Field Cage design

For flashover, we are operating on the right side of the Paschen curve; increasing pressure gives increasing resistance to flashover. Therefore, we need to make sure flashover does not occur at lowest operating pressure and internal breakdown does not occur at highest operating pressure.

PCB substrate thickness:

For PTFE, we need to use a thick substrate for rigidity, best estimate is 1.5mm. Dielectric strength for this thickness is typically:

$$E_{bd\_PTFE\_thk} := 285 \frac{kV}{in}$$

from: http://www.boedeker.com/teflon_p.htm (lowest number found, for thinner substrates 500 V/mil is typ.)

To give rigidity in the longitudinal direction, we use overlapping traces on both sides and limit the trace to trace width, so as too minimize the longitudinal breaks in the sandwich structure.

IPC typ. V_{bd} is 30-40 V/mil @ 1 atm air

$$E_{tr} := 30 \frac{kV}{in} \qquad E_{tr} = 1.181 \frac{kV}{mm}$$

Xenon relative (to air) electric strength

$$\eta_{Xe} := 0.8$$

DRAFT

lowest pressure used:

$$P_{Xe\_l} := 150psi$$

highest pressure used

$$P_{Xe\_h} := 300psi$$

Maximum allowable trace to trace voltage gradient

Pressure multiplier for gas breakdown:

$$\beta_{pXe} := \eta_{Xe} \cdot \frac{P_{Xe\_l}}{15psi} \qquad \beta_{pXe} = 8$$

Gas Dielectric Strength

$$E_{tr\_TPC} := \beta_{pXe} \cdot E_{tr} \qquad E_{tr\_TPC} = 9 \frac{kV}{mm} \qquad E_{tr\_TPC} = 240 \frac{kV}{in}$$

Gas breakdown is limit at lower pressure, but just barely.

Highest field cage gradient is end region(s) with:

$$V_{end} := 20kV$$

We need a minimum total gap width of:

$$w_{gap} := \frac{V_{end}}{E_{tr\_TPC}} \qquad w_{gap} = 2.117\,mm$$

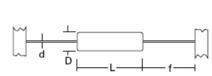
to avoid flashover. Over 10 gaps, we could have a trace to trace gap of 0.25mm, but this could be difficult to fab well. We double trace gap to ~0.5mm

		GC55	GC65	GC70
Power rating at 70°C	watts	0.25	0.5	1.0
Resistance range	ohms	47k to 900 meg	47k to 900 meg	47k to 1G
Limiting element voltage	Volts dc or ac Peak	1700	3500	10000
Isolation voltage	volts	700		
TCR (20°C to 70°C)	ppm/°C	100		
Resistance tolerance	%	1, 2, 5		
Values		E24 & E96 preferred		
Thermal impedance	°C/watt	140	90	70
Ambient temperature range	°C	- 55 to 155		

Physical Data

Dimensions (mm) and Weight (g)

Type	L max.	D max.	f min.	d nom.	PCB mounting centres	Min bend radius	Wt nom.
GC55	6.2	2.5	21.0	0.6	10.2	0.6	0.3
GC65	9.0	3.6	19.6	0.8	13.7	1.2	0.6
GC70	14.5	5.3	23.6	0.8	20.3	1.2	1.1



Single layer design on 1/4 " PTFE

trace to race centerline distance (pitch)

gap width

$p_{sl} := 6mm$ $w_{gsl} := 1mm$

trace width

$w_{tr} := p_{sl} - w_{gsl}$ $w_{tr} = 5\,mm$

Trace voltages and resistor values

Voltage on traces will be set proportionally to their centerline positions. This method does not correct for the harmonics introduced by the asymmetric mesh frames, but until they are determined to be significant, this will remain the baseline design. We start from the PMT mesh plane and work through the three field cage regions, called here the cathode, drift and anode field cages. There is no field cage in the electroluminescent region (EL) where voltage jumps from +11 kV to = 20 kV across a 3mm gap.

