

BEYOND

SMART CITIES

CERTIFIED INDUSTRIAL ENERGY PROFESSIONAL

CIEP TRAINING PROGRAM

FOR INDUSTRIAL ENERGY SPECIALISTS

KRISHNAJI PAWAR, LEED AP BD+C, GSAS CGP, ISO 14001:2015, GCP

ENERGY SPECIALIST CURRICULUM

CERTIFIED INDUSTRIAL ENERGY SPECIALIST

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INDUSTRIAL SYSTEMS - PUMP SYSTEMS - 1

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WHAT SHOULD YOU LEARN

Savings Estimates for Pumps, Compressed Air Systems and Waste Heat Recovery

Pumps: Pump Curves and System Optimization Approaches

Identifying Energy Waste Streams within Industrial Facilities

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## INTRODUCTION

Pumping is the process of addition of kinetic and potential energy to a liquid for the purpose of moving it from one point to another. This energy will cause the liquid to do work such as flow through a pipe or rise to a higher level. A centrifugal pump transforms mechanical energy from a rotating impeller into a kinetic and potential energy required by the system.

✓ The most critical aspect of energy efficiency in a pumping system is matching of pumps to loads. Hence even if an efficient pump is selected, but if it is a mismatch to the system then the pump will operate at very poor efficiencies.

✓ In addition efficiency drop can also be expected over time due to deposits in the impellers. Performance assessment of pumps would reveal the existing operating efficiencies in order to take corrective action.

## WASTE HEAT RECOVERY

✓ Successful waste heat recovery requires

- ⇒ Sufficient quantity
- ⇒ Sufficient quality (sufficiently high temperature)
- ⇒ Appropriate use Timely production (or storage)
- ⇒ Economic use

✓ The problem of sufficient quantity is obvious—there must be enough waste heat to make the recovery project worthwhile.

## WASTE HEAT RECOVERY +

✓ Classifications of waste heat by quality or temperature

| Temp. Range | T, °C                   | Source                                          |
|-------------|-------------------------|-------------------------------------------------|
| High        | $500 \leq T \leq 1,500$ | Exhausts from furnaces, kilns, and incinerators |
| Medium      | $200 \leq T \leq 500$   | Exhausts from engines, boilers, and furnaces    |
| Low         | $25 \leq T \leq 200$    | Cooling water, process liquids                  |



## WASTE HEAT RECOVERY +



- ✓ Low temperature heat is difficult to use
  - ⇒ Industrial heat pumps may be able to use the heat and increase its quality
  - ⇒ Absorption refrigeration processes may be able to use heat with temperatures near 100 °C
- ✓ Low to medium temperature heat can be used in economizers
  - ⇒ Economizers heat boiler water using the exhaust heat from the boiler as a heat source
  - ⇒ Economizers in general use hot gas exhaust from some process to heat liquid



## WASTE HEAT RECOVERY +



- ✓ Medium to high temperature heat uses
  - ⇒ "Air preheater" to preheat combustion air
  - ⇒ Generate steam in waste heat boiler
- ✓ How much waste heat is available?
- ✓ Conduct a waste heat survey
  - ⇒ Economizers heat boiler water using the exhaust heat from the boiler as a heat source
  - ⇒ Economizers in general use hot gas exhaust from some process to heat liquid



## WASTE HEAT RECOVERY +



- ✓ Medium to high temperature heat uses
  - ⇒ Other concerns "Air preheater" to preheat combustion air
  - ⇒ Generate steam in waste heat boiler
- ✓ How much waste heat is available?
- ✓ Conduct a waste heat survey
  - ⇒ Temperature of waste stream
  - ⇒ Quantity of waste stream
  - ⇒ Heat available is

$$q = MC_p (T_{\text{initial}} - T_{\text{final}})$$



## WASTE HEAT RECOVERY +

### ✓ Other concerns

- ⇒ How close is location where heat is needed?
- ⇒ Is the waste heat available when needed?
- ⇒ Is the waste heat compatible with a suitable heat exchanger?
- Fouling
- Plugging
- Corrosion



## WASTE HEAT RECOVERY +

### ✓ Limits on heat recovery

- ⇒ Final temperature of heated stream
- ⇒ Extract maximum heat from waste heat stream and lower its T as much as possible
- ⇒ T<sub>final</sub>, waste limited by cold-end corrosion considerations and type of heat exchanger



