# Engineering Methods of Reducing Hazard Risk

- Specifying Current Limiting Fuses on Low Voltage Switchgear Breakers
- IR detectors / IOC relays / Pressure relays in switchgear
- Dual Setting relays
- Specifying ARC Resistant Switchgear
- Remote Control of Switchgear Breakers
- Remote Racking of Switchgear Breakers
- High Resistance Grounding on Low Voltage and Medium Voltage (15kV and below) Systems
- Others???





# Common Electrical Task


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## Safer Engineering Design


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## Flash Boundary

$$D_c = \left[2.65 \times MVA_{bf} \times t\right]^{1/2}$$

***$D_c$ = 2nd degree burn distance***
***$MVA_{bf}$ = bolted fault at point of arc***
***t = clearing time***

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## Flash Boundary

$$D_c = \left[53 \times MVA \times t\right]^{1/2}$$

***$D_c$ = 2nd degree burn distance (ft)***
***MVA = Transformer MVA rating***
***t = clearing time (sec)***
***(alternate formula )***
***Dc = [2.65 * MVAbf * t]^0.5***
***MVAbf = bolted fault MVA at point of fault.***

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## Personal Protective Equipment

- PPE for Shock Protection
- PPE for Thermal Protection from Arc

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## PPE

- PPE shall be provided and used
- Shall be inspected prior to each use

*Art Wise in protective clothing and gear as he inserts a starter bucket into a Motor Control Center.*



## Hazard Risk Category Table 130.7(C)(9)(a)

Table 130.7(C)(9)(a) Hazard/Risk Category Classifications

| Task (Assumes Equipment Is Energized, and Work Is Done Within the Flash Protection Boundary) | Hazard/ Risk Category | V-rated Gloves | V-rated Tools |
|---|---|---|---|
| **Panelboards Rated 240 V and Below — Notes 1 and 3** | | | |
| Circuit breaker (CB) or fused switch operation with covers on | 0 | N | N |
| CB or fused switch operation with covers off | 0 | N | N |
| Work on energized parts, including voltage testing | 1 | Y | Y |
| Remove/install CBs or fused switches | 1 | Y | Y |
| Removal of bolted covers (to expose bare, energized parts) | 1 | N | N |
| Opening hinged covers (to expose bare, energized parts) | 0 | N | N |



## Table Notes

- 1. Maximum of 25 kA short circuit current available, 0.03 second (2 cycle) fault clearing time.
- 2. Maximum of 65 kA short circuit current available, 0.03 second (2 cycle) fault clearing time.
- 4. Maximum of 42 kA short circuit current available, 0.33 second (20 cycle) fault clearing time.
- 5. Maximum of 35 kA short circuit current available, 0.5 second (30 cycle) fault clearing time.

## Ancillary Protective Equipment

- Tools
- Temporary grounds
- Rubber insulating equipment
- Barriers
- Inspection and maintenance

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## PPE matrix

Table 130.7(C)(10) Protective Clothing and Personal Protective Equipment (PPE) Matrix

| Protective Clothing and Equipment | Protective Systems for Hazard/Risk Category | | | | | |
|---|---|---|---|---|---|---|
| Hazard/Risk Category Number | −1 (Note 3) | 0 | 1 | 2 | 3 | 4 |
| **Non-melting (according to ASTM F 1506-00) or Untreated Natural Fiber** | | | | | | |
| a. T-shirt (short-sleeve) | X | | | X | X | X |
| b. Shirt (long-sleeve) | | X | | | | |
| c. Pants (long) | X | X | X (Note 4) | X (Note 6) | X | X |
| **FR Clothing (Note 1)** | | | | | | |
| a. Long-sleeve shirt | | | X | X | X (Note 9) | X |
| b. Pants | | | X (Note 4) | X (Note 6) | X (Note 9) | X |
| c. Coverall | | | (Note 5) | (Note 7) | X (Note 9) | (Note 5) |
| d. Jacket, parka, or rainwear | | | AN | AN | AN | AN |
| **FR Protective Equipment** | | | | | | |
| a. Flash suit jacket (multilayer) | | | | | | X |
| b. Flash suit pants (multilayer) | | | | | | X |
| c. Head protection | | | | | | |
| 1. Hard hat | | | X | X | X | X |
| 2. FR hard hat liner | | | | | AR | AR |
| d. Eye protection | | — | — | — | — | — |
| 1. Safety glasses | X | X | X | AL | AL | AL |
| 2. Safety goggles | | | | AL | AL | AL |
| e. Face and head area protection | | — | — | — | — | — |
| 1. Arc-rated face shield, or flash suit hood | | | | X (Note 8) | | |
| 2. Flash suit hood | | | | | X | X |
| 3. Hearing protection (ear canal inserts) | | | | X (Note 8) | X | X |
| f. Hand protection | | | — | — | — | — |
| Leather gloves (Note 2) | | | AN | X | X | X |
| g. Foot protection | | | | | | |
| Leather work shoes | | | AN | X | X | X |

