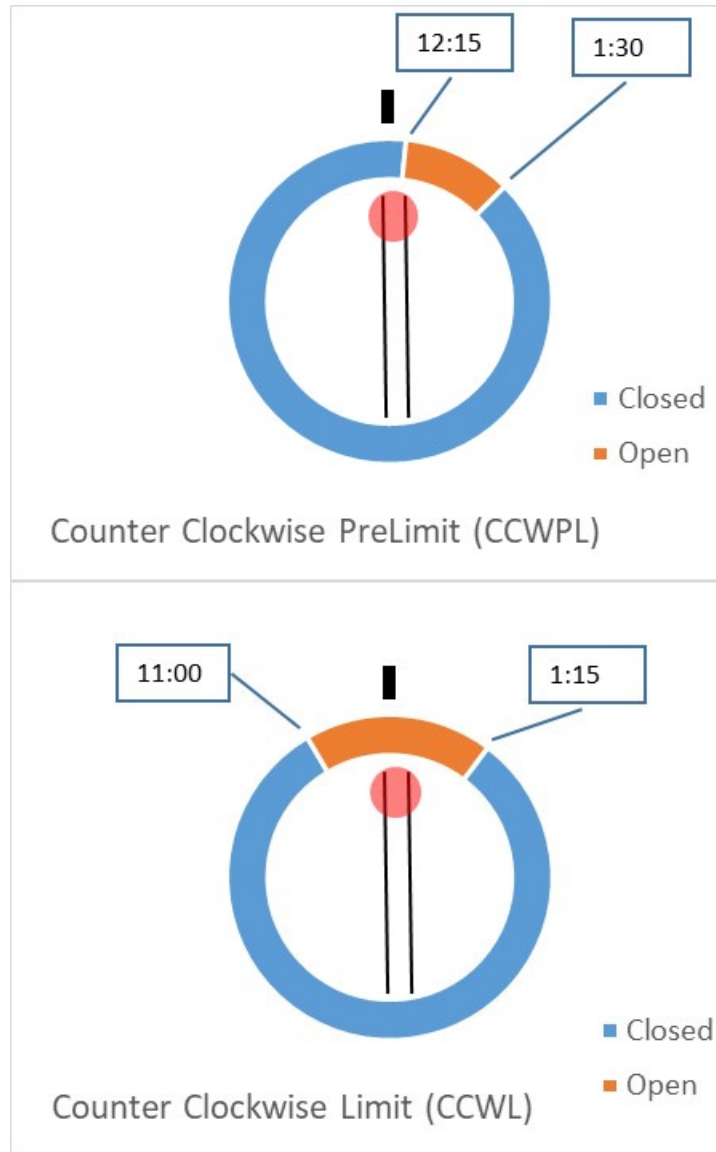


Photo of the back of the 7 ganged limit switches. Note the hours of the clock for adjustment and the directions for making the adjustments. Note the red dot on one side of the slot on the end of the shaft for position indication.







The above 7 images show the proper pre-adjustment for each of the seven limit switches. The red dot on the center slot present the indicator on the end of the shaft of the limit switches. The single black line above the circular diagram represents the 12 o'clock position for reference.

Fine Tune the new Limit switch location

This section of the original text does not specifically call out the procedure for the initial alignment of the limit switch in the mount. This detail is explained here.

- 1) After the initial pre-adjustment, install the limit switch back on the structure. Use the procedure previously defined in this document. The limit switch assembly should be oriented such that the solder tabs are at the 3 o'clock position when the switched is viewed from the shaft opposite the attachment to the telescope structure. 12 o'clock is oriented vertically upward.
- 2) The next step is to reference the rotational position of the switch to the position of the telescope. There are 3 known appropriate references, a) 0° , b) CCW Lanyard location (CCS 65.6°) and c) CW Lanyard location (CW 195.3°) Using the 0° structure makes the most sense as this is midpoint in the switch position with the likely outcome that errors in the prepositioning on either side of this central location will be balanced. To accomplish this, move the telescope to 0° azimuth. Next pull the gear teeth of the limit switch away from the mating gear ring. Using a multimeter on the COM-NC connections of the Cable Wrap (CW) switch,, rotate the gear at the end of the switch shaft to the 1 o'clock position. Rotate the gear back and forth to find the position where the COM-NC continuity goes from open to short. When this position is identified, place the gear back on the gear ring. Move the telescope back and forth about the 0° position to verify the point and with the switch trips. Use the multimeter for this definition