## WASTE HEAT RECOVERY +

### ✓ Heat exchanger effectiveness, $\epsilon$

$$\epsilon = \frac{\text{actual heat transfer to cold fluid}}{\text{maximum possible heat transfer}}$$

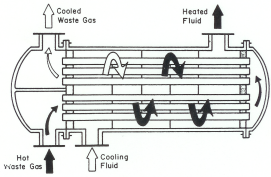
- ✓ Effectiveness generally increases with heat exchanger area but not linearly
- ✓ At some point a large area increase produces only a small effectiveness increase
- ✓  $50\% < \epsilon < 90\%$



## WASTE HEAT RECOVERY—EQUIPMENT TYPES



### ✓ Shell and tube—for liquids and gases at all temperatures



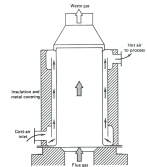
\*B.L. Capehart, et. al., *Guide to Energy Management*, 5th ed., Fairmont Press, 2003, p. 320.



## WASTE HEAT RECOVERY—EQUIPMENT TYPES



### ✓ Radiation recuperator—for gases from medium to high temperatures



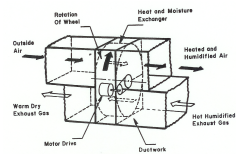
\*B.L. Capehart, et. al., *Guide to Energy Management*, 5th ed., Fairmont Press, 2003, p. 319.



## WASTE HEAT RECOVERY—EQUIPMENT TYPES



### ✓ Rotary heat wheel—for gases at all temperatures



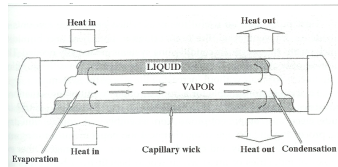
\*B.L. Capehart, et. al., *Guide to Energy Management*, 5th ed., Fairmont Press, 2003, p. 321.



## WASTE HEAT RECOVERY—EQUIPMENT TYPES



- ✓ Heat pipes (capillary tubes)—for liquids and gases at all temperatures



\*B.L. Capehart, et. al., Guide to Energy Management, 5th ed., Fairmont Press, 2003, p. 253.



## INDUSTRIAL INSULATION



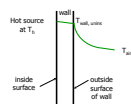
- ✓ Industrial insulation problems
  - ➔ Walls of vats, tanks, pipes or machines that were never insulated.
  - ➔ Damaged insulation.
  - ➔ Insulation removed for a repair and never replaced



## INDUSTRIAL INSULATION+



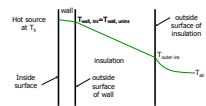
- ✓ Uninsulated walls result in the following temperature profile:



## INDUSTRIAL INSULATION+



- ✓ With insulation the profile changes:



## INDUSTRIAL INSULATION+



- ✓ From the Building Envelope Section recall-
- ✓ At steady-state, the heat loss in W is

$$q = \frac{A \times \Delta T}{\Sigma R} \quad W$$

- ✓ Where  $q$  is heat loss rate and  $\Sigma R$  is the sum of the resistances to the heat flow



## INDUSTRIAL INSULATION+



- ✓ For the uninsulated case

$$\Sigma R = R_{\text{wall}} + R_{\text{surface}}$$

- ✓ For the metal walls and thicknesses generally seen,  $R_{\text{wall}}$  is much smaller than  $R_{\text{surface}}$  so