Nominal Intertrace Resistance (may or may not be the same for all regions

$R_{it} := 100M\Omega$

Cathode (PMT to drift start; -1 kV to -20kV))

Mesh voltages Mesh positions along axis

$V_{cl} := -1kV$ $V_{ch} := -20kV$ $z_{cl} := 0cm$ (baseline) $z_{ch} := 5cm$

First trace (centerline) position

$z_{c0} := 1.0645cm$

There are 7 traces, and thus 8 resistors (2 end resistors and 6 intertrace resistors):

$n_{tc} := 7$

trace number:

$i_c := 1, 2 .. n_{tc}$

trace centerline position:

$z_c(i_c) := z_{c0} + p_{sl}\cdot(i_c - 1)$

$$z_c(i_c) = \begin{pmatrix} 1.065 \\ 1.664 \\ 2.264 \\ 2.865 \\ 3.465 \\ 4.064 \\ 4.665 \end{pmatrix} cm$$

trace voltages

$$V_c(i_c) := \frac{V_{ch} - V_{cl}}{z_{ch} - z_{cl}}\cdot z_c(i_c) + V_{cl}$$

$$V_c(i_c) = \begin{pmatrix} -5.045 \\ -7.325 \\ -9.605 \\ -11.885 \\ -14.165 \\ -16.445 \\ -18.725 \end{pmatrix} kV$$

Max power, per panel

$P_{max} := 1W$

Min resistance total:

$$R_{tc} := \frac{(V_{ch} - V_{cl})^2}{P_{max}} \qquad R_{tc} = 361\,M\Omega$$

Number of resistors (assume all same for start)

$N_{rc} := n_{tc} + 1$

Intertrace resistance, minimum:

$$R_{c\_min} := \frac{R_{tc}}{N_{rc}} \qquad R_{c\_min} = 45.125\,M\Omega$$

Choose intertrace resistor value:

$R_c := R_{it}$ $R_c = 100\,M\Omega$

End resistor values:

$$R_{cl} := R_c \cdot \frac{z_{c0}}{p_{sl}} \qquad R_{cl} = 177.417\,\mathrm{M\Omega}$$ low side, z_c= 0 cm

$$R_{ch} := R_c \cdot \frac{\left(z_{ch} - z_c\left(n_{tc}\right)\right)}{p_{sl}} \qquad R_{ch} = 55.9\,\mathrm{M\Omega}$$ high side z_c = 5 cm

Resistance total:

$$R_{ct} := R_{cl} + \left(n_{tc} - 1\right)\cdot R_c + R_{ch} \qquad R_{ct} = 833.3\,\mathrm{M\Omega}$$

trace voltages, actual, are now:

$$V_{c\_a}\left(i_c\right) := \left(V_{ch} - V_{cl}\right)\cdot \frac{\left[R_{cl} + R_c\cdot\left(i_c - 1\right)\right]}{R_{ct}} + V_{cl}$$

$$V_{c\_a}\left(i_c\right) = \begin{pmatrix} -5.045 \\ -7.325 \\ -9.605 \\ -11.885 \\ -14.165 \\ -16.445 \\ -18.725 \end{pmatrix} \mathrm{kV}$$ compare --> $$V_c\left(i_c\right) = \begin{pmatrix} -5.045 \\ -7.325 \\ -9.605 \\ -11.885 \\ -14.165 \\ -16.445 \\ -18.725 \end{pmatrix} \mathrm{k\backslash}$$

$$\Delta V_c := V_c(1) - V_c(2) \qquad \Delta V_c = 2.28\,\mathrm{kV}$$

$$\Delta V_{cl} := V_{cl} - V_c(1) \qquad \Delta V_{cl} = 4.045\,\mathrm{kV}$$ <--use 2 resistors for R low

$$\Delta V_{ch} := V_c\left(n_{tc}\right) - V_{ch} \qquad \Delta V_{ch} = 1.275\,\mathrm{kV}$$

We will need to use a network of resistors on each end to obtain the proper resistance values. These resistors will be mounted to the support panel.

Current: $$I_c := \frac{V_{ch} - V_{cl}}{R_{ct}} \qquad I_c = -0.023\,\mathrm{mA}$$

Power: $$P_c := \frac{\left(V_{ch} - V_{cl}\right)^2}{R_{ct}} \qquad P_c = 0.433\,\mathrm{W}$$

Power per resistor

intertrace	low	high
$P_{rc} := I_c^{\,2} R_c$	$P_{rcl} := I_c^{\,2} R_{cl}$	$P_{rch} := I_c^{\,2} R_{ch}$
$P_{rc} = 0.052\,\mathrm{W}$	$P_{rcl} = 0.092\,\mathrm{W}$	$P_{rch} = 0.029\,\mathrm{W}$

