LAPD Temperature Profile Measurement

Hans Jostlein 12/1/2009

Abstract

We describe a device to make very accurate measurements of vertical temperature profiles in liquid Argon of the Liquid Argon Purity Demonstration project (LAPD).

See the following figure for a drawing of the LAPD tank.

The device ("The RTD Spooler") can move a set of 4 RTD's (resistive temperature devices) in programmable steps vertically from the bottom to well above the liquid level. Two such devices are planned, one at the center of the tank and one about 1 ft from the tank's edge. We describe here the motivation, requirements, implementation and require effort for this system.

Intoduction

The Liquid Argon Purity Demonstration project has at its primary goal to show that liquid Argon can be sufficiently purified to reach an electron lifetime of 3 to 5 msec without first evacuating the cryostat.

One of the secondary goals is to measure the temperature uniformity and distribution in the liquid Argon. Only small temperature variations are allowed, because the related density fluctuations affect drift velocity and may impair the accuracy of the track reconstruction.

Detailed and accurate temperature profiles will be used to verify FEA models

(see "Liquid Argon Tank Temperature Distribution (2)", Zhijing Tang, September 22, 2009, LARTPC DocDB document # 471-V2)

of the liquid, which are based on heat input and flow drivers such as the liquid return from the filters. The following figures show a few of Zhijing's temperature and velocity distributions:

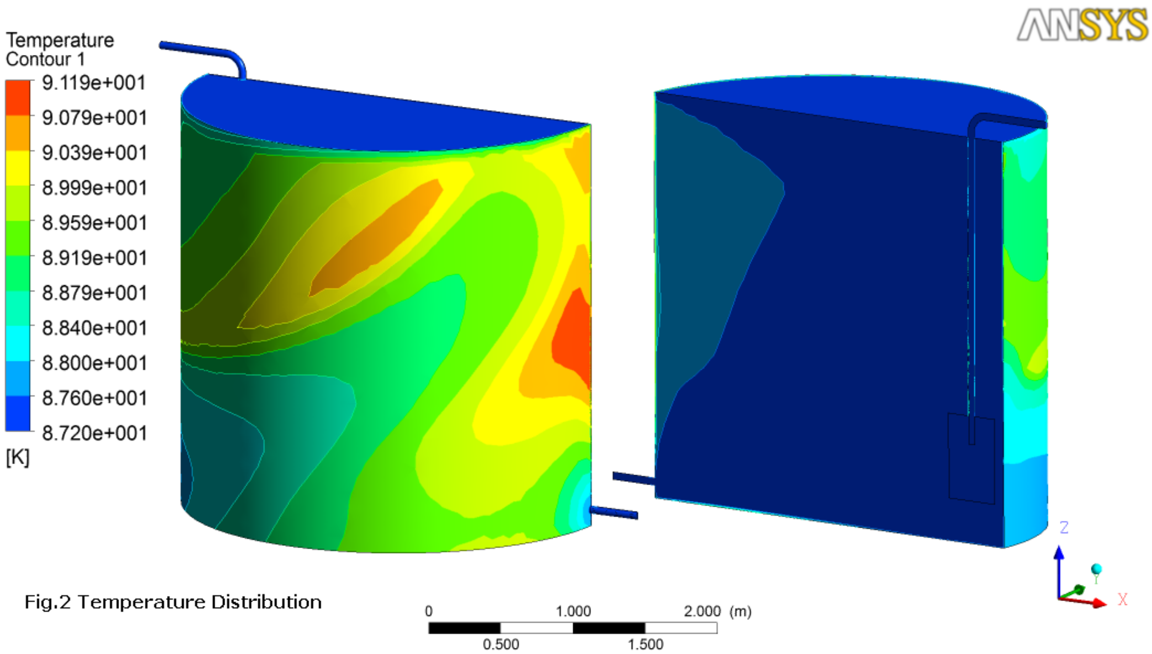


Fig.2 Temperature Distribution