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## Protective Clothing Characteristics

| Hazard risk category | Description | Min arc rating Cal/sqcm |
|---|---|---|
| 0 | Non-melting flammable | N/A |
| 1 | FR shirt/pant or FR coverall | 4 |
| 2 | Cotton underwear + FR shirt/pant | 8 |
| 3 | Cotton underwear + FR shirt & pants + FR coveralls | 25 |
| 4 | Cotton underwear + FR shirt & pants + FR coverall | 40 |

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## PPE examples

- *Troubleshooting live equipment, such as testing a contactor (left), requires hazard/risk level 2 PPE, suitable for protection from an arc flash of 8 cal/cm$^2$, but racking of a circuit breaker (right) demands hazard/risk level 3 PPE, suitable for protection from an arc flash of 25 cal/cm$^2$.*



## Alerting Techniques

- Safety signs and tags
- Barricades outside Limited Approach Boundary
  - How about if arc boundary > limited approach boundary?
- Attendants



## Electrical Safety – Safe work practices

***~~Video~~***

## Powerplant Engineering Session 2

Download Steam table &/or software
Homework review – Question two out
How was homework easy or hard?
Syllabus Update – No session next week
Tour Optional
Homework 2 guidance
- Nuclear SG = Saturated Steam
- If substance subcooled, used T-s plot or software, table will not work
Questions?



## Steam Fundamentals

Temperature – Average Molecular KE
Steam cycle (Thermodynamics)
Temperature (hot to cold)

$T_R = T_F + 460$

$T_K = T_C + 273$

Use R (or K) for engineering calculations



## Steam Fundamentals

Pressure – force per unit area
Pisa – Psig – "hg

| % | Torr | | psia, | Inches | Inches | kPa |
|---|---|---|---|---|---|---|
| Vacuum | (mm Mercury) | | ($lb/in^2$) | Mercury | Mercury | abs |
| | | Micron | abs | Absolute | Gauge | |
| 0 | 760 | 760,000 | 14.7 | 29.92 | 0 | 101.4 |
| 1.3 | 750 | 750,000 | 15.5 | 29.5 | 0.42 | 99.9 |
| 1.9 | 735.6 | 735,600 | 14.2 | 28.9 | 1.02 | 97.7 |
| 7.9 | 700 | 700,000 | 13.5 | 27.6 | 2.32 | 93.5 |
| 21 | 600 | 600,000 | 11.6 | 23.6 | 6.32 | 79.9 |
| 34 | 500 | 500,000 | 9.7 | 19.7 | 10.22 | 66.7 |
| 47 | 400 | 400,000 | 7.7 | 15.7 | 14.22 | 53.2 |
| 50 | 380 | 380,000 | 7.3 | 15 | 14.92 | 50.8 |
| 61 | 300 | 300,000 | 5.8 | 11.8 | 18.12 | 40 |
| 74 | 200 | 200,000 | 3.9 | 7.85 | 22.07 | 26.6 |
| 87 | 100 | 100,000 | 1.93 | 3.94 | 25.98 | 13.3 |
| 89.5 | 80 | 80,000 | 1.55 | 3.15 | 26.77 | 10.7 |
| 93 | 51.7 | 51,700 | 1 | 2.03 | 27.89 | 6.9 |
| 96.1 | 30 | 30,000 | 0.58 | 1.18 | 28.74 | 4 |
| 97.4 | 20 | 20,000 | 0.39 | 0.785 | 29.14 | 2.7 |
| 98.7 | 10 | 10,000 | 0.193 | 0.394 | 29.53 | 1.3 |
| 99 | 7.6 | 7,600 | 0.147 | 0.299 | 29.62 | 1 |
| 100 | 0 | 0 | 0 | 0 | 29.92 | 0 |