$$\Sigma R \cong R_{\text{surface}}$$

- ✓ In addition, one can show that for metal walls

$$T_h \cong T_{\text{wall,ins}} \cong T_{\text{wall,unins}}$$



## AIR FILM RESISTANCES (INDUSTRIAL)

| Surface film coefficients, $R_s$ Values $((M^2 \cdot ^\circ C)/W)$ |                                                  |                             |                                    |
|--------------------------------------------------------------------|--------------------------------------------------|-----------------------------|------------------------------------|
| Still Air                                                          |                                                  |                             |                                    |
| $t_s - t_a$ ( $^\circ C$ )                                         | Plain fabric,<br>Dull metal,<br>$\epsilon = .95$ | Aluminum<br>$\epsilon = .2$ | Stainless steel<br>$\epsilon = .4$ |
| 5                                                                  | .093                                             | .159                        | .143                               |
| 14                                                                 | .092                                             | .155                        | .139                               |
| 28                                                                 | .088                                             | .151                        | .134                               |
| 42                                                                 | .085                                             | .148                        | .132                               |
| 55                                                                 | .081                                             | .141                        | .127                               |
| Wind velocity (km/h)                                               |                                                  |                             |                                    |
| With wind velocities                                               |                                                  |                             |                                    |
| 8.3                                                                | .062                                             | .072                        | .070                               |
| 16.7                                                               | .053                                             | .062                        | .060                               |
| 33.3                                                               | .042                                             | .049                        | .048                               |



## INDUSTRIAL INSULATION+

- ☑ Thus for the uninsulated case with metal walls, And both  $T_h$  and  $T_{air}$  are easily measured.

$$q_{unins} = \frac{A(T_h - T_{air})}{R_{surface}}$$



## INDUSTRIAL INSULATION+

- ☑ For the insulated metal wall case,

$$\sum R = R_{wall} + R_{insulation} + R_{surface}$$

- ☑ And again, the resistance of the wall can be neglected so that

$$\sum R = R_{insulation} + R_{surface}$$





## INDUSTRIAL INSULATION+

✓  $R_{\text{insulation}}$  is given by the general formula for  $R$ .

$$R_{\text{insulation}} = \frac{t}{k}$$

✓ In general,  $R$  is proportional to the thickness of the substance resisting the heat flow.



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## K FOR COMMON MATERIALS

|                            | Temperature<br>(°C) | W/m·°C               |                      |                       |
|----------------------------|---------------------|----------------------|----------------------|-----------------------|
|                            |                     | $T_M = 24\text{ °C}$ | $T_M = 93\text{ °C}$ | $T_M = 260\text{ °C}$ |
| Calcium silicate blocks    | To 750              | .053                 | .059                 | .076                  |
| Glass fibre blankets       | To 600              | .035 - .045          | .046 - .071          | .062 - .105           |
| Glass fibre boards         | To 500              | .032                 | .040                 | .074 - .088           |
| Glass fibre pipe coverings | To 425              | .033                 | .043                 | .089                  |
| Mineral fibre blocks       | To 950              | .033 - .049          | .040 - .056          | .065 - .118           |
| Cellular glass blocks      | To 450              | .055                 | .089                 | .104                  |

$T_M$  is mean temperature of  $T_{\text{hot}}$  &  $T_{\text{surface}}$ .

Thickness is in metres \*B.L. Capehart, et. al., Guide to Energy Management, 5th ed., Fairmont Press, 2003, p. 401.



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## INDUSTRIAL INSULATION TYPES

- ✓ Glass fibre (fibreglass)
- ✓ Calcium silicate
- ✓ Mineral fibre or “rock wool”
- ✓ Ceramic fibres
- ✓ Fire brick Plastic foams
- ✓ Phenolic foams
- ✓ Cellular glass
- ✓ Elastomeric cellular plastic



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## INDUSTRIAL INSULATION

- ✓ The North American Insulation Manufacturers Association (NAIMA) has a useful insulation program, 3E Plus
- ✓ 3E Plus calculates
  - ⇒ Insulation thicknesses
  - ⇒ Energy loss and gain
  - ⇒ Economic thicknesses
  - ⇒ CO<sub>2</sub>, NO<sub>x</sub>, and carbon equivalent (CE) reductions
  - ⇒ Useful software can be downloaded from <http://www.pipeinsulation.org>



## INDUSTRIAL INSULATION

- ✓ Big energy consumers in most manufacturing plants, commercial facilities and other large buildings.
- ✓ Often oversized and not managed well.
- ✓ Hydraulic Institute estimates that 20% of the cost of existing pumping systems can be saved through good engineering analysis.
- ✓ This section explores how to obtain those savings.
- ✓ Much of this material is taken from ENERGY REDUCTION IN PUMPS AND PUMPING SYSTEMS, Hydraulic Institute, 1997.1
- ✓ This course is available from the Institute and we highly recommend it.



**BEYOND**  
SMART CITIES

THANK YOU

**THE WORLD'S 1ST GREEN TECHNOLOGY  
MARKETPLACE**