First Attempt at Improving SO-110 Source Cooling

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MINI-REPORT #23 – *for documentation & general housekeeping.*

December 3, 2015

A first attempt at better cooling the SO-110 target and source region using a custom heat-exchanger is described. The heat exchanger consisted of a dewar filled with Syltherm XLT (hereafter 'dewar') into which was placed: (1) the cold finger of a compressor/chiller to remove heat from the Syltherm in the dewar, (2) an 18 inch (length) × 1/4 inch (OD) coil of copper pipe set into the closed Syltherm cooling loop of the SO-110 (hereafter 'inline'), and (3) two thermocouples: one in the dewar (T1) and one inline the flow of Syltherm to the source head (T2). The purpose of the heat exchanger was to transfer heat from the inline loop to the dewar, thus lowering the temperature of the target and souce head. Running the SO-110 under typical conditions (ionizer 18A, Cs=100°C) without any additional chilling produced highest temperatures of +18.9°C (inline) and +18.5°C (dewar). With addtional cooling using a Beckman compressor/chiller capable of reaching dewar temperatures below -80°C (no heat load), the lowest temperatures obtained with the working SO-110 were -28.1°C (dewar) and +11.8°C (inline). Thus the temperature of the chilled source-head decreased by only ~7°C compared to without chilling. This experiment shows that the present setup is providing only marginal heat exchange, and should be modified or replaced with a better heat-exchanger to increase surface-area, while not significantly impeding the flow. A secondary pump to push Syltherm through a better heat exchanger may be needed.

1 Experimental Setup:

Figure 1 summarizes the experiment setup. The closed-loop Syltherm feed to the SO-110 was essentially 'broken into' with the custom heat exchanger as shown. The idea here was to transfer heat from the source head, through its closed Syltherm chilled loop, directly to a much colder reservoir of Syltherm, then recirculate the chilled Syltherm in its closed loop back to the source head.

1.1 Copper Coil Problems

The heart of the heat exchanger was an 18 inch length of 1/4 inch (OD) copper pipe, coiled vertically in the dewar (Figure 2 for photos). The original coil (made by Norm and Mo) was approximately 75 inches (1.9 meters) total length when uncoiled, however we found the Grundfos reservoir pump of the SO-110 incapable of pumping Syltherm through the 75 inch coiled pipe (we also tried removing quick connects and replacing with 1/4 inch Swagelok connections to reduce potential imedance to flow, but to no avail). Xiaolei, Mo and myself subsequently uncoiled the pipe and tried to see if the Grundfos pump could handle a large loop with no turns, however this also failed. We then cut the pipe in half (approximately 37.5 inch length) but again Syltherm could not be pumped through that length.

Cutting the pipe to an 18 inch length finally worked with the Grundfos pump; this length was used as the coil in these experiments described here (see Figure 2), but note that this length has not been optimized. The 18 inches of the copper pipe were coiled vertically, into about four turns (as few turns as possible) and immersed in the dewar Syltherm. The compressor cold finger was also immersed in the Syltherm, next to the copper pipe in the dewar. The dewar was protected from atmospheric moisture by a tight aluminum foil cover (Figure 2).

1.2 Temperature Measurement

Figure 1 shows the location of the temperature measurements T1 (dewar Syltherm temperature) and T2 (inline with the flow of the SO-110 Syltherm source cooling closed loop). T2 thus gives an accurate temperature of the Syltherm actually entering the source region; T1 gives an accurate temperature of the compressor cold finger that is providing additonal cooling.

An Omega thermocouple (diameter 1/8 inch; part# GKMQSS-125U-6, obtained from Gilles) was attached to a 3/8 inch Swagelok tee using 1/8 inch to 3/4 inch Swagelok fittings. Care was taken to ensure the thermocouple did not touch the metal of the tee or obstruct flow of the Syltherm, but only poked slightly into the flow by about 1-2 mm (checked visually). We used a 3/8 inch tee to increase the area of Syltherm flow around the thermocouple, to ensure the thermocouple could not impede the flow. The T1 thermocouple arrangement was positioned on the feed (F) in Figure 1, as written on the SO-110 itself, directly after the copper coil and right before entering the source (see Figures **??** and 2). The T2 thermocouple was a wire-style junction Omega thermocouple (part #???) placed in the dewar Syltherm as seen in Figure 2. Temperature was measured using a handheld Omega HH801A thermocouple sensor. Note that both thermocouple were not calibrated, and were used as-is out of the box.