## Steam Fundamentals

**Density – mass per unit volume ($Lbm/ft^3$)**
**Specific Volume is 1/D**

**Specific Heat – Heat transferred / temperature change (per unit mass)**



## Steam Fundamentals

**Sensible Heat – Heat added (or removed) that changes temperature**

**Latent Heat – Heat added (or removed) that changes phase**

## Steam Fundamentals

**Three modes of heat transfer –**
**Conduction**
**Convection**
**Radiation**

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## Steam Fundamentals

Conduction is the transfer of energy through matter from particle to particle. It is the transfer and distribution of heat energy from atom to atom within a substance. Conduction is most effective in solids-but it can happen in fluids.

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## Steam Fundamentals

Convection is the transfer of heat by the actual movement of the warmed matter. Convection is the transfer of heat energy in a gas or liquid by movement of currents. (It can also happen is some solids.) The heat moves with the fluid.

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## Steam Fundamentals

Radiation: Electromagnetic waves that directly transport ENERGY through space (no medium needed for heat transfer).



## Steam Fundamentals

**Enthalpy – total useful energy in substance (BTU/lbm)**

**Includes internal & flow energy**

$h = (u + p*v)/J$

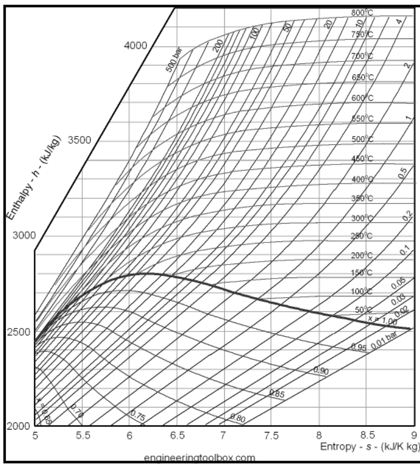
**Entropy – energy not available for work (BTU/lbm*R)**



## Steam Fundamentals

**States – solid – liquid – gas**

**Value of h defined by properties of material.**




**Mollier Diagram**

**Blue = Pressure**

**Green = Temperature**

**Red = Quality**

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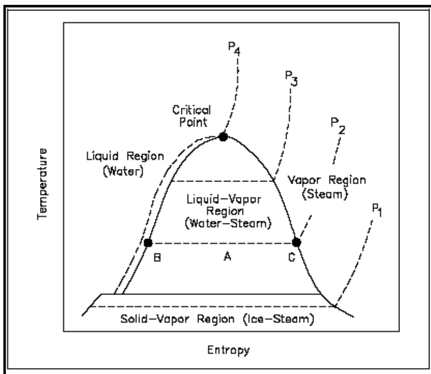


Figure 13 T-s Diagram for Water

**T-S Diagram**

**Lines of constant P**

**4 regions**

**B = 0% quality**

**A = 50% quality**

**C = 100% quality**

**Critical point**

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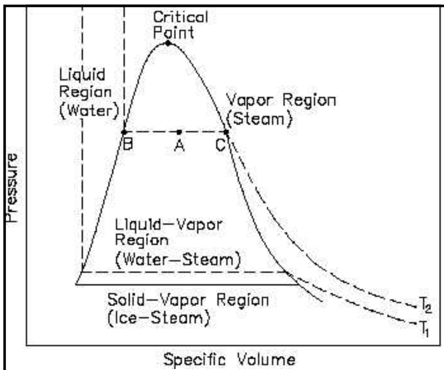