Trace to trace gap:

$$z_{tt} := .07\mathrm{cm}$$

Trace to trace voltage gradient

$$E_c := \frac{V_c(1) - V_c(2)}{z_{tt}} \qquad E_c = 32.571\,\frac{\mathrm{kV}}{\mathrm{cm}} \qquad E_c = 82.7\,\frac{\mathrm{kV}}{\mathrm{in}}$$

Mesh frame to trace distances:

$$g_{cl} := 0.2\mathrm{cm} \qquad g_{ch} := .085\mathrm{cm}$$

Mesh frame to trace voltage gradients

$$E_{cl} := \frac{V_{cl} - V_c(1)}{g_{cl}} \qquad E_{cl} = 20.2\,\frac{kV}{cm}$$

$$E_{ch} := \frac{V_c(n_{tc}) - V_{ch}}{g_{ch}} \qquad E_{ch} = 15\,\frac{kV}{cm}$$

All gap gradients are lower than the standard design value multiplied by the pressure/gas ratio as calculated above:

$$E_{tr\_TPC} = 94.5\,\frac{kV}{cm}$$

Drift (drift start to EL start; -20 kV to +11kV))

Mesh voltages — Mesh positions along axis

$V_{dl} := -20kV$ $V_{dh} := 11kV$ $z_{dl} := 0cm$ (baseline) $z_{dh} := 8cm$

First trace position

$z_{d0} := 1.0cm$

There are 11 traces, and thus 12 resistors (2 end resistors and 10 intertrace resistors):

$n_{td} := 11$

trace number:

$i_d := 1, 2 .. n_{td}$

trace centerline position:

$$z_d(i_d) := z_{d0} + p_{sl}\cdot(i_d - 1) \qquad z_d(i_d) = \begin{pmatrix} 1 \\ 1.6 \\ 2.2 \\ 2.8 \\ 3.4 \\ 4 \\ 4.6 \\ 5.2 \\ 5.8 \\ 6.4 \\ 7 \end{pmatrix} cm$$

trace voltages

$$V_d(i_d) := \frac{V_{dh} - V_{dl}}{z_{dh} - z_{dl}}\cdot z_d(i_d) + V_{dl} \qquad V_d(i_d) = \begin{pmatrix} -16.125 \\ -13.8 \\ -11.475 \\ -9.15 \\ -6.825 \\ -4.5 \\ -2.175 \\ 0.15 \\ 2.475 \\ 4.8 \\ 7.125 \end{pmatrix} kV$$

Max power, per panel

$$P_{max} = 1\,W$$

Min resistance total:

$$R_{td} := \frac{(V_{dh} - V_{dl})^2}{P_{max}} \qquad R_{td} = 961\,M\Omega$$

Number of resistors (assume all same for start)

$$N_{rd} := n_{td} + 1$$

Intertrace resistance, minimum:

$$R_{d\_min} := \frac{R_{td}}{N_{rd}} \qquad R_{d\_min} = 80.083\,M\Omega$$

Choose intertrace resistor value:

$$R_d := R_{it} \qquad R_d = 100\,M\Omega$$

End resistor values:

$R_{dl} := R_d \cdot \frac{z_{d0}}{p_{sl}}$ $R_{dl} = 166.7\,M\Omega$ low side z_d=0

$R_{dh} := R_d \cdot \frac{\left(z_{dh} - z_d(n_{td})\right)}{p_{sl}}$ $R_{dh} = 166.67\,M\Omega$ high sid z_d=8cm

Resistance total :

$R_{dt} := R_{dl} + (n_{td} - 1)R_d + R_{dh}$

$R_{dt} = 1.333\,G\Omega$

Trace voltages, actual, are now:

$$V_{da}(i_d) := (V_{dh} - V_{dl}) \cdot \frac{\left[R_{dl} + R_d \cdot (i_d - 1)\right]}{R_{dt}} + V_{d}$$

$$V_{da}(i_d) = \begin{pmatrix} -16.125 \\ -13.8 \\ -11.475 \\ -9.15 \\ -6.825 \\ -4.5 \\ -2.175 \\ 0.15 \\ 2.475 \\ 4.8 \\ 7.125 \end{pmatrix} kV$$

compare -->

$$V_d(i_d) = \begin{pmatrix} -16.125 \\ -13.8 \\ -11.475 \\ -9.15 \\ -6.825 \\ -4.5 \\ -2.175 \\ 0.15 \\ 2.475 \\ 4.8 \\ 7.125 \end{pmatrix} kV$$

$\Delta V_d := V_d(2) - V_d(1)$ $\Delta V_d = 2.325\,kV$

$\Delta V_{dl} := V_d(1) - V_{dl}$ $\Delta V_{dl} = 3.875\,kV$ <-use 2 resistors for R_l

$\Delta V_{dh} := V_{dh} - V_d(n_{td})$ $\Delta V_{dh} = 3.875\,kV$ <-use 2 resistors for R_h

We will need to use a network of resistors on each end to obtain the proper resistance values. These resistors will be mounted to the support panel.