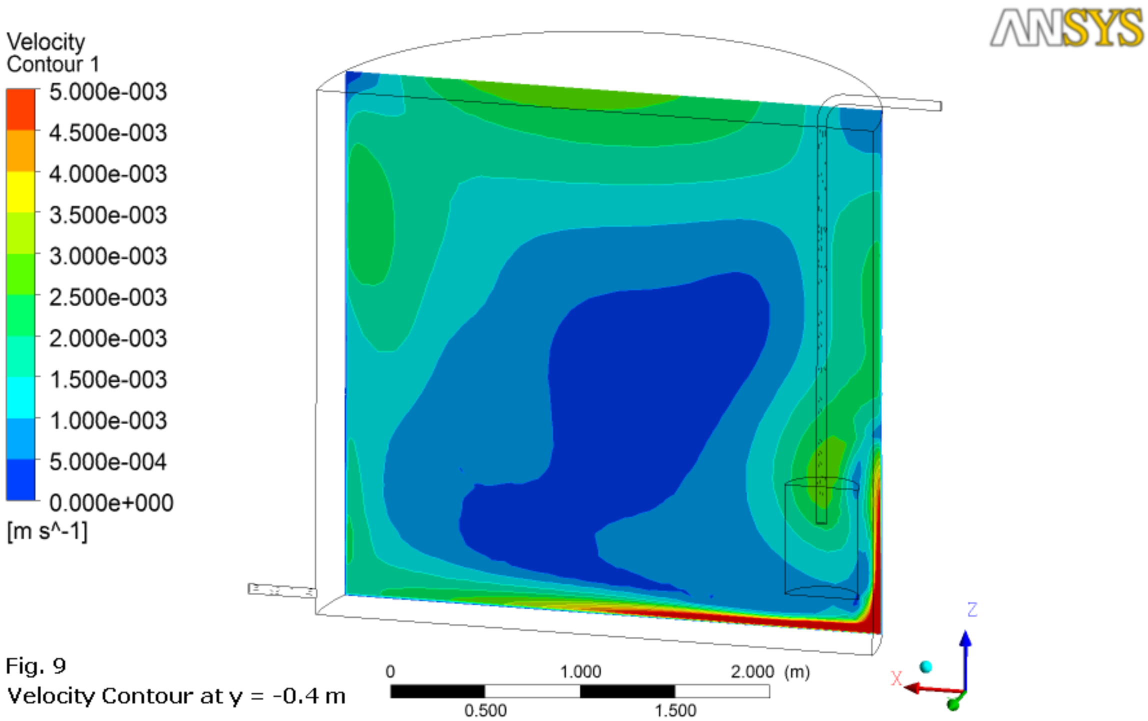
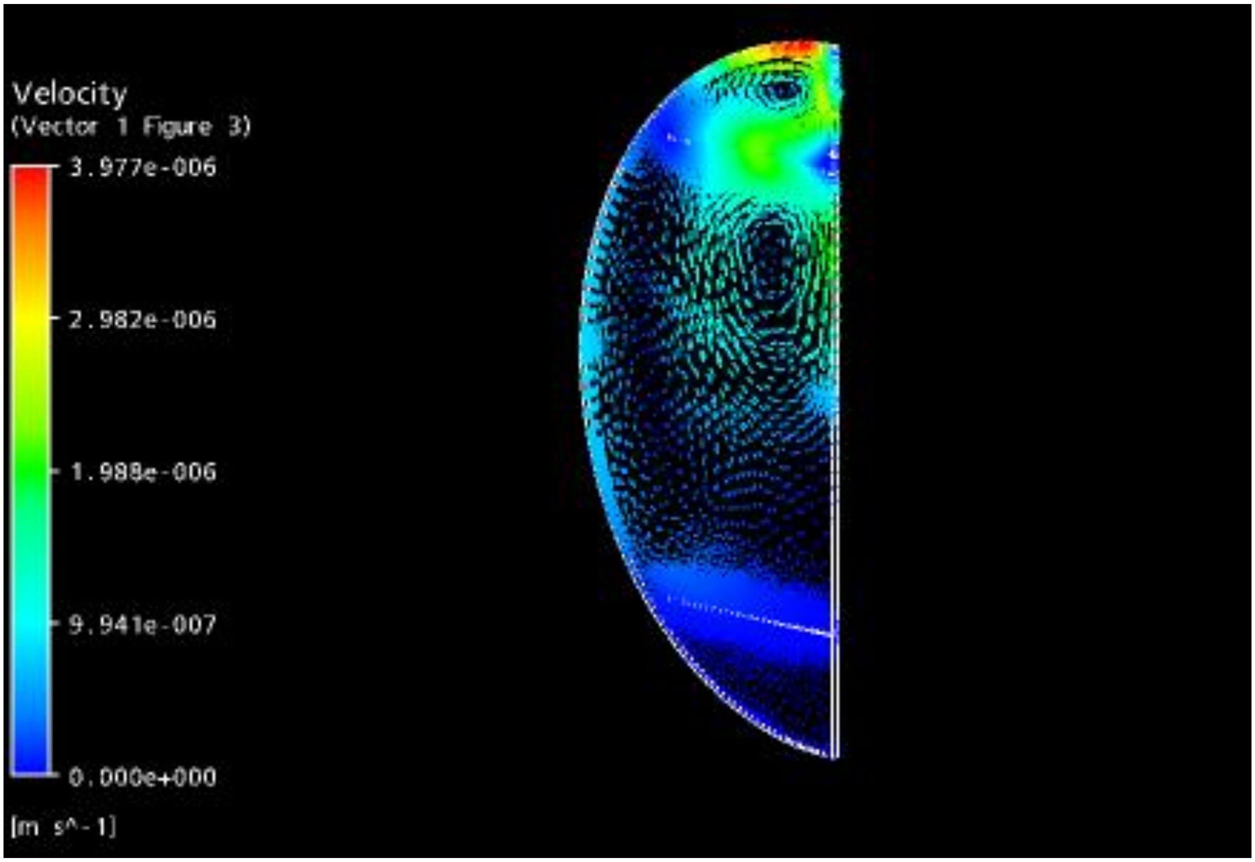