**P-v Diagram**

**Lines of constant T**

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## Steam Fundamentals

**Steam Tables – Download Available at**
**Class website**
**thomasblairpe.com/ppe.html**

**Steam Property Software – Link to software available at class website**
**Thomasblairpe.com/ppe.html**



## Steam Fundamentals

**Steam Tables – Saturated & Superheated Steam sections**

**First for Saturated section – How to use:**



**Table 1. Saturated Steam: Temperature Table**

| Temp Fahr t | Abs Press. Lb per Sq In. p | Specific Volume Sat. Liquid $v_f$ | Evap $v_{fg}$ | Sat. Vapor $v_g$ |
|---|---|---|---|---|
| 32.0* | 0.08859 | 0.016022 | 3304.7 | 3304.7 |
| 34.0 | 0.09600 | 0.016021 | 3061.9 | 3061.9 |
| 36.0 | 0.10395 | 0.016020 | 2839.0 | 2839.0 |
| 38.0 | 0.11249 | 0.016019 | 2634.1 | 2634.2 |

**Temperature (°F)**
**Abs Press (psia)**
**Vf = 0% quality Specific Volume**
**Vg = 100% quality Specific Volume**
**Vfg = Specific Volume difference between Vg and Vf**

**Table 1. Saturated Steam: Temperature Table**

| Enthalpy Sat. Liquid $h_f$ | Enthalpy Evap $h_{fg}$ | Enthalpy Sat. Vapor $h_g$ | Entropy Sat. Liquid $s_f$ | Entropy Evap $s_{fg}$ | Entropy Sat. Vapor $s_g$ | Temp Fahr t |
|---|---|---|---|---|---|---|
| −0.0179 | 1075.5 | 1075.5 | 0.0000 | 2.1873 | 2.1873 | 32.0 * |
| 1.996 | 1074.4 | 1076.4 | 0.0041 | 2.1762 | 2.1802 | 34.0 |
| 4.008 | 1073.2 | 1077.2 | 0.0081 | 2.1651 | 2.1732 | 36.0 |
| 6.018 | 1072.1 | 1078.1 | 0.0122 | 2.1541 | 2.1663 | 38.0 |

**Entropy (BTU/(lbm * $^{O}$F)**
**sf = 0% quality Enthalpy**
**sg = 100% quality Enthalpy**
**sfg = Enthalpy difference between sg and sf**



**Table 1. Saturated Steam: Temperature Table**

| Enthalpy Sat. Liquid $h_f$ | Enthalpy Evap $h_{fg}$ | Enthalpy Sat. Vapor $h_g$ | Entropy Sat. Liquid $s_f$ | Entropy Evap $s_{fg}$ | Entropy Sat. Vapor $s_g$ | Temp Fahr t |
|---|---|---|---|---|---|---|
| −0.0179 | 1075.5 | 1075.5 | 0.0000 | 2.1873 | 2.1873 | 32.0 * |
| 1.996 | 1074.4 | 1076.4 | 0.0041 | 2.1762 | 2.1802 | 34.0 |
| 4.008 | 1073.2 | 1077.2 | 0.0081 | 2.1651 | 2.1732 | 36.0 |
| 6.018 | 1072.1 | 1078.1 | 0.0122 | 2.1541 | 2.1663 | 38.0 |

**Enthalpy (BTU/lbm)**
**hf = 0% quality Enthalpy**
**hg = 100% quality Enthalpy**
**hfg = Enthalpy difference between hg and hf**

**This is used to determine available energy in fluid**



**Table 1. Saturated Steam: Temperature Table**

| Enthalpy Sat. Liquid $h_f$ | Enthalpy Evap $h_{fg}$ | Enthalpy Sat. Vapor $h_g$ | Entropy Sat. Liquid $s_f$ | Entropy Evap $s_{fg}$ | Entropy Sat. Vapor $s_g$ | Temp Fahr t |
|---|---|---|---|---|---|---|
| −0.0179 | 1075.5 | 1075.5 | 0.0000 | 2.1873 | 2.1873 | 32.0 * |
| 1.996 | 1074.4 | 1076.4 | 0.0041 | 2.1762 | 2.1802 | 34.0 |
| 4.008 | 1073.2 | 1077.2 | 0.0081 | 2.1651 | 2.1732 | 36.0 |
| 6.018 | 1072.1 | 1078.1 | 0.0122 | 2.1541 | 2.1663 | 38.0 |

