D-ZERO CENTRAL CALORIMETER

INNER VESSEL PUMPDOWN

INFORMATION

D-ZERO ENGINEERING NOTE # 3740.214-EN-270

Russ Rucinski

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SUMMARY

The information presented in this engineering note can be of value to others who wish to predict pumping times and water content of vessels containing G-10 material. Four predictions of the water content of the G-10 in the D-Zero Central Calorimeter (CC) are given. Experience from pumping on the NWA cryostat was used to help predict the pumpdown time required for the CC. The actual pumpdown time and water removal from the CC agrees quite well with those predicted which gives confidence for future predictions done using the information presented in this engineering note. A listing of the predictions and actual CC pumpdown particulars is given below.

Water load estimate in CC:

BASIS	ESTIMATE
ASTM D570	0.4 to 2.7 gallons
NASA RP-1124	4.3 gallons
MH module pumpdown	1.2 gallons
J. Christenson	1.85 gallons

Predicted pumpdown time for 1.2 gallons of water removal:

BASIS	ESTIMATE
NWA stall pressure	72 pumping days
NWA cold trap content	42.5 pumping days
NWA rate of rise	45 pumping days

Predicted CC ultimate stall pressure was 7 microns.

Actual pumping parameters:

1.1 to 1.2 gallons of water were removed from the CC over a period of 46 days. Actual pumping time was about 41.5 pumping days. A vacuum level of 12 microns was obtained.

WATER LOAD ESTIMATE

The majority of the water that is in the CC is believed to be stored in the G-10 signal boards. There are sixteen FH modules, sixteen CH modules, and 32 EM modules. Looking at a summary of the G-10 from the modules;

Volume of G-10 = 68 cubic feet
Surface area of G-10 = 37,000 square feet
Weight of G-10 = 7630 lb

Four different sources/methods were used to come up with an estimate of the stored water in the G-10.

1.) For a high level bound, ASTM D570 shows % water absorbed by G-10 after twenty four hours of immersion to be 0.04% to 0.30%. By weight this comes out to between 3.0 and 22.9 lbs water. This converts to 0.4 to 2.7 gallons water.

2.) From Nasa report #NASA RP-1124, outgassing data for selecting space craft materials, % total mass loss after pumping on G-10 was 0.47%. The numbers figure out to 35.9 lbs of mass lost. Substances other than water are included in that weight, however, for comparison if it is assumed only water then it converts to 4.3 gallons.

3.) Fermilab data from pumping on a MH module was scaled up. After 100 hours of pumping on an MH 64.3 cubic centimeters of water was released. The following is how it was scaled;

V(H20 in CC)= V(H20 in MH) * {Ratio of G-10 area CC : MH }

Doing the math says there will be 1.2 gallons of water in the CC.

4.) The source for this estimate is J. Christenson. He estimated that there would be about 7 liters = 1.85 gallons of water in the CC.

PUMPING SPEEDS

Calculations were done to determine the pumping speed of the CC vacuum pumping system and to get some useful information by comparing this with the vacuum pumping system performance of the Test Beam cryostat at NWA.

The CC vacuum system consisted of four major parts. There were two 4" O.D. tubing runs which connected the relief port and utility vacuum port to mechanical/blower pumps. There was a mechanical pump connected to the CC drain line. There was a LN2 filled cryogenic pump which was connected to a signal box side plate. See schematic of the system drg#3740.514-MC-294870 rev. A for details of the arrangement.

The pumping speed of the CC system at P(avg)=100 microns [Laminar flow regime] was calculated to be 28 cfm, 20 cfm, 14 cfm, and 500 cfm for the relief port, UV port, drain, and cryopump respectively. This sums to a total effective pumping speed of 562 cfm at P(avg)=100 microns.

The pumping speed of the CC system at P(avg)=15 microns [Molecular flow regime] was calculated to be 8 cfm, 6 cfm, 4 cfm, and 220 cfm for the relief port, UV port, drain, and cryopump respectively. This sums to a total effective pumping speed of 238 cfm at P(avg)=15 microns.

