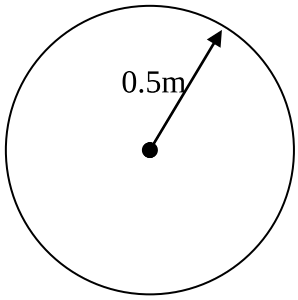
Calculating the Cost of Steam Leaks

I am currently working for EDF Energy at Torness Power Station, at power stations steam leaks can be a big problem, they negatively affect efficiency and can be very expensive.
I work within the Operations department where we track station efficiency; we use this calculation to find the cost of steam leaks, as it is important to be able to quantify losses.

This is an example of the calculation:

Firstly the mass of the steam being produced each second must be worked out.

Starting with the cross section area of the stack:



Stack Cross Section

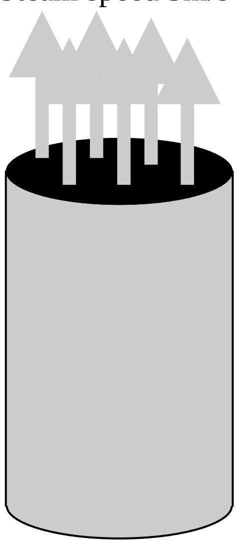
$A=\pi r^2$

A=? (Area)
$\pi = \pi$
r = 0.5m

$A= \pi \times 0.5^2$
$A= \frac{1}{4} \pi \text{ m}^2$

Next the flow rate through the stack has to be established:

Steam speed 3m/s



Stack Diagram

Q=vA

Q=? (Volumetric flow rate)
v = 3m/s
$A= \frac{1}{4}\pi \text{ m}^2$

$Q=3 \times \frac{1}{4}\pi$
$Q=\frac{3}{4}\pi \text{ m}^3/\text{s}$

Then the volumetric flow rate has to be converted into a mass flow rate:

$m = \rho Q$

m=? (mass flow rate)
$\rho = 0.590 \text{ kg/m}^3$
$Q = \frac{3}{4}\pi \text{ m}^3/\text{s}$

$m=0.590 \times \frac{3}{4}\pi$
$m=177/400\pi = 1.39014759 \text{ kg/s}$

Now that the mass flow rate has been established the next part of the equation can be undertaken.

The next part of the calculation is to find the energy used to heat up the water.

The water has been heated from 20°C to 500°C
Because the water changes state there are three parts to the energy calculation.

The first part of the calculation is to work out the energy to take the water to 100 °C:

<u>**Q_1=cmΔT**</u>

Q_1=? (heat)
c = 4.186 kJ/kg
m = 177/400π kg/s
ΔT = 80 °C

Q_1=4.186 x 177/400π x 80
Q_1=465.5350224 kJ/s

An example of a steam leak

The next part of the calculation is to work out the latent heat of evaporation:

<u>**Q_2=mL_v**</u>

Q_2=? (heat)
m = 177/400π kg/s
L_v = 2257 kJ/kg

Q_2=177/400π x 2257
Q_2=3137.579269 kJ

The third part of the calculation is to work out the energy taken in by the steam to reach 500°C:

<u>**Q_3=cmΔT**</u>

Q_3=? (heat)
c = 2.0267 kJ/kg
m = 177/400π kg/s
ΔT = 400 °C

Q_3=2.0267 x 177/400π x 400
Q_3=1126.970652 kJ

Then all the calculated heat energy must be added together to produce the total heat energy used:

<u>**Q_1+Q_2+Q_3=Q_T**</u>

465.5350224 + 3137.579269 + 1126.970652 = 4730.084943 kJ/s

Q_T must then be converted into kW so that the cost of the leak can be calculated

1 kJ/s = 1 kW
4730.084943 kJ/s = 4730.084943 kW

If the price of electricity is 0.5p per kWh then this leak costs:

4730.084943 kW x 0.5p = £23.65/hour
(= £567.60/day = £3,973.20/week = £206,606.40/year)

Once this calculation has been done we are then able to raise the importance of the leak to get it fixed to stop the losses and improve the efficiency of the power station. In the case of this example the station would be losing £206,606.40 per year due to the steam leak.