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memorandum

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SUBJECT: SNS – EFFECTS OF DTL DRIFT-TUBE VIBRATIONS ON THE BEAM POSITION AT THE FOIL.

Recently there has been concern that beam centroid jitter caused by DTL drift tube vibrations will exceed the requirements at the ring injection foil. This would lead to an increased effective emittance at the foil and could lead to increased beam activation of the ring. We have completed simulations to estimate the magnitude of the beam jitter at the foil. The results are presented below.

Calculated Drift Tube RSM Dynamic Motion

The engineers involved in the design of the DTL have completed a structural analysis and have estimated the rms displacements of the drift tubes in Tank 2 of the DTL due to structural vibrations [1]. Because of the drift tube geometry and the stem sizes in this tank, the displacements here are expected to be the worst case throughout the DTL. The results are summarized in Table 1 below.

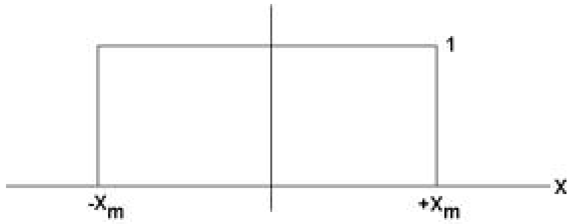
Table 1 – Summary of calculated rms drift tube displacements.

	RMS Displacement		
Drift Tube	**x-axis**	**y-axis**	**z-axis**
First	124 μ-in.	24 μ-in.	85 μ-in.
Middle	200 μ-in.	10 μ-in.	85 μ-in.
End	148 μ-in.	46 μ-in.	86 μ-in.
Combined x-, y-, z-axis base excitation ½% structural damping (conservative)			

RMS of a Uniform Distribution

Presently, our simulation codes only generate uniform error distributions. In order to perform simulations and generate uniform error distributions having the equivalent rms values given by the engineers above, we need to know the rms value of a uniform distribution. The derivation is given below for future reference:

For a uniform distribution having a maximum value, X_m



$$Area = \int_{-X_m}^{+X_m} dx = 2X_m$$

$$s^2 = \frac{1}{2X_m}\int_{-X_m}^{+X_m} x^2 dx = \frac{1}{2X_m}\frac{2X^3{}_m}{3} = \frac{X^2{}_m}{3}$$

$$s = \frac{1}{\sqrt{3}} X_m$$

Therefore, in order to generate uniform error distributions having the same rms values as those given in Table 1 above, each rms value must be multiplied by the square root of 3 to obtain the maximum value of the uniform distribution.

For our simulations we included only random displacements in x and y. We have assumed ±200 μ-in in x and ±10 μ-in in y for all drift tubes in DTL Tanks 1-6. This should be a worst case scenario.

Simulation Results

PARMILA simulations using a uniform distribution of 10,000 macroparticles and a 56 mA peak beam current were used for this study. The beam was transported throughout the entire linac and HEBT, starting at the MEBT. No other errors were included in the simulations and it was assumed that the beam was initially aligned with the beam-line axis. Twenty separate simulation runs were completed in order to get distributions of the beam centroids at the foil. Figures 1-4 summarize the simulation results.

The mean rms normalized transverse emittance at the foil as calculated from the 20 runs was 0.02922 π-cm-mrad for the uniform input distribution. This value is only 1.4% larger than the nominal, no error case as might be expected.

The maximum centroid displacement observed was 0.0193 cm. This is within the 0.2 mm specification required for the present injection scheme [2]. For this case the rms (maximum) beam size at the foil was 0.1128 cm (0.5619 cm). Taking the sum of the maximum beam size and the centroid displacement gives 0.5812 cm to the edge of the beam with respect to the beam axis (origin). The foil size in its maximum dimension is expected to be only ±0.4 cm. Clearly, some fraction of the beam will miss the foil with the present HEBT tune. The maximum beam size for the nominal case with no drift tube displacements and the beam centered on the axis is also approximately 0.6 cm. Again, with this HEBT tune a large fraction of the beam will miss the foil. The addition of alignment and operational errors which lead to emittance growth and therefore, an increase in the beam size will only make matters worse unless a HEBT tune can be found that reduces the spot size on the foil to an acceptable value.

References

[1] Private communication, T. Ilg, October 13, 2000.
[2] Private communication by J. Stovall via email, October 12, 2000.