Fig. 9
Velocity Contour at y = -0.4 m



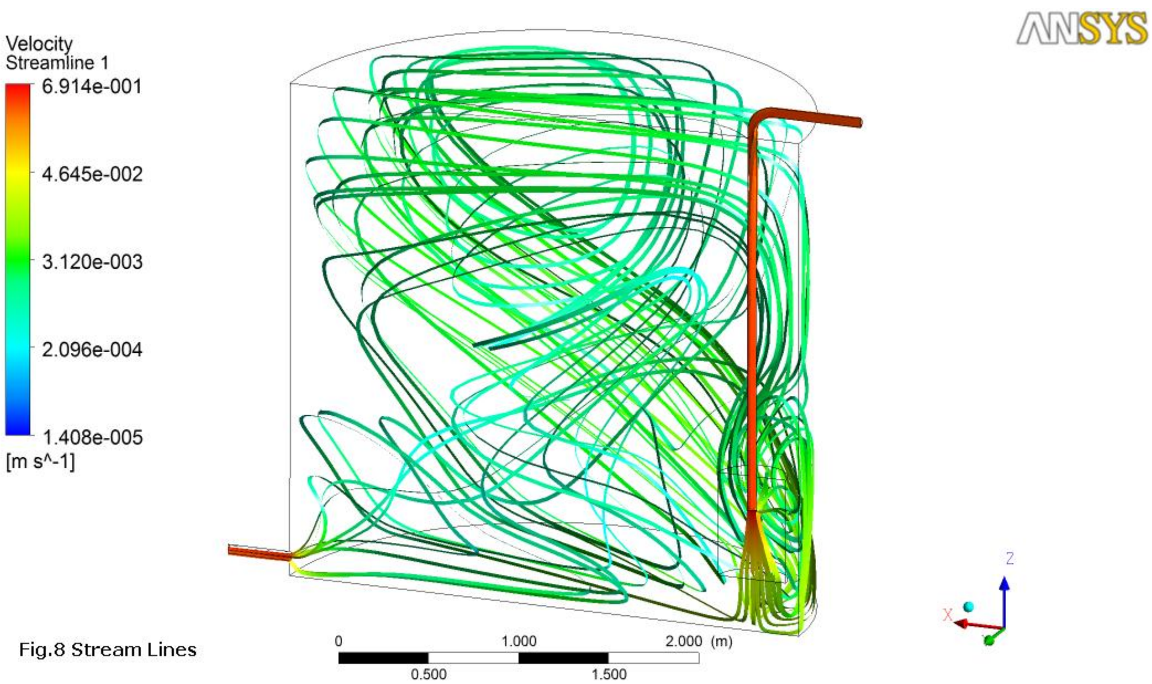


Fig.8 Stream Lines

From the temperature distributions (“Figure 2”) we note that they cover a large range, 87.2 K to 91.2 K.