Current: $I_d := \frac{V_{dh} - V_{dl}}{R_{dt}}$ $I_c = -0.023\,mA$

Power: $P_d := \frac{(V_{dh} - V_{dl})^2}{R_{dt}}$ $P_d = 0.721\,W$

Power per resistor

intertrace	low	high
$P_{rd} := I_d^{\,2} R_d$	$P_{rdl} := I_d^{\,2} R_{dl}$	$P_{rdh} := I_d^{\,2} R_{dh}$
$P_{rd} = 0.054\,W$	$P_{rdl} = 0.09\,W$	$P_{rdh} = 0.09\,W$

Trace to trace gap:

$z_{tt} = 0.07\,cm$

Trace to trace voltage gradient

$E_d := \frac{V_d(2) - V_d(1)}{z_{tt}}$ $E_d = 33.214\,\frac{kV}{cm}$ $E_d = 84.4\,\frac{kV}{in}$

Mesh frame to trace distances:

$g_{dl} := 0.2cm$ $g_{dh} := 0.2cm$

Mesh frame to trace voltage gradients

$$E_{dl} := \frac{V_d(1) - V_{dl}}{g_{dl}} \qquad E_{dl} = 19.4\,\frac{kV}{cm}$$

$$E_{dh} := \frac{V_{dh} - V_d(n_{td})}{g_{dh}} \qquad E_{dh} = 19.4\,\frac{kV}{cm}$$

All gap gradients are lower than the standard design value multiplied by the pressure/gas ratio as calculated above:

Anode (EL end to SiPMT plane; +20 kV to 0kV))

Mesh voltages

$V_{al} := 20kV \quad V_{ah} := 0kV$

Mesh positions along axis

$z_{al} := 0cm$ (baseline) $\qquad z_{ah} := 5cm$

First trace centerline position

$z_{a0} := 1.0cm$

There are 6 traces, and thus 7 resistors (2 end resistors and 5 intertrace resistors):

$n_{ta} := 6$

trace number:

$i_a := 1, 2 .. n_{ta}$

trace centerline position:

$$z_a(i_a) := z_{a0} + p_{sl}\cdot(i_a - 1) \qquad z_a(i_a) = \begin{pmatrix} 1 \\ 1.6 \\ 2.2 \\ 2.8 \\ 3.4 \\ 4 \end{pmatrix} cm$$

trace voltages

$$V_a(i_a) := \frac{V_{ah} - V_{al}}{z_{ah} - z_{al}}\cdot z_a(i_a) + V_{al} \qquad V_a(i_a) = \begin{pmatrix} 16 \\ 13.6 \\ 11.2 \\ 8.8 \\ 6.4 \\ 4 \end{pmatrix} kV$$

Max power, per panel

$P_{max} = 1\,W$

Min resistance total:

$$R_{ta} := \frac{(V_{ah} - V_{al})^2}{P_{max}} \qquad R_{ta} = 400\,M\Omega$$

Number of resistors (assume all same for start)

$N_{ra} := n_{ta} + 1$

Intertrace resistance, minimum:

$$R_{a\_min} := \frac{R_{ta}}{N_{ra}} \qquad R_{a\_min} = 57.143\,M\Omega$$

Choose intertrace resistor value:

$R_a := R_{it} \qquad R_a = 100\,M\Omega$

End resistor values:

$$R_{al} := R_a\cdot\frac{z_{a0}}{p_{sl}} \qquad R_{al} = 166.7\,M\Omega$$

low side, z_a= 0 cm

$$R_{ah} := R_a \cdot \frac{(z_{ah} - z_a(n_{ta}))}{p_{sl}} \qquad R_{ah} = 166.7\,M\Omega$$ high side z_a = 5 cm