The total effective NWA pumping speed at P(avg)=100 microns was calculated to be 287 cfm. At P(avg)=15 microns, the total effective pumping speed was calculated to be 16 cfm.

PREDICTING REQUIRED PUMPING TIME

To get some information from NWA's pumping experience, a comparison of pertinent G-10 facts had to be known. NWA had an exposed G-10 surface area of 5500 sq. ft. and a volume of 41.7 cu. ft.. The CC had an exposed G-10 surface area of 37000 sq. ft. and a volume of 68 cu. ft. . Note that the EM and IH modules in the first load at NWA had G-10 boards .158" and .167" respectively, while all the G-10 signal boards in the CC had thicknesses of 0.044". The correct scaling factor in the rate of water desorption was that of area. The G-10 area ratio CC to NWA was 6.7.

Using the pumping equation:[1]

Q=S(eff)*P(ult)-Q(leak)

where: Q is net flow rate
S(eff) is effective pumping speed
P(ult) is ultimate pressure
Q(leak) is total "leak" {water desorption rate}

NWA's pressure versus time curve went flat at 15 microns. Considering this as P(ult)=15 microns, Q=0 and S(eff)=16 cfm, the water desorption rate comes out to be 240 cfm-microns.

Assuming water desorption rate is proportional to G-10 surface area, the CC's water desorption rate would be equal to 1608 cfm-microns. Also, you can use the above equation to predict the CC stall pressure at 7 microns.

At low pressures you can assume ideal gas behavior and mass flow rate is given by; [2]

G=Q*M/(R*T)

where: Q is throughput (Pa-m**3/s)
M is molecular wt.
R is 8314.3 kJ/(K-kgmol)
T is temperature (K)
G is mass flow rate (kg/s)

In the case of the CC, Q is the desorption rate at stall pressure, (.10092 Pa-m**3/s), M is water's molecular weight and T is room temperature. G works out to be 7.28 E-7 kg/s. To get 1.2 gallons of water (4.55 kg by weight), the above equation predicts it would take 72 pumping days.

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[1] Kaminsky, Manfred, *Vacuum Science and Technology* course notes (Presented at Fermilab in March 1990), p.77.
[2] O'Hanlon, John F., *A User's Guide to Vacuum Technology*, 2nd ed. (N.Y.: John Wiley & Sons, 1989), p.102.

Another way to predict the required pumping time from NWA is by using the fact that 6 cubic centimeters (.006 kg) of water were removed from the cold trap at NWA after 9 hours of service. This gives another way to calculate G for the CC. Let's call this G, G(prime) for clarity.

G(prime)=Ratio G-10 area CC/NWA * .006 kg/32,400 s = 1.24 E-6 kg/s

The above equation predicts it would take 42.5 days of pumping time to get 1.2 gallons of water out of the CC.

A rate of rise done at NWA assuming water vapor predicted 15 cc of water was released in a 24 hour period. This gives a G(prime) of 1.17 E-6 kg/s for the CC. Using this value, it predicts 45 days of pumping time to remove 1.2 gallons of water from the CC.

ACTUAL CC PUMPING

While pumping was taking place on the CC in the cleanroom, water that was collected by the cold traps was collected and measured. Pumping took place from 6/29/90 thru 8/25/90. During that period of time approximately 4345 ml plus or minus 75 ml was reported collected. By conversion, this is between 1.1 to 1.2 gallons of water. Due to final welding of the pressure vessel and leak checking, only 41.5 of the 46 calendar days were spent pumping.

During the first week or so of pumping, known air leaks were found. The vessel was considered reasonably tight 7/7/90. Thru that time 1275 ml of water was collected. Around 7/20/90 it was noticed that the water collected from the cryo-pump had a green G-10 tint color to it. From that time until the end of pumping the tint gradually deepened in color and changed to blue. This "G-10 juice" as it's called also gave off a strong odor.