On closer inspection we note that the temperature extremes are right at the vessel wall;

the bulk liquid has only 2 color bands, from 87.02K to 87.08 K, a range of just 0.06 K.

The next   two figures (“Fig 8”) show why the liquid temperature is so uniform: convection currents are in the range of 1 mm / sec or so, or 3.6 m /hr. The liquid mixes on a time constant of about one hour.

While this range is much narrower than required by TPC performance (0.5 K) this makes it challenging to make meaningful measurements. A resolution and stability of 0.01K is needed. This rules out the used of stationary temperature probes, because intercalibration and long term stability (at 87 K) cannot be guaranteed at the 0.01 K level

Design of the RTD spooler

We have chosen a design where a string of 4 RTD’s (on a narrow PC board, at 6 inch vertical spacing) is suspended by a thin (0.020” diameter) SS cable, which can be extended or retracted by a motorized spooler that is built into a warm CF Tee mounted on one of the cryostat “nozzles’ at the top. We will use two locations, one very close to the tank center and the other about a foot from the tank wall. Nozzles exist only at very limited number of radii.

The RTD’s will be read out by a Lakeshore Cryotronics temperature monitor, model 218 E:

Front Panel Back Panel

Product Description

The Model 218 is our most versatile temperature monitor. With eight sensor inputs, it can be used with nearly any diode or resistive temperature sensor. It displays all eight channels continuously in K, °C, V or Ω. The measurement input was designed for the demands of cryogenic temperature measurement, however, the monitor's low noise, high resolution, and wide operating range make it ideal for noncryogenic applications as well. More...

Model 218 Features

- Operates down to 1.4 K with appropriate sensor
- 8 sensor inputs
- Supports diode and RTD sensors
- Continuous 8-input display with readings in K, ºC, V or Ω
- IEEE-488 and RS-232C interfaces, analog outputs, and alarm relays
- Available in two versions: Model 218S and 218E

Sensor Input Reading Capability

Temperature Response Curves

Interface

Display

Sensor Selection: Sensor Temperature Range

Sensor Selection: Typical Sensor Performance

S	Example Lake Shore Sensor	Temp	Nominal Resistance/ Voltage	Typical Sensor Sensitivity[7]	Measurement Resolution: Temperature Equivalents	Electronic Accuracy: Temperature Equivalents	Temperature Accuracy including Electronic Accuracy, CalCurve™, and Calibrated Sensor
100 Ω Platinum RTD 500 Ω Ful Scale	PT-103 with 1.4J calibration	30 K	3.66 Ω	0.19 Ω/K	10.5 mK	±25 mK	±35 mK
		77 K	20.38 Ω	0.42 Ω/K	4.8 mK	±20 mK	±32 mK
		300 K	110.35 Ω	0.39 Ω/K	5.2 mK	±68 mK	±91 mK
		500	185.668 Ω	0.378 Ω/K	5.3 mK	±109 mK	±155 mK

		K					

Spooler Design

Materials

The spooler must not introduce impurities that may affect the electron life time.

This has guided the choice of materials:

The housing is made from stainless teel and sealed with CF flanges

The rotary feedthrough is of ferrofluidic design and rated for UHV service.

The electric feedthrough is glass-sealed and will be mounted with Stycast epoxy to the flange.

The sightglass is fused to its SS flange.

The ACMR screw and plastic nut do not need lubrication.

The RTD carrier circuit board will be of pre-tested materials (Tefzel or Kapton)

The support cable is stainless steel.

All materials will be tested for their effect on lifetime in the warm vapor space of the MTS.