Resistance total:

$$R_{at} := R_{al} + (n_{ta} - 1) \cdot R_a + R_{ah} \qquad R_{at} = 833.3\,M\Omega$$

trace voltages, actual, are now:

$$V_{a\_a}(i_a) := (V_{ah} - V_{al}) \cdot \frac{[R_{al} + R_a \cdot (i_a - 1)]}{R_{at}} + V_{al}$$

$$V_{a\_a}(i_a) = \begin{pmatrix} 16 \\ 13.6 \\ 11.2 \\ 8.8 \\ 6.4 \\ 4 \end{pmatrix} kV$$ compare --> $$V_a(i_a) = \begin{pmatrix} 16 \\ 13.6 \\ 11.2 \\ 8.8 \\ 6.4 \\ 4 \end{pmatrix} kV$$

$$\Delta V_a := V_a(1) - V_a(2) \qquad \Delta V_a = 2.4\,kV$$

$$\Delta V_{al} := V_{al} - V_a(1) \qquad \Delta V_{al} = 4\,kV$$ <-use 2 resistors for R_l

$$\Delta V_{ah} := V_a(n_{ta}) - V_{ah} \qquad \Delta V_{ah} = 4\,kV$$ <-use 2 resistors for R_h

We will need to use a network of resistors on each end to obtain the proper resistance values. These resistors will be mounted to the support panel.

Current: $$I_a := \frac{V_{ah} - V_{al}}{R_{at}} \qquad I_a = -0.024\,mA$$

Power: $$P_a := \frac{(V_{ah} - V_{al})^2}{R_{at}} \qquad P_a = 0.48\,W$$

Power per resistor

intertrace	low	high
$P_{ra} := I_a^{\,2} R_a$	$P_{ral} := I_a^{\,2} R_{al}$	$P_{rah} := I_a^{\,2} R_{ah}$
$P_{ra} = 0.058\,W$	$P_{ral} = 0.096\,W$	$P_{rah} = 0.096\,W$

Trace to trace gap:

$$z_{tt} = 0.07\,cm$$

Trace to trace voltage gradient

$$E_a := \frac{V_a(1) - V_a(2)}{z_{tt}} \qquad E_a = 34.286\,\frac{kV}{cm} \qquad E_a = 87.1\,\frac{kV}{in}$$

Mesh frame to trace distances:

$$g_{al} := 0.22cm \qquad g_{ah} := 0.22cm$$

Mesh frame to trace voltage gradients

$$E_{al} := \frac{V_{al} - V_a(1)}{g_{al}} \qquad E_{al} = 18.2\,\frac{kV}{cm}$$

$$E_{ah} := \frac{V_a(n_{ta}) - V_{ah}}{g_{ah}} \qquad E_{ah} = 18.2\,\frac{kV}{cm}$$

All gap gradients are lower than the standard design value multiplied by the pressure/gas ratio as calculated above:

$$E_{tr\_TPC} = 94.5\,\frac{kV}{cm}$$

Summary cathode drift anode

Trace to trace voltages:

$\Delta V_c = 2.28\,kV$ $\Delta V_d = 2.325\,kV$ $\Delta V_a = 2.4\,kV$

Intertrace resistance

$R_c = 100\,M\Omega$ $R_d = 100\,M\Omega$ $R_a = 100\,M\Omega$

Intertrace resistor power

$P_{rc} = 0.052\,W$ $P_{rd} = 0.054\,W$ $P_{ra} = 0.058\,W$

End Voltages

$\Delta V_{cl} = 4045\,V$ $\Delta V_{ch} = 1275\,V$ $\Delta V_{dl} = 3875\,V$ $\Delta V_{dh} = 3875\,V$ $\Delta V_{al} = 4000\,V$ $\Delta V_{ah} = 4000\,V$

End resistances

$R_{cl} = 177.4\,M\Omega$ $R_{ch} = 55.9\,M\Omega$ $R_{dl} = 166.7\,M\Omega$ $R_{dh} = 166.7\,M\Omega$ $R_{al} = 166.7\,M\Omega$ $R_{ah} = 166.7\,M\Omega$

End resistor voltage ratings

$V_{cerl} := 1.5kV$ $V_{cerh\_50} := 1.5kV$ $V_{da\_er\_100} := 2.5kV$ $V_{da\_er\_50} := 1.5kV$ $V_{da\_er\_15} := 1.5kV$

