ρ = Density of air = 1.225 kg/m^3 at 25℃
V = volume of air inside main storage box = 0.381*0.381*0.381 m^3
= 0.0553 m^3
∴ m_{air} = 1.225*0.0553 = 0.0677 kg
$C_{(v)air}$ = 0.718 kJ/kg-k
$\Delta T = T_1 - T_2$
T_1= Temperature inside the main storage box = 70℃
T_2= Lowest atmospheric temperature = 18℃
∴ ΔT = 70 −18 = 52℃
∴ Q_{air} = 0.0677*0.718*10^3*52
= 2529.23 J

For Aluminum box

$Q_{Al} = m_{Al} C_{Al} \Delta T$
m_{Al}= mass of aluminum box = $\rho * V$
ρ = Density of aluminum = 2700 kg/m^3

Calculation of mass of aluminum box:

Iteration 1:

Assume thickness of aluminum sheet = 16 gauge
= 1.291 mm
= 0.001291 m
∴ Volume of aluminum box = 0.381*0.381*0.001291
= 1.8740*10^{-4} m^3
∴ m_{Al} = 2700*1.8740*10^{-4} = 0.5 kg
This is quite light.

Iteration 2:

Assume thickness of aluminum sheet = 14 gauge
= 1.628 mm
= 0.001628 m
∴ Volume of aluminum box = 0.381*0.381*0.001628
= 2.36*10^{-4} m^3
∴ m_{Al} = 2700*2.36*10^{-4} = 0.638 kg

This is suitable mass for aluminum box.
C_{Al} = 0.921 kJ/kg-k
$\Delta T = T_1 - T_2$
T_1= Temperature inside the main storage box = 70℃
T_2= Lowest atmospheric temperature = 18℃
∴ ΔT = 70 −18 = 52℃
∴ Q_{Al} = 0.638*0.921*10^3*52
= 30561.60 J

Total heat requirement:

Q_{total}= 2529.23 + 30561.60
= 33090.83 J
Time up to which we required Q_{total} amount of heat = 5 min
= 300 sec
∴ Power required = Q_{total} / time
= 33090.83 / 300
= 110.30 watts

Input power (source power):

P = V*I
V = Voltage of alternator = 14.4 v at full load condition
I = Current from alternator = 55 Amps (maximum capacity)
∴ P = 14.4*55
= 792 watts

Dimension calculation of heating coil:

Outer diameter of strip on which heating coil is wrapped
= 35.4 mm (assume)

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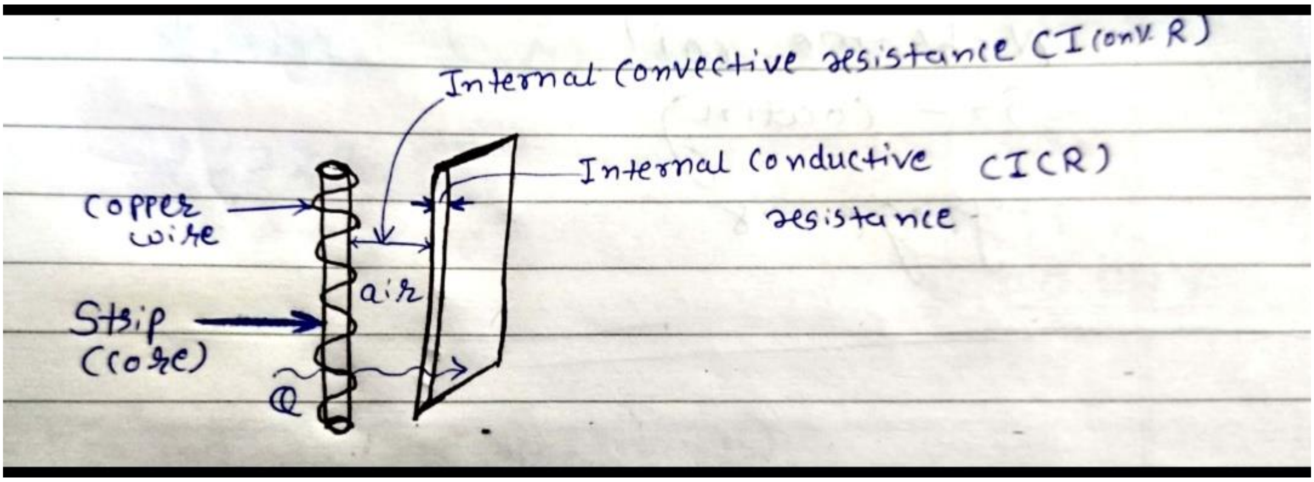
∴ Perimeter of the strip = π D
= 0.1112 m
Length of the coil / strip = (0.1112)*0.381 / d
Where, d = diameter of heating coil
We know that, P = I^2*R
110.3= 55^2*R
∴ R = 0.036 Ω
We know that,
$R = \frac{\rho l}{A}$
ρ = Resistivity of heating coil material