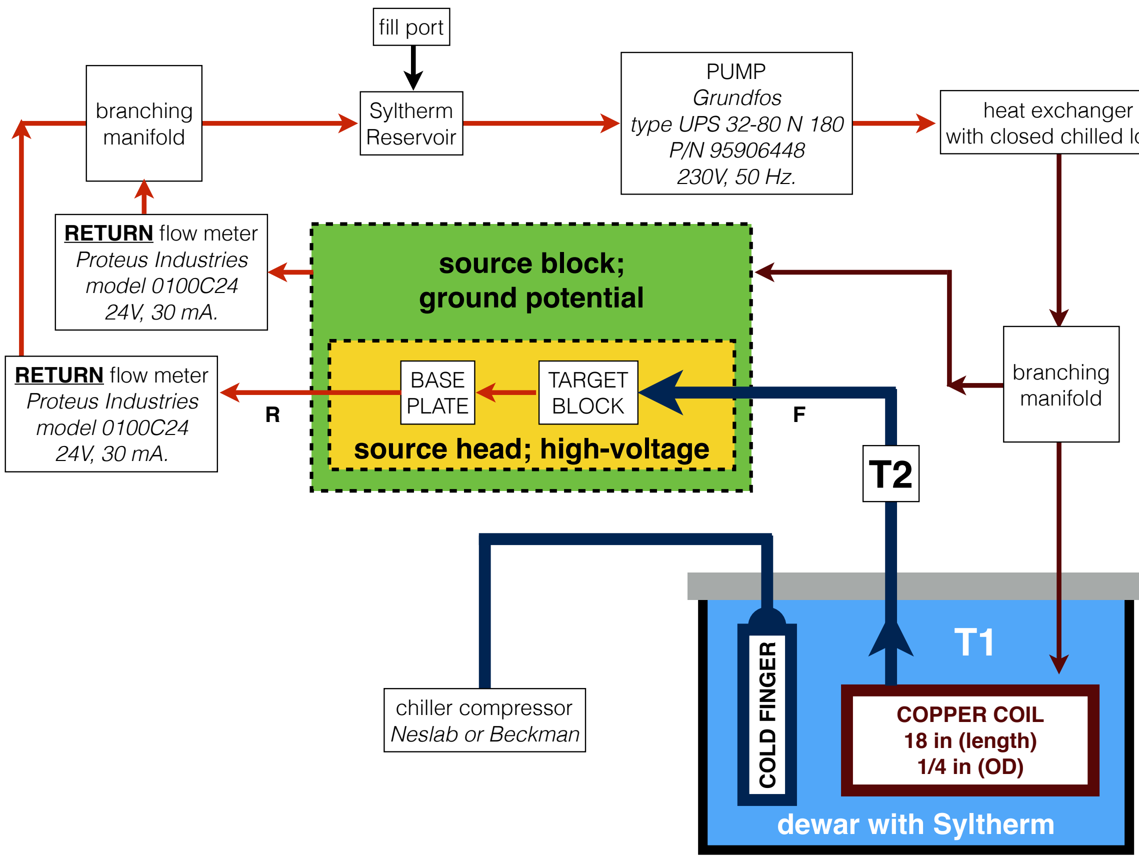

Figure 1: The SO-110 closed Syltherm cooling loop for the souce-head, shown with the added-in heat exchanger (bottom). Temperature T1 is measured in the dewar Syltherm chilled by the compressor; temperature T2 is meausred inline with the closed loop Syltherm flow directly to the source.