**Enthalpy (BTU/lbm) for percent quality is:**

**H = hf + hfg * (%Quality/100%)**

**Table 1. Saturated Steam: Temperature Table**

| Enthalpy |  |  | Entropy |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Sat. Liquid $h_f$ | Evap $h_{fg}$ | Sat. Vapor $h_g$ | Sat. Liquid $s_f$ | Evap $s_{fg}$ | Sat. Vapor $s_g$ | Temp Fahr t |
| -0.0179 | 1075.5 | 1075.5 | 0.0000 | 2.1873 | 2.1873 | **32.0** * |
| 1.996 | 1074.4 | 1076.4 | 0.0041 | 2.1762 | 2.1802 | **34.0** |
| 4.008 | 1073.2 | 1077.2 | 0.0081 | 2.1651 | 2.1732 | **36.0** |
| 6.018 | 1072.1 | 1078.1 | 0.0122 | 2.1541 | 2.1663 | **38.0** |

**Example above, for fluid at 38 $^{O}$F,**
**hf = 6.018 (BTU/lbm)**
**hg =** 1072.1 (BTU/lbm)
**h(50% Quality) =**
**6.018 +** 1072.1 * (50/100) =
542 (BTU/lbm)



## Steam Fundamentals

Example 1: For **saturated** water at temperature of (212 $^{O}$F);

A. What is the enthalpy for a sample with 0% steam quality?

**B. What is enthalpy for sample with 100% steam quality?**

**C. What is enthalpy for sample with 50% steam quality?**

**D. What is pressure for above?**



|  |  | Enthalpy |  |  |
| --- | --- | --- | --- | --- |
| Temp Fahr t | Abs Press. Lb per Sq In. p | Sat. Liquid $h_f$ | Evap $h_{fg}$ | Sat. Vapor $h_g$ |
| **180.0** | 7.5110 | 148.00 | 990.2 | 1138.2 |
| **182.0** | 7.850 | 150.01 | 989.0 | 1139.0 |
| **184.0** | 8.203 | 152.01 | 987.8 | 1139.8 |
| **186.0** | 8.568 | 154.02 | 986.5 | 1140.5 |
| **188.0** | 8.947 | 156.03 | 985.3 | 1141.3 |
| **190.0** | 9.340 | 158.04 | 984.1 | 1142.1 |
| **192.0** | 9.747 | 160.05 | 982.8 | 1142.9 |
| **194.0** | 10.168 | 162.05 | 981.6 | 1143.7 |
| **196.0** | 10.605 | 164.06 | 980.4 | 1144.4 |
| **198.0** | 11.058 | 166.08 | 979.1 | 1145.2 |
| **200.0** | 11.526 | 168.09 | 977.9 | 1146.0 |
| **204.0** | 12.512 | 172.11 | 975.4 | 1147.5 |
| **208.0** | 13.568 | 176.14 | 972.8 | 1149.0 |
| **212.0** | 14.696 | 180.17 | 970.3 | 1150.5 |
| **216.0** | 15.901 | 184.20 | 967.8 | 1152.0 |

## Steam Fundamentals

Answer:

A. From table, hf = 180.7 (BTU/lbm)
**B. From table, hg = 1150.5**
**C. Using equation;**

**h(50%) = 180.17 + 970.3 * (50/100) = 665 (BTU/lbm)**

**D. Pressure is Psat = 14.7 psia**



## Steam Fundamentals

**Saturated steam also given with pressure instead of temperature SAME INFO**

| Abs Press. Lb/Sq In. p | Temp Fahr t | Specific Volume Sat. Liquid $v_f$ | Evap $v_{fg}$ | Sat. Vapor $v_g$ |
|---|---|---|---|---|
| 0.08865 | 32.018 | 0.016022 | 3302.4 | 3302.4 |
| 0.25 | 59.323 | 0.016032 | 1235.5 | 1235.5 |
| 0.50 | 79.586 | 0.016071 | 641.5 | 641.5 |
| 1.0 | 101.74 | 0.016136 | 333.59 | 333.60 |
| 5.0 | 162.24 | 0.016407 | 73.515 | 73.532 |
| 10.0 | 193.21 | 0.016592 | 38.404 | 38.420 |
| 14.696 | 212.00 | 0.016719 | 26.782 | 26.799 |
| 15.0 | 213.03 | 0.016726 | 26.274 | 26.290 |