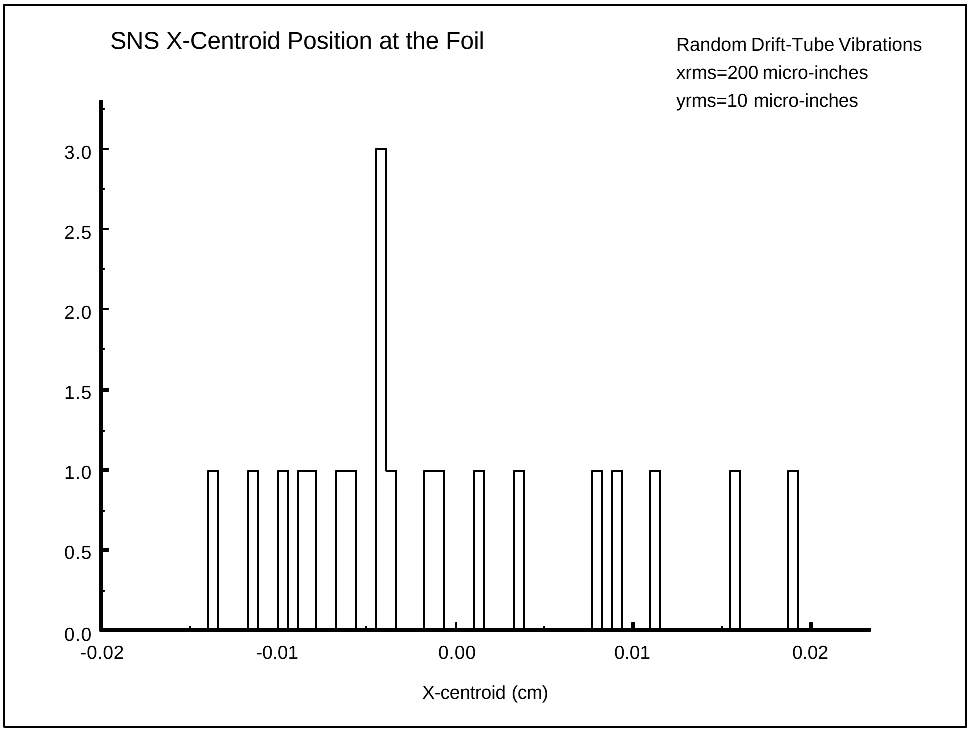


Figure 1 – X beam centroid distribution at the foil for random drift tube displacements.

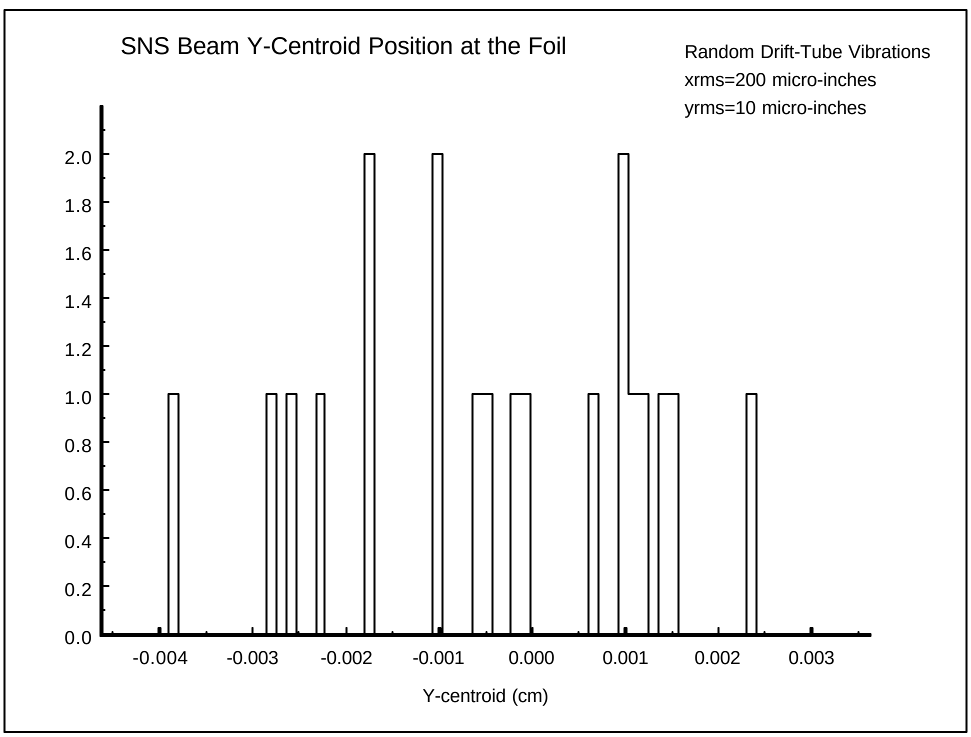


Figure 2 – Y beam centroid distribution at the foil for random drift tube displacements.