$V_{cerh\_6} := 250V$

use (180||180)+(180||180) use 50+6 |-------------------------use 100+50+15)--

Resistance totals

$R_{ct} = 0.833\,G\Omega$ $R_{dt} = 1.333\,G\Omega$ $R_{at} = 0.833\,G\Omega$

Power

$P_c = 0.433\,W$ $P_d = 0.721\,W$ $P_a = 0.48\,W$

Total power:

$$P_t := 6(P_c + P_d + P_a) \qquad P_t = 9.8\,W$$

Number of intertrace resistors:

$$N_{it} := 6\cdot(n_{tc} + n_{td} + n_{ta} - 3) \qquad N_{it} = 126$$

http://www.interfacebus.com/PWB_External_Trace_Capacity.html

Conductor Spacing per MIL-STD-275

Voltage Between Conductors	Minimum Trace Spacing	
DC or AC peak volts	Surface Layers	Internal Layers
0 - 100v	0.005"	0.004"
101 - 300v	0.015"	0.008"
301 - 500v	0.030"	0.010"

http://www.smpspowersupply.com/ipc2221pcbclearance.html

IPC-2221 is widely accepted throughout the world as a generic PCB design standard. The table below (which is not an official IPC table) is derived from "IPC 2221", Table 6-1, and provides recommended minimum spacing between conductors and component leads as a function of working voltage level and application. Note that IPC table gives the spacings up to 500V and provides formulas for the spacings above 500V. For your convenience, I added calculated spaces for voltages above 500V and added the columns with inches (IPC currently provides all distances only in metric units). For power conversion circuits **IPC-9592** provides the following circuit board spacing requirements: **SPACING (mm) = 0.6 + Vpeak x .005**. For products covered by UL safety standards the creepage and clearance requirements of the respective UL/IEC standard shall take precedence over IPC.
Note that all IPC standards are voluntarily rather than mandatory. For more information see the **Guide to PCB Spacing**.
This page is for a general reference only and does not constitute a professional or a legal advice. Consult with respective standards for final design decisions.

	Bare Board								Assembly					
	Internal layers		External conductors, uncoated		External conductors, uncoated, >3050 m		External conductors coated		External conductors with conformal coating		External component leads, uncoated		Component leads with conformal coating	
Vpk, V	mm	inch	mm	inch	mm	inch	mm	inch	mm	inch	mm	inch	mm	inch
15	0.05	0.002	0.1	0.004	0.1	0.004	0.05	0.002	0.13	0.006	0.13	0.006	0.13	0.006
30	0.05	0.002	0.1	0.004	0.1	0.004	0.05	0.002	0.13	0.006	0.25	0.01	0.13	0.006
50	0.1	0.004	0.6	0.024	0.6	0.024	0.13	0.006	0.13	0.006	0.4	0.016	0.13	0.006
100	0.1	0.004	0.6	0.024	1.5	0.06	0.13	0.006	0.13	0.006	0.5	0.02	0.13	0.006
150	0.2	0.008	0.6	0.024	3.2	0.13	0.4	0.016	0.4	0.016	0.8	0.032	0.4	0.016
170	0.2	0.008	1.25	0.05	3.2	0.13	0.4	0.016	0.4	0.016	0.8	0.032	0.4	0.016
250	0.2	0.008	1.25	0.05	6.4	0.26	0.4	0.016	0.4	0.016	0.8	0.032	0.4	0.016
300	0.2	0.008	1.25	0.05	12.5	0.5	0.4	0.016	0.4	0.016	0.8	0.032	0.8	0.032
500	0.25	0.01	2.5	0.1	12.5	0.5	0.8	0.032	0.8	0.032	1.5	0.06	0.8	0.032
1000	1.5	0.06	5	0.2	25	0.99	2.33	0.092	2.33	0.1	3.03	0.12	2.33	0.092
2000	4	0.158	10	0.4	50	1.97	5.38	0.22	5.38	0.22	6.08	0.24	5.38	0.22
3000	6.5	0.256	15	0.6	75	2.96	8.43	0.34	8.43	0.34	9.13	0.36	8.43	0.34
4000	9	0.355	20	0.79	100	3.94	11.48	0.46	11.48	0.46	12.18	0.48	11.48	0.46
5000	11.5	0.453	25	0.99	125	4.93	14.53	0.58	14.53	0.58	15.23	0.6	14.53	0.58