## Steam Fundamentals

**Steam Tables – Superheated Steam sections - How to use:**

**Table 3. Superheated Steam**

| Abs Press. Lb/Sq In. (Sat. Temp) | | Sat. Water | Sat. Steam | Temperature — Degrees Fahrenheit 200 | 250 | 300 | 350 | 400 |
|---|---|---|---|---|---|---|---|---|
| 1 (101.74) | Sh | | | 98.26 | 148.26 | 198.26 | 248.26 | 298.26 |
| | v | 0.01614 | 333.6 | 392.5 | 422.4 | 452.3 | 482.1 | 511.9 |
| | h | 69.73 | 1105.8 | 1150.2 | 1172.9 | 1195.7 | 1218.7 | 1241.8 |
| | s | 0.1326 | 1.9781 | 2.0509 | 2.0841 | 2.1152 | 2.1445 | 2.1722 |

Abs Press (psia) / Tsat also
Sh = Superheat, F
v = Specific Volume, ($F^3$/lbm)
h = enthalpy, (BTU/lbm)
s = entropy, (BTU/(lbm * F)



**Table 3. Superheated Steam**

| Abs Press. Lb/Sq In. (Sat. Temp) | | Sat. Water | Sat. Steam | Temperature — Degrees Fahrenheit 200 | 250 | 300 | 350 | 400 |
|---|---|---|---|---|---|---|---|---|
| 1 (101.74) | Sh | | | 98.26 | 148.26 | 198.26 | 248.26 | 298.26 |
| | v | 0.01614 | 333.6 | 392.5 | 422.4 | 452.3 | 482.1 | 511.9 |
| | h | 69.73 | 1105.8 | 1150.2 | 1172.9 | 1195.7 | 1218.7 | 1241.8 |
| | s | 0.1326 | 1.9781 | 2.0509 | 2.0841 | 2.1152 | 2.1445 | 2.1722 |

Sh, v, h, and s values given for
- saturation conditions
- various higher temps



## Steam Fundamentals

Example 2: For **superheated steam** at 400 $^{O}$F at atmospheric pressure (14.7 psia);

A. What is the enthalpy?
**B. What is amount of "Superheat"**

**Table 3. Superheated Steam**

| Abs Press. Lb/Sq In. (Sat. Temp) | | Sat. Water | Sat. Steam | 200 | 250 | 300 | 350 | 400 |
|---|---|---|---|---|---|---|---|---|
| | Sh | | | | 38.00 | 88.00 | 138.00 | 188.00 |
| **14.696** | v | .0167 | 26.799 | | 28.42 | 30.52 | 32.60 | 34.67 |
| (212.00) | h | 180.17 | 1150.5 | | 1168.8 | 1192.6 | 1216.3 | 1239.9 |
| | s | .3121 | 1.7568 | | 1.7833 | 1.8158 | 1.8459 | 1.8743 |

A.Enthalpy is 1239.9 (BTU/lbm)

**B.Amount of "super heat" is 188 $^{O}$F**
**(note: this is given in table, but also can**
**Calculate as 400 $^{O}$F – 212 $^{O}$F)**



## Steam Fundamentals

Example 3: For **superheated steam** at 350 $^{O}$F at atmospheric pressure (14.7 psia);

A. What amount of energy is required to raise 2 lbm of steam from 350 $^{O}$F to 400 $^{O}$F?

**B. What is change in volume of that 2 lbm sample when it changes from 350 $^{O}$F to 400 $^{O}$F?**



**Table 3. Superheated Steam**

| Abs Press. Lb/Sq In. (Sat. Temp) | | Sat. Water | Sat. Steam | 200 | 250 | 300 | 350 | 400 |
|---|---|---|---|---|---|---|---|---|
| | Sh | | | | 38.00 | 88.00 | 138.00 | 188.00 |
| **14.696** | v | .0167 | 26.799 | | 28.42 | 30.52 | 32.60 | 34.67 |
| (212.00) | h | 180.17 | 1150.5 | | 1168.8 | 1192.6 | 1216.3 | 1239.9 |
| | s | .3121 | 1.7568 | | 1.7833 | 1.8158 | 1.8459 | 1.8743 |

A.Energy = h * m

**= (1239.9 – 1216.3)(BTU/lbm) * 2(lbm)**
**= 47.2 BTU**
**B. (34.67 – 32.5)(F$^3$/lbm) * 2(lbm)**
**= 4.34 F$^3$**

## Steam Fundamentals

Why Enthalpy is important value!!!