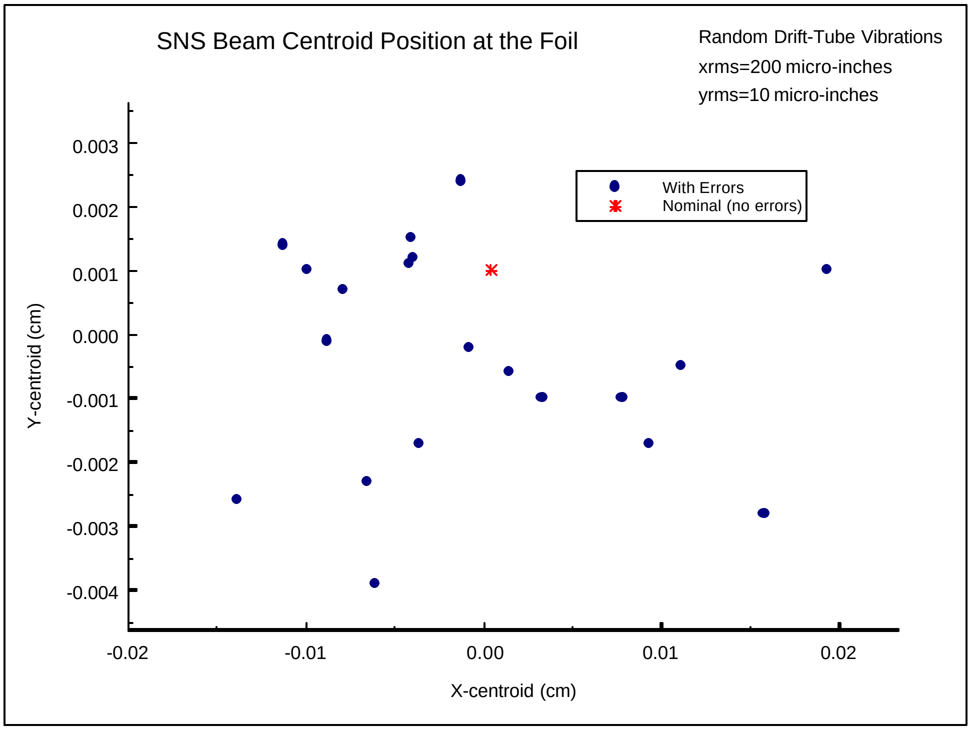


Figure 3 – 2-D plot of X- and Y-centroids. The red point near x=y=0 is the nominal beam.

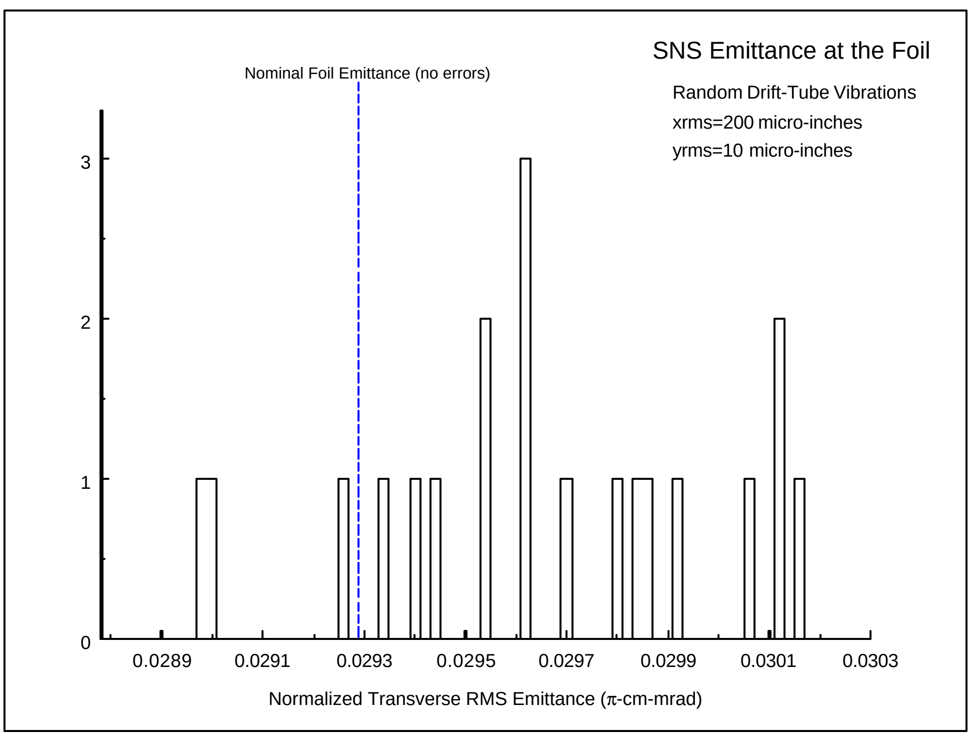


Figure 4 – Distribution of emittance values at the foil .

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