Iteration 1:
We take Nichrome as a heating coil material.
$\rho_{nichrome}$ = 1.1*10^{-6} Ω.m
∴ 0.036 = 6* $[\frac{1.1*10^{-6}}{\frac{\pi}{4}d^2} * (\frac{0.1112*0.381}{d})]$
∴ d = 21.46 mm
This is a very large diameter of heating coil which is not suitable.

Iteration 2:
Now, we take Copper as a heating coil material.
ρ_{copper} = 1.72*10^{-8} Ω.m
∴ 0.036 = 6* $[\frac{1.72*10^{-8}}{\frac{\pi}{4}d^2} * (\frac{0.1112*0.381}{d})]$
∴ d = 5.36 mm
This is quite suitable diameter as compared to nichrome diameter.
∴ d = 5.36 mm = 4 gauge
So, length of wire / strip = (0.1112)*0.381 / 5.36*10^{-3}
= 7.9 m
L_{total} = 6*7.9 m = 47.42 m

Temperature generated on the strip:
$Q_{required} = m_{cu}C_{cu}\Delta T$
$Q_{required}$ = 33090.83 J
C_{copper} = 0.385 kJ/kg-°C
m_{copper}= mass of copper wire = $\rho * V$
ρ = Density of copper wire = 8960 kg/m^3
V = volume of copper wire = $\frac{\pi}{4}d^2 * l = \frac{\pi}{4}0.00536^2 * 7.9$
= 1.78*10^{-4} m^3
∴ m_{copper} = 8960*1.78*10^{-4} = 1.6 kg
∴ 33090.83 = 1.6*385*($T_1 - 25$)
T_1= Temperature generated on the strip
25°C = Surrounding temperature
∴ T_1= 78.7°C ≈ 80°C

Heat loss calculations:

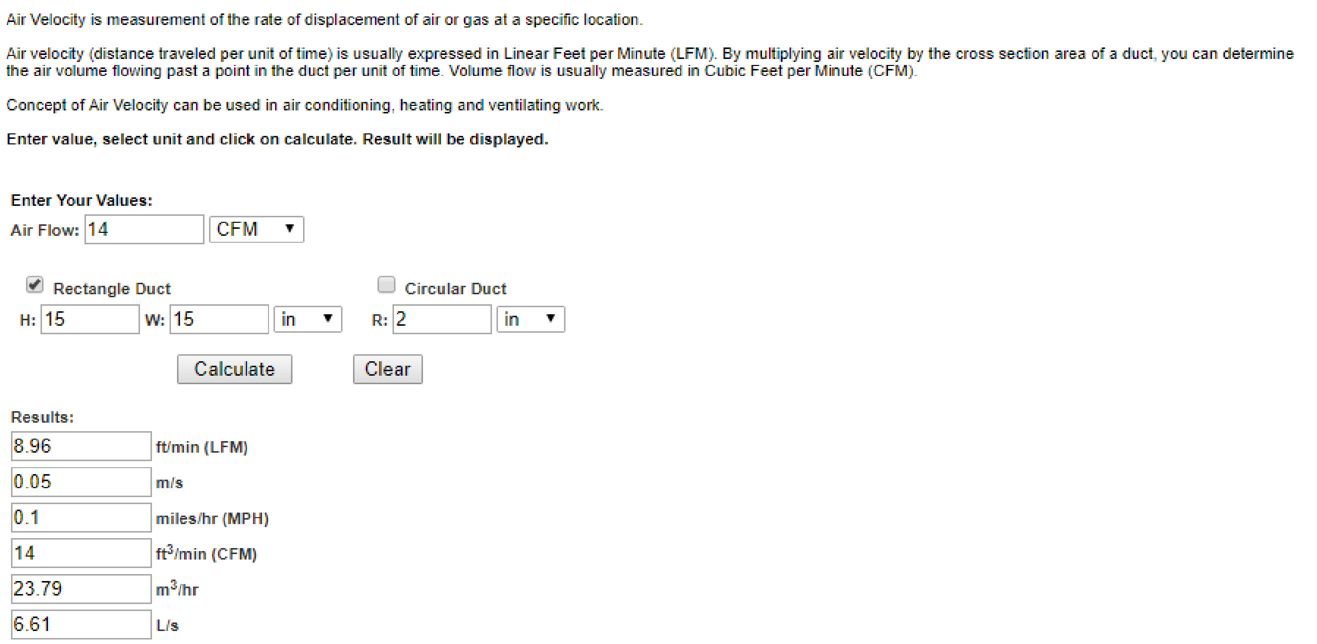


Internal convective resistance = $\frac{1}{hA}$

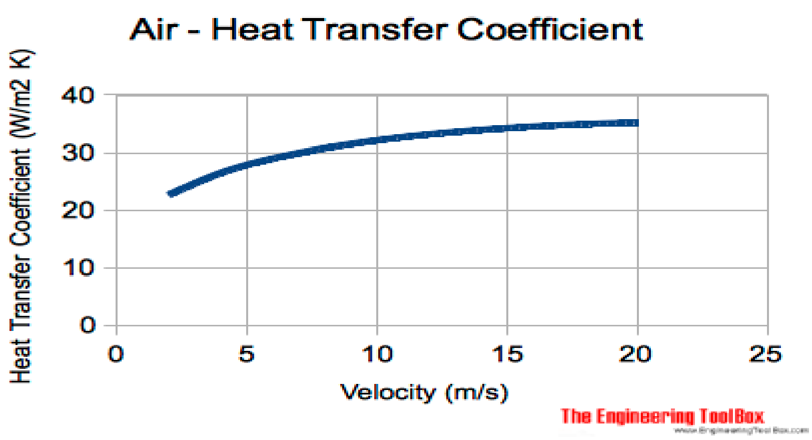
Calculation of h (heat transfer coefficient):

Fan given below is used for proper circulation of hot air inside heating box so that it can be kept warm uniformly leading to increased efficiency of heating box.

Specification of fan:
Length: 40mm
Width: 40mm
Thickness: 15mm
Voltage: 12V
Current: 0.9Amps
RPM: 12000
Air flow: 14 CFM (Cubic feet per minute)



Conversion of CFM: Image given above shows conversion of unit of air flow from CFM to m/s using online convertor [3].
From above figure,
14 CFM = 0.05 m/s (air velocity)



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Graph of h vs. air velocity

From graph it is clear that value of h for air = 22 W/m^2-k

Internal convective resistance = $\frac{1}{22*(0.381*0.381)}$

= 0.313 k/W

Internal conductive resistance in aluminium sheet

$= \frac{thickness\ of\ sheet}{kA}$

Thickness of sheet = 0.001628 m

k = 235 W/m-k

∴ Internal conductive resistance in aluminium sheet

$= \frac{0.001628}{235*(0.381*0.381)}$

= $4.77*10^{-5}$ k/W (Negligible)

Total resistance = 0.313 k/W

Power loss ($\dot{Q}$) = $\frac{T_1-T_2}{R_{total}}$

∴ $\dot{Q} = \frac{80-70}{0.313*6}$

= 5.32 watts

∴ POWER LOSS = 5.32 W

6.CONCLUSION:

After shortlisting certain materials for heating box and coil, calculations were carried out to finalize the materials for same along with them calculations for temperature generated on strip using this material, for power loss in conduction ,convection and radiation were also done and here is a summary of all the calculations:

Considering extreme conditions of achieving 52 degree celsius temperature difference,under which this system might have to operate, using aluminium box of 14 guage thickness is preferable with heating coil having copper as a material. Resistivity of copper is perfectly suitable for this system as diameter calculated based on it satisfies space criterion of this system. Applying all these specifications, temperature generated on strip comes out to be approximately around 80 degree celsius along with power loss of 5.32 watt which is viable for industry requirements.

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