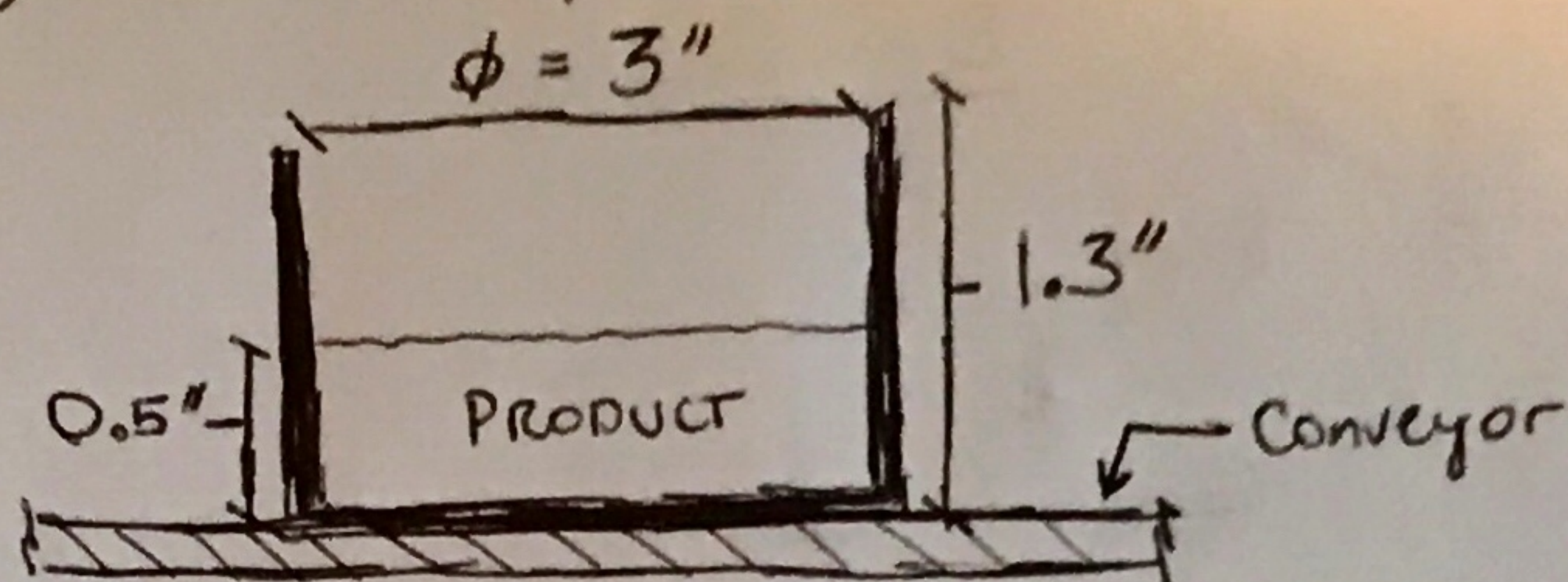


## Heat transfer geometry

for 2oz. product:



PRODUCT CONTAINER IS 1.3" height, 3"  $\phi$  and is made of polypropylene.

PRODUCT FILL HEIGHT IS 0.5"

Heat transfer geometry is

$$A = \frac{\pi}{4} * d^2 + \pi * d * h$$

## ASSUMPTIONS

Heat transfer coeff. =  $200 \frac{W}{m^2 \cdot K}$

PRODUCT THERMAL PROPERTIES ARE WATER

NEGLECTING CONDUCTION THROUGH P.P. CONTAINER

## Heat transfer:

$$\frac{T_f - T_B}{T_i - T_B} = e^{\frac{-h * A * t}{\rho * V * c}}$$

$$t = \frac{\rho * V * c}{-h * A} \ln\left(\frac{T_f - T_B}{T_i - T_B}\right)$$

$\rho$  = product density ~ water

$V$  = product volume

$C$  = spec heat ~ water

$h$  = heat trans. coeff.

$A$  = SURFACE AREA for heat trans.

$T_f$  = desired temp.

$T_i$  = initial temp.

$T_B$  = Bulk cooling temp.

$t$  = time to cool

## SIZING COOLING TUNNEL REFRIGERATION CYCLE:

Total heat that needs to be removed is equal to the Fill RATE (gal/min) and the difference between the initial + desired product temperature.



### Cooling Tunnel Residence Time

	2 OZ		4 OZ		8 OZ
Diameter of Jar (in)	<b>3.0000</b>		<b>2.8125</b>		<b>3.5625</b>
Product Volume (oz)	<b>2</b>		<b>4</b>		<b>8</b>
Diameter (m)	0.0762		0.0714		0.0905
Cross Sectional Area (m2)	0.0046		0.0040		0.0064
Product Volume (m3)	5.91E-05		1.18E-04		2.37E-04
Product Fill Height (m)	0.0130		0.0295		0.0368
Heat Transfer Surface Area (m2)	<b>0.0077</b>		<b>0.0106</b>		<b>0.0169</b>
		°C		°C	
Bulk Cooling Temp (°F)	<b>50</b>	10	<b>50</b>	10	<b>50</b>
Product Initial Temp (°F)	<b>150</b>	66	<b>150</b>	66	<b>150</b>
Product Final Temp (°F)	<b>70</b>	21	<b>70</b>	21	<b>70</b>
Product Density (kg/m3)	<b>1,000</b>		<b>1,000</b>		<b>1,000</b>
Heat Trans. Coeff (W/m2*K)	<b>200</b>		<b>200</b>		<b>200</b>
Spec. Heat (kJ/kg*K)	<b>4.20</b>		<b>4.20</b>		<b>4.20</b>
Time to cool (mins)	<b>4.35</b>		<b>6.27</b>		<b>7.89</b>

### Cooling Tunnel Refrigeration Cycle Sizing

Production Rate (containers/min)	<b>60</b>	<b>60</b>	<b>60</b>
Fill Rate (gpm)	0.94	1.88	3.75
Total Heat Removed (BTU/hr)	37,530	75,060	150,120
Tons Refrigeration	<b>3.1</b>	<b>6.3</b>	<b>12.5</b>

### Cooling Tunnel Specifications

Conveyor Rate (ft/min)	15	14.0625	17.8125
Length of Cooling Tunnel (ft)	<b>19.7</b>	<b>19.7</b>	<b>19.7</b>
No. of Passes	<b>5</b>	<b>5</b>	<b>5</b>
Total Residence Time (mins)	<b>6.6</b>	<b>7.0</b>	<b>5.5</b>