Functional Description

There is a thin stainless support cable and a separate electrical flat cable from the sensor assembly. We were unable to use the flat cable as support because we could not identify a suitable electrical rotary coupler.

The flat cable is festooned from the RTD assembly to the spooler assembly. A small weight on a pulley keeps the cable from floating up and tangling in the Argon. The flat cable and support cable are separated by a small distance to discourage them from wrapping around each other.

The support cable is wound around a grooved cable drum with a 0.050” pitch. The drum rotates on a plastic nut around a stationary ACME screw (1/2-20). As the cable spools/unspools on the drum, the drum advances along its axis by exactly the right amount to deliver the cable at a fixed spot. This has two advantages: it provides a spot for a cable guide to ensure proper threading o the drum, and the drum shift actuates limit switches at the desired ends of travel.

The drum is rotated by an external stepper motor

Motor PK268MB from Oriental Motor / PAPCO
Part of package UMK268MBA
with controller EMP400
$ 488.-

High-Resolution Type **Motor Frame Size 42 mm (1.65 in.), 56.4 mm (2.22 in.)**

■ Specifications

Model	
Double Shaft	**UMK268MBA**
Maximum Holding Torque N・m (oz-in)	1.35 (191)
Rotor Inertia J kg・m2 (oz-in2)	480×10−7 (2.6)
Rated Current A/Phase	2
Basic Step Angle	0.9˚

Power Source

Single-Phase 115 VAC±15% 60 Hz or Single-Phase 100 VAC ±15% 50/60 Hz

2.2 A

Excitation Mode

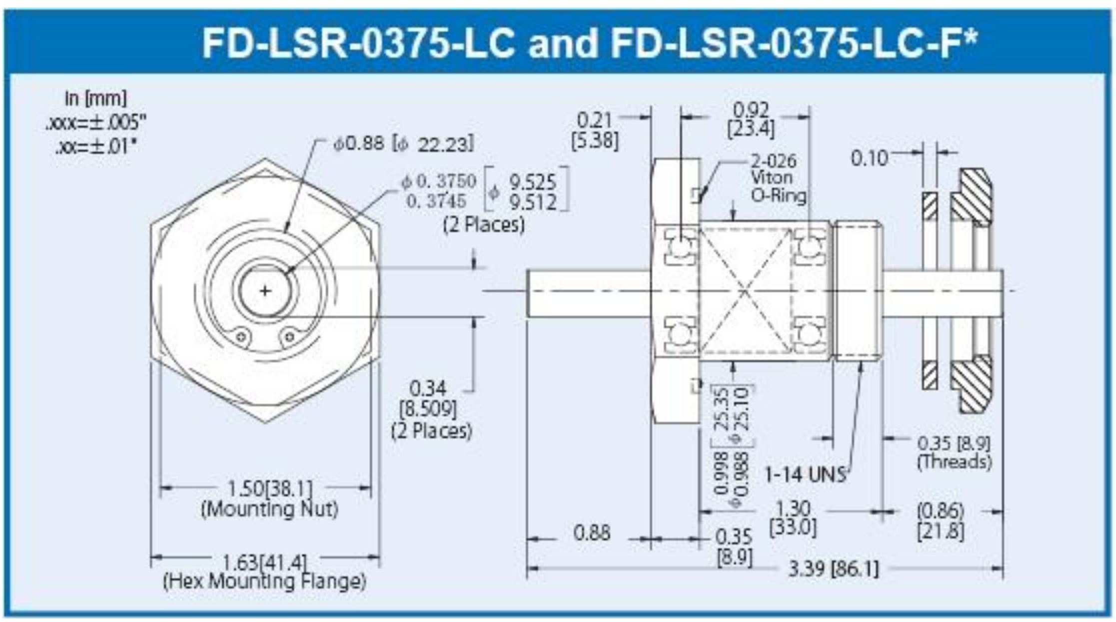
Full Step:	0.9˚/step
Half Step:	0.45˚/step

Mass

Motor kg (lb.)	1 (2.2)
Driver kg (lb.)	0.47 (1)

through a rotary feedthrough

Rigaku model FD-LSR-0375-LC-S5



Operating specifications

Feedthrough usable on thinner baseplates by ordering additional washers: Product No 10C-91081741