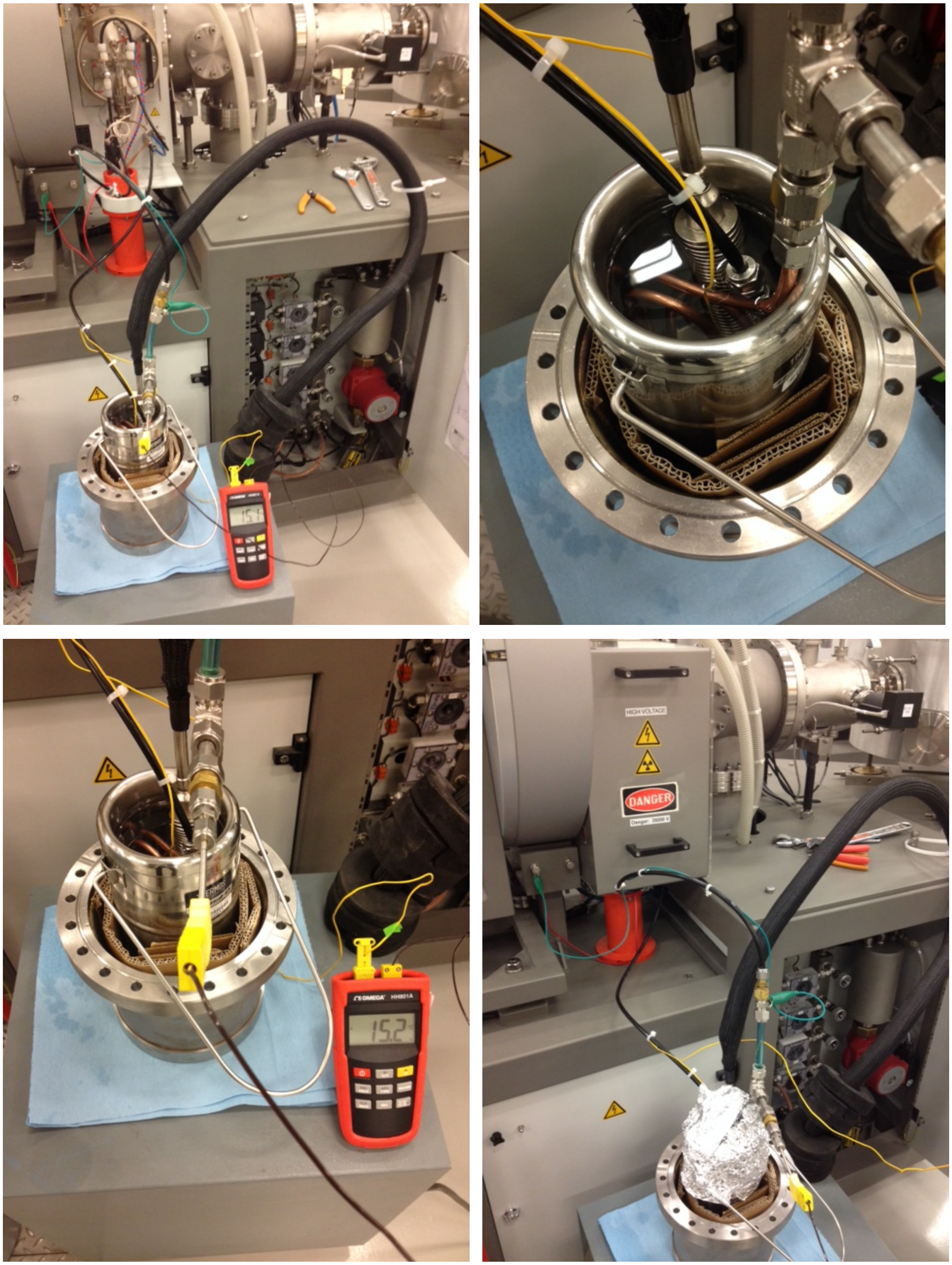

Figure 2: Photos of the experiment setup on December 3, 2015.

