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Engineering Note
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Project

Solenoidal Tracker at RHIC (STAR)

Subproject

Time Projection Chamber - Assembly and Test

Title

Installation Beam Suspension Cable Insertion

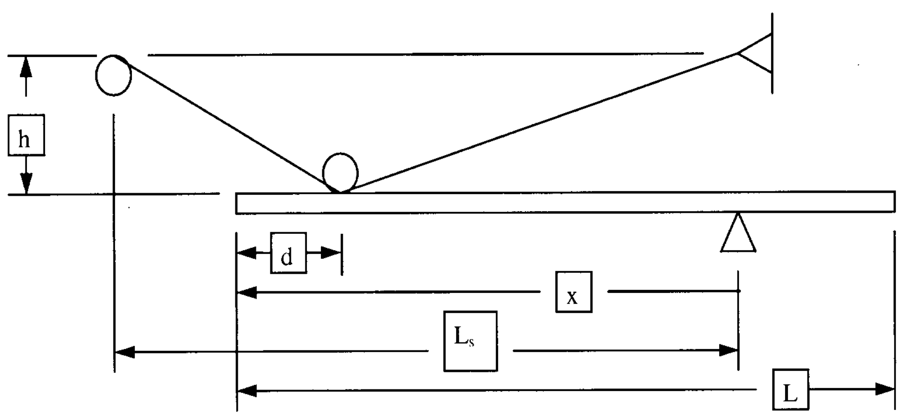
Revision A - change STAR Note number from 372 to 371

1.0 Introduction

A method of inserting the TPC Installation Beam using cable suspension has been proposed. The following calculation specifies the amount of cable tension required for the TPC-EMC-Magnet geometry. The height, h, was determined by Bob Caylor from the STAR Integration drawings.

2.0 Calculations

Determine the cable tensions and force on beam mounted sheave.



Dimensions

Length of beam: $L := 352\ \text{in}$

Distance between support rollers: $L_s := 298\ \text{in}$

Distance from center of beam mounted suspension cable sheave to leading edge of beam:

$$d := 7.5\ \text{in}$$

Vertical distance from top of magnet mounted sheave to bottom of beam sheave:

$$h := 15.5\ \text{in}$$

Load

The cable must support a varying portion of the beam's weight as it traverses between the support rollers mounted to the magnet end rings.

Beam weight $w := \frac{116.8\ \mathrm{lbf}}{12\ \mathrm{in}}$ Refer to beam fabrication drawing TPC800-E-1

Calculation of cable tension at discrete points during beam insertion.

$i := 0..8$

$x_i := 210\ \mathrm{in} + i \cdot 10\ \mathrm{in}$ No downward force until beam passes mid-span. x=0 at right side (east roller) support.

Angle between horizontal and the cable to the left (alpha) and right (beta) of the beam mounted sheave.

$$\alpha_i := \left[\operatorname{atan}\left[\frac{h}{L_s - (x_i - d)}\right]\right] \qquad \beta_i := \operatorname{atan}\left(\frac{h}{x_i - d}\right)$$