Product number	0C-97092600 1	0C-98082500
Model	FD-LSR-0375-LC	FD-LSR-0375-LC-F
Price	$395	$445

Transmission torque (lbs-in)	160	160
Drag torque (oz-in), break-away	11	20
Drag torque (oz-in) @ 100 RPM / 1000 RPM	6 / 9	22 / 28
Fits base plates	3/4" to 1"	3/4" to 1"
Maximum no-load RPM	5000	2500
Ferrofluid type	A300S	F-310
Bearing type	R6	R6
Maximum bearing static load (lbs)	305	305
Bearing dynamic load (lbs)	575	575

and a linear coupler. The feedtrough is a ferrofluidic device rated for UHV service, hence emits no organic vapor. The stepper motor comes with a drive that is easily programmed for speed, stops, and waiting times, through an RS232 / USB interface , using text commands.

A sight glass is provided to monitor operation in case that problems are suspected.

The spooler enclosure has a tubing connection to allow drawing a small argon gas flow for continuous purging.

Construction and Operation

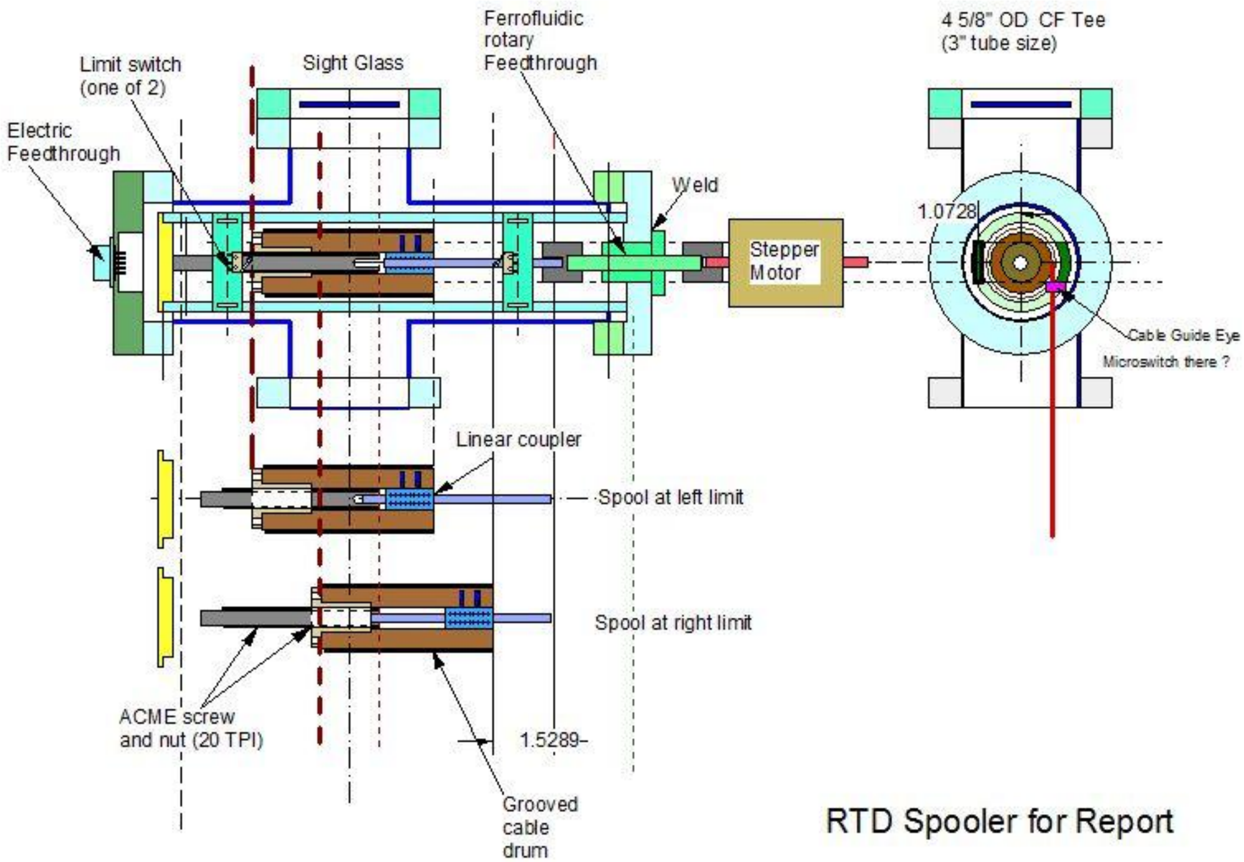
We intend to assemble one unit for functionality and durability tests. The unit will be operated in air automatically for many cycles.