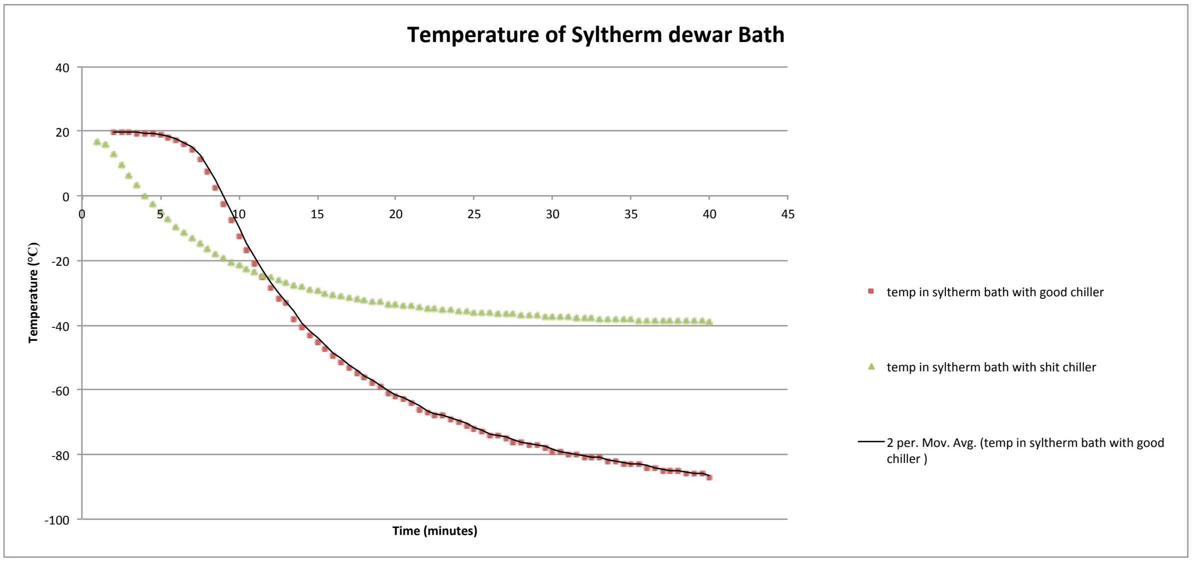

Figure 3: Cooling curves obtained by Mo for the Beckman ('good') and Neslab chillers, as measured in the dewar Syltherm with no heat load, using thermocouple T1.

1.3 Chiller/Compressors

Two chiller/compressors were tested here: (1) an older Neslab 'Bath Cooler, model PBC-2' obtained from UofT Mississauga, and (2) a newer Beckman (also made by Neslab, model 1-01113-23) belonging to Ian D. Clark. Mo has already characterized the cooling characteristics of both compressors; the Neslab can chill the Syltherm-filled dewar with no coil or heat loading to -40°C whereas the Beckman reaches -80 to -100°C. This was found to be very reproducible in subsequent tests here. Mo has data for the cooling curves of both chillers; his plot is shown below in Figure 3.

2 Results

Figure 4 summarizes cooling results with the Neslab and Beckman chillers. With the SO-110 on, at an ionizer current of 18.0A and Cs boiler of 100°C, the Neslab chiller reached a minimum temperature of -7.5°C (dewar) while the Beckman reached -28.1°C (dewar) thus clearly the Beckman is more capable of removing heat from the dewar. However the minimum Syltherm temperature in the closed cooling loop reached using the Beckman, with the same SO-110 conditions, was +11.8°C (inline). As the dewar temperature was a stable -28.1°C at the same time the inline temperature stabalized at +11.8°C, clearly the heat transfer efficiency is quite marginal at best. With no chillers, a maximum temperature of ~18.5°C was reached with the SO-110 fully off; this temperature must be due to the heat-exchange between the uOttawa chilled water and the SO-110 closed-loop (inline) Syltherm. Therefore the source head lost only about 7°C, a quite modest drop.

With the Beckman chiller on but SO-110 off, lowest temperatures reached were 10.5°C