Continue with the fine adjustment of the other limit switches per the main document. This is done by moving the telescope azimuth to the predefined location, adjusted the specific limit switch and then verifying this position per azimuth rotation.

Be aware that there are only four additional switch positions to adjust, CWL, CWPL, CCWPL and CCWL. The CW and CCW lanyard positions are fixed in azimuth. They represent the azimuth where a pin is pulled from a switch to trip the main power breaker to the structure azimuth computer. The CW and CCW software limit positions are positions fixed in software.

The CWVL and the CCWVL switches are no longer being used by the structure control system and may be left open.

Update the actual azimuth locations

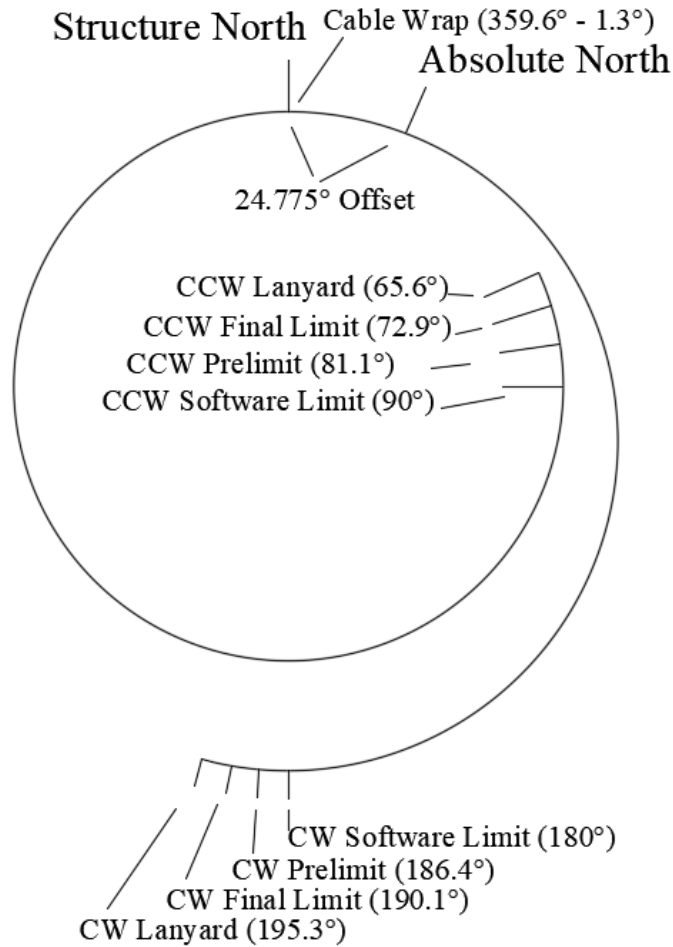


Figure showing the structure azimuth limit locations that resulted from the installation of a new limit switch on Aug 23, 2019.

Table 4 (Updated). Calculated and measured azimuth positions for each of the limit switches installed on Aug 23, 2019. Also shown are the software limits.

Limit	Calculated Azimuth	Measured Azimuth	Comments
CW	0°	0.8° CW	Switch Adjustment
Software CWL	N/A	180° CW	Software Defined
CWPL	185° CW	186.4° CW	Switch Adjustment
CWL	190° CW	190.1° CW	Switch Adjustment
CWVL	>190° CW		Not Used
Software CCWL	N/A	90° CCW	Software Defined
CCWPL	81° CCW	81.1° CCW	Switch Adjustment
CCWL	73° CCW	72.9° CCW	Switch Adjustment
CCWVL	<73° CCW		Not Used