At that point (and after suitable improvements) a second (and, possibly , a third) unit will be built.

Once in the tank, the measurement strategy includes advancing by just 6 inches (the same as the RTD spacing) after every stop in order to intercalibrate the RTD's. There will also be studies of settling time by checking the time evolution of RTD readings when they are brought quickly from the (warmer) vapor space into the liquid. This will tell us how long one needs to wait at each stop. Self-heating will be studied by cycling the excitation current on/off, and by studying the readout value versus excitation current.

A typical vertical scan can consist of a round trip (first down , then up). The difference in readings at the same depth tells about drift of readings. The average over up/down takes out first order drift. Possible changes in temperature are best studies by staying a t a given depth for an extended time. The 4-fold RTD redundancy will be important here.

The spoolers will, of course, be quite useful both during the purge/ cooldown phase and after the liquid argon filling.



RTD Spooler for Report

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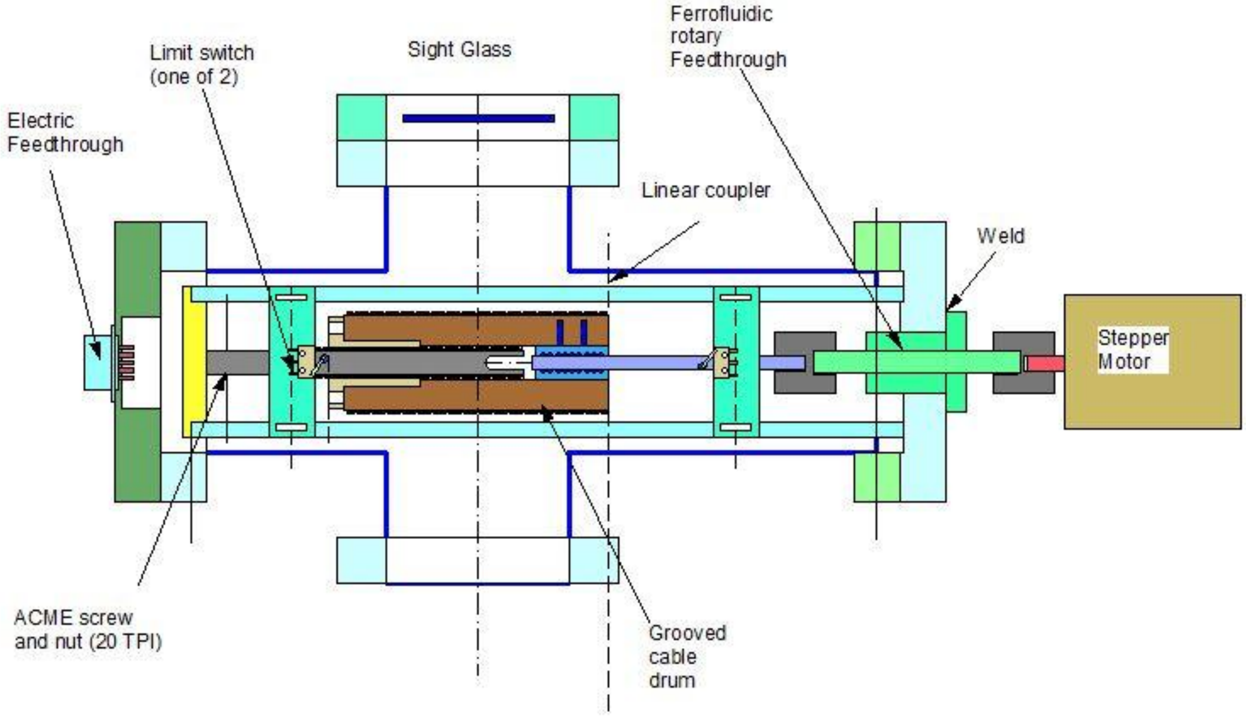
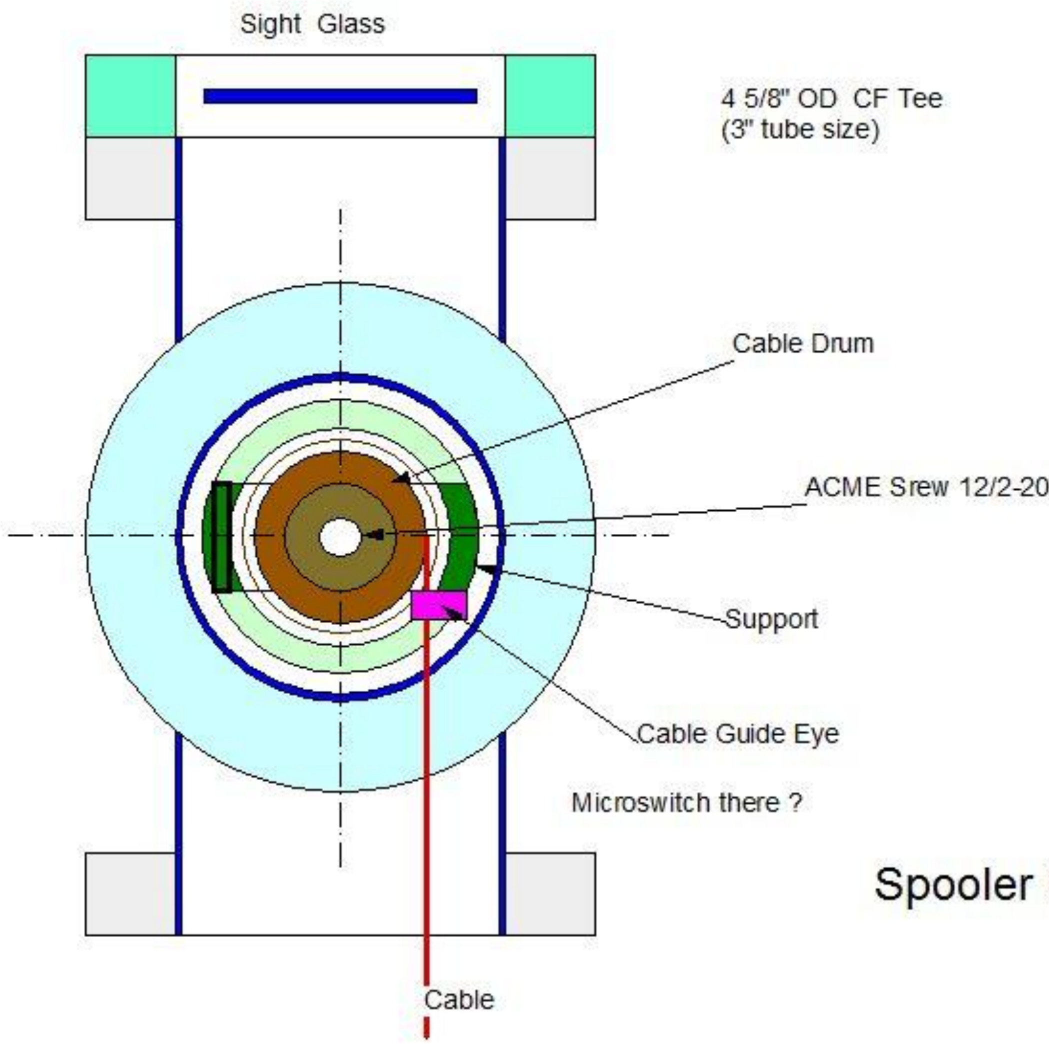

Ferrofluidic rotary Feedthrough
Limit switch (one of 2)
Sight Glass
Electric Feedthrough
Linear coupler
Weld
Stepper Motor
ACME screw and nut (20 TPI)
Grooved cable drum



Spooler End View