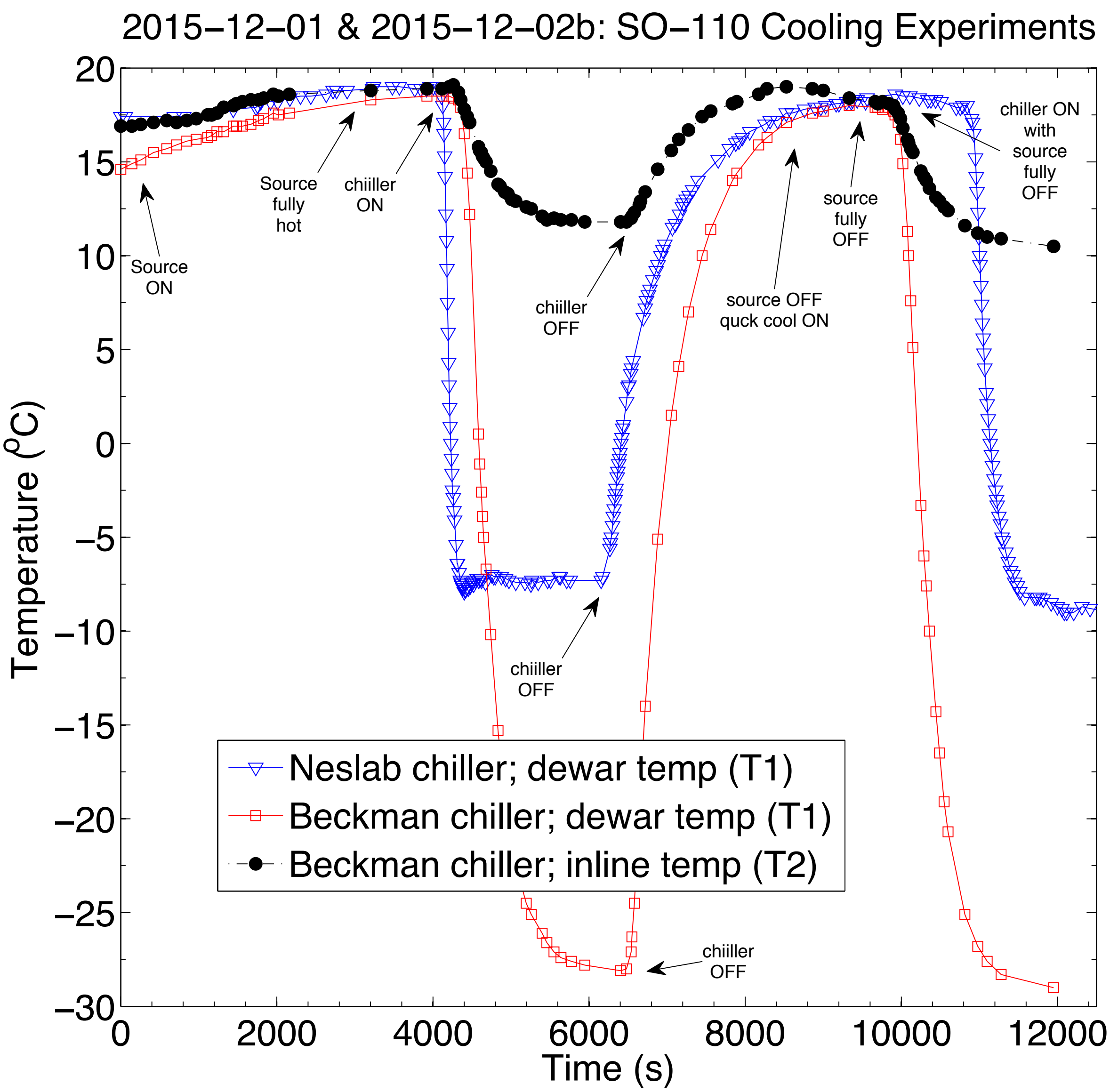

Figure 4: First results of the SO-110 cooling experiment, comparing the Neslab and Beckman chillers. Important actions done during the experiment are shown with arrows.

(inline) and -29.0°C (dewar). Therefore the inline temperature is about 1.3°C higher with the SO-110 on, indicating the SO-110 is not adding a significant amount of heat to the Syltherm loop.

3 Suggestions for Improvement

- Use a better heat exchanger with more surface area to increase heat loss between the closed loop Syltherm and dewar Syltherm.
- Increase the diameter of the piping to 3/8 inches instead of 1/4 inches, so that flow impedance is further decreased, and the Syltherm spends a longer residence time in the dewar.
- Add some turbulence in the flow of the coil to increase mixing of Syltherm in the coil, and increase residence time in the coil (may, however, further impede the flow).
- Use a commercial heat exchanger with a large surface area that does not impede flow, immersed in the Syltherm dewar.
- Use a second pump to pump through a better coiled or commercial heat exchanger.
- Many other suggestions are of course welcomed and certainly possible...