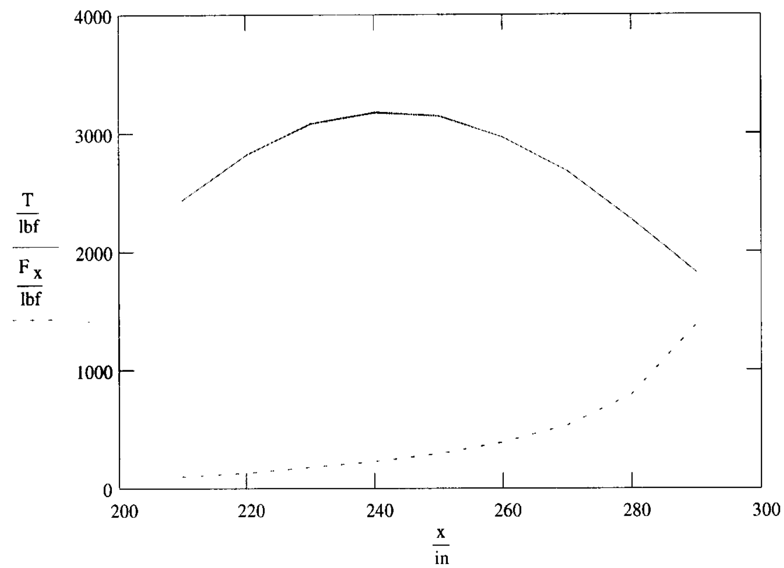
Support Cable tension

$$T_i := \frac{\left(\frac{w}{2}\right)\cdot\left[\frac{(x_i)^2 - (L - x_i)^2}{x_i - d}\right]}{\left(\sin(\alpha_i) + \sin(\beta_i)\right)}$$

Pull Cable tension

$$F_{x_i} := \frac{\left(\frac{w}{2}\right)\cdot\left[\frac{(x_i)^2 - (L - x_i)^2}{x_i - d}\right]\cdot\sin(\alpha_i)}{\left(\cos(\alpha_i)\right)}$$

$$T = \begin{bmatrix} 2.432\cdot10^3 \\ 2.825\cdot10^3 \\ 3.073\cdot10^3 \\ 3.178\cdot10^3 \\ 3.142\cdot10^3 \\ 2.97\cdot10^3 \\ 2.672\cdot10^3 \\ 2.269\cdot10^3 \\ 1.815\cdot10^3 \end{bmatrix} \circ \mathrm{lbf} \qquad x = \begin{bmatrix} 210 \\ 220 \\ 230 \\ 240 \\ 250 \\ 260 \\ 270 \\ 280 \\ 290 \end{bmatrix} \circ \mathrm{in} \qquad F_x = \begin{bmatrix} 93.366 \\ 128.607 \\ 170.708 \\ 223.178 \\ 291.987 \\ 388.278 \\ 535.681 \\ 794.809 \\ 1.383\cdot10^3 \end{bmatrix} \circ \mathrm{lbf}$$



Suspension and Pull cable tension as a function of the position of the leading edge of the beam wrt. the right side support (east end magnet mounted roller).

Vertical force on beam mounted sheave

$$F_{bs_i} := T_i \cdot \left(\sin(\alpha_i) + \sin(\beta_i)\right)$$

$$F_{bs} = \begin{bmatrix} 575.252 \\ 709.411 \\ 831.511 \\ 943.108 \\ 1.046 \cdot 10^3 \\ 1.14 \cdot 10^3 \\ 1.227 \cdot 10^3 \\ 1.308 \cdot 10^3 \\ 1.383 \cdot 10^3 \end{bmatrix} \circ lbf$$

Sheave mounting screws.

The sheave is attached to the beam via two 1/2"-13 UNC socket head cap screws. These screws have a minimum ultimate strength of 150 kpsi.

Axial (tensile) stress on screw:

Stress area: $A_{xs} := 0.1419\ in^2$

$$\sigma := \frac{F_{bs}}{2 \cdot A_{xs}} \qquad \sigma = \begin{bmatrix} 2.027 \cdot 10^3 \\ 2.5 \cdot 10^3 \\ 2.93 \cdot 10^3 \\ 3.323 \cdot 10^3 \\ 3.684 \cdot 10^3 \\ 4.016 \cdot 10^3 \\ 4.323 \cdot 10^3 \\ 4.607 \cdot 10^3 \\ 4.872 \cdot 10^3 \end{bmatrix} \circ \frac{lbf}{in^2}$$

3.0 Conclusions

The maximum tension in the suspension cable is less than 3150 lb. which therefore has a safety factor in excess of 4.5 on the rated strength of the cable (14,400 lb. breaking). The pull cable will experience a maximum tension of roughly 1400 lb. which is 1/5 th of its 7000 lb.rating. Similarly the rated working capacity of the beam mounted sheave is 2500 lb. and the maximum force is 1400 lb. so this unit operates safely below the limit. The sheave mounting screws enjoy a safety factor of greater than 30.