Example 4: For **superheated steam** at 400 $^{O}$F at atmospheric pressure (14.7 psia) that is flowing into a turbine at a rate of 100,000 lbs/hr

A. What is the ideal rate of energy delivery (POWER) into the turbine (excluding energy of exhaust)?

Energy/Time = Power = h * flow rate



**Table 3. Superheated Steam**

| Abs Press. Lb/Sq In. (Sat. Temp) | | Sat. Water | Sat. Steam | Temperature – Degrees Fahrenheit 200 | 250 | 300 | 350 | 400 |
|---|---|---|---|---|---|---|---|---|
| 14.696 (212.00) | Sh | | | | 38.00 | 88.00 | 138.00 | 188.00 |
| | v | .0167 | 26.799 | | 28.42 | 30.52 | 32.60 | 34.67 |
| | h | 180.17 | 1150.5 | | 1168.8 | 1192.6 | 1216.3 | 1239.9 |
| | s | .3121 | 1.7568 | | 1.7833 | 1.8158 | 1.8459 | 1.8743 |

A.Power = h * (m/t)

**= (1239.9)(BTU/lbm) * 100,000(lbm/hr)**

**= 123.99 MBTU/hr**



## Steam Fundamentals

Why Enthalpy is important value!!!

Example 5: For the system described in example 4, if the turbine exhaust steam is at 1 psia, saturated steam conditions, steam quality of 90%, what is net power delivered to the turbine by the steam?

From example 4, enthalpy into turbine was (1239.9)(BTU/lbm)

| Abs Press. Lb/Sq In. p | Temp Fahr t | Sat. Liquid $h_f$ | Enthalpy Evap $h_{fg}$ | Sat. Vapor $h_g$ |
|---|---|---|---|---|
| **0.08865** | 32.018 | 0.0003 | 1075.5 | 1075.5 |
| **0.25** | 59.323 | 27.382 | 1060.1 | 1087.4 |
| **0.50** | 79.586 | 47.623 | 1048.6 | 1096.3 |
| **1.0** | 101.74 | 69.73 | 1036.1 | 1105.8 |
| **5.0** | 162.24 | 130.20 | 1000.9 | 1131.1 |
| **10.0** | 193.21 | 161.26 | 982.1 | 1143.3 |
| **14.696** | 212.00 | 180.17 | 970.3 | 1150.5 |
| **15.0** | 213.03 | 181.21 | 969.7 | 1150.9 |

A. hf = 69.73 & hfg = 1036.1

**h = hf + hfg * (%quality/100%)**

**= 69.73 + 1036.1 * (90/100)**

**= 1002.22 (BTU/lbm) = enthalpy out of turb.**



## Steam Fundamentals

Net enthalpy drop is 1239.9 – 1002.22

= 237.68 (BTU/lbm)

**Given that mass flow is 100,000 lbm/hr**

**Net power delivered to turbine is**

**237.68 BTU/lbm * 100,000 lbm/hr =**

**23.768 MBTU/hr**



## Steam Fundamentals

If we define efficiency (ignoring pump work) as;

P(turb)out / P(turb)in * 100%, efficiency of this turbine is;

(23.768/123.99) * 100% =

**19.2% efficient**

**Perhaps this is why we do not run turbines at atmospheric pressure ☺**

## Steam Fundamentals

Previous steam fundamentals critical to understand –

**Lets practice using steam tables now.**

PPE Lecture 2 Tom Blair, P.E. 58

## Steam Fundamentals

Ideal Gas Law – approximation for steam

PV = nRT or

PV/T = constant

Therefore

$P_1V_1/T_1 = P_2V_2/T_2$

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## Steam Fundamentals

Ideal Gas Law Continued – PV/T = const

With V constant, if you raise T, you raise P.

With P constant, if you raise T, you raise V.

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Steam Powerplants

Questions?

See you in two weeks!