PROFESSIONAL ENGINEERS OF ONTARIO

ANNUAL EXAMINATIONS – May 2012

07-Mec-B2 Environmental Control in Buildings

3 hours duration

INSTRUCTIONS:

1. **If doubt exists as to the interpretation of any of the questions, the candidate is urged to submit a clear statement of the assumption(s) that he/she has had made with the answer.**

2. **The examination paper is open book and so candidates are permitted to make use of any textbooks, references or notes that they wish.**

3. **Any non-communicating calculator is permitted. Candidates must indicate the type of calculator(s) that they have used by writing the name and model designation of the calculator(s) on the first inside left hand sheet of the first examination workbook. The usage of computers, internet and smart phones is prohibited.**

4. **Candidates are expected to have copies of both an environmental control book and steam tables, since it will be necessary to use information presented in the tables and graphs contained in books.**

5. **Candidates are required to solve five questions.**

6. **All questions carry the same value. Indicate which five questions are to be graded on the cover of the first examination workbook.**

7. **Psychrometric charts and the p-h diagram for the refrigerant are attached.**

PROBLEM 1 (20 POINTS).

A suite of offices is to be air conditioned. The following conditions apply:

Outside design	**95°F dB, 82°F wB**
Inside design	**78°F dB, 53% RH (relative humidity)**
Room sensible-heat gain	**75,000 Btu/hr**
Room latent-heat gain	**40,000 Btu/hr**
Ventilation (outside) air through conditioner	**2200 cfm (cubic feet per minute)**

A four-row coil (by pass factor BPF =0.1) will be used.

Neglect all friction losses and fan and pump work. Assume sea level conditions.

- **a.** **Draw a diagram of the system.**
- **b.** **Draw the operating cycle on the psychrometric chart provided and identify each significant point, on the diagram and psychrometric chart, and note for each of these points its dry bulb and wet bulb temperature.**
- **c.** **Determine the Room ADP (apparatus dew point) temperature.**
- **d.** **Determine the condition of air leaving the coil.**
- **e.** **Calculate the total quantity of air required.**
- **f.** **Calculate the total refrigeration capacity.**

PROBLEM 2 (20 POINTS).

A room is maintained at 23°C in summer and 21°C in winter, by fan coil units that mix room and outside air in the ratio of 7:1 before cooling or heating takes place. For the summer design case the room relative humidity (RH) is 55%, but there is no humidification in winter. The summer ambient design temperatures are 29°C dB and 23°C wB when the room gains are 40 kW sensible and 5 kW latent. The winter design ambient temperature is 0°C, 100% RH when the room sensible heat loss is 20 kW and the room latent gain is 5 kW. The air leaves the coil in summer at a temperature of 15°C, and the temperature rise across the fan is negligible. Neglect all friction losses and fan and pump work. Assume sea level conditions

- **a.** **Draw a diagram of the system.**
- **b.** **Draw the operating cycle on the psychrometric chart provided. Identify each significant point, on the diagram and psychrometric chart.**
- **c.** **Determine the size of the cooling coils.**
- **d.** **Calculate the minimum size of the heating coils and the relative humidity in winter.**

PROBLEM 3 (20 POINTS).

a. 15 points

A house is heated with an air heat pump using R134a as the working fluid. On a particular day when the outside temperature is 6°C, the house requires a heat transfer rate of 15 kW in order to maintain an inside temperature of 20°C

Specify appropriate evaporator and condenser pressures for this cycle. Let the refrigerant to be saturated at evaporator exit and saturated liquid at condenser exit. If you want to consider other conditions please specify.

Calculate:

- **mass flow of refrigerant.**
- **compressor power**
- **coefficient of performance**

b. 5 points

Comment on advantages and disadvantages of air heat pumps.

PROBLEM 4. (20 POINTS)

A small commercial building located in Ottawa, Ontario has a heating load of 400,000 Btu/hr sensible and 55,000 Btu/hr latent. Design conditions are 76°F and -14°F. The owner has to decide between two heating options:

- natural gas warm air furnace with an efficiency of 80%.
- electric resistance heating elements with an efficiency of 100%.

The heating value of natural gas is 1000 Btu/std ft^3 (standard cubic feet).

Using the degree day method, and knowing that the price of natural gas is 4.00 $/thousands cubic feet, and the price of electricity is 0.10$/kWh, compare the annual heating costs. Neglect the cost of initial installation.

A contractor suggested to the owner of the above building, to install a heat pump. The contractor claims that the heat pump has a COP (coefficient of performance) of 4.2. The compressor/motor has an efficiency of 82%. How much will be the yearly heating cost with the heat pump.

Comment on your results. What are the environmental impacts of each alternative?
Comment on the fact that the power plant that produces electricity uses coal as the fuel, and has an overall efficiency of 38%.

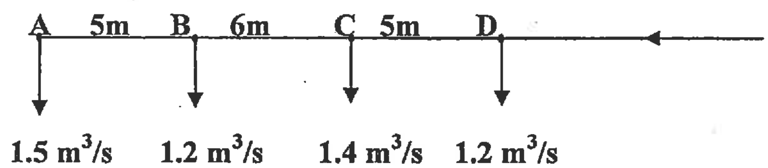
PROBLEM 5. (20 POINTS)

a. 5 points

Explain in a few sentences, the principles of equal friction, balanced-capacity method, and static regain method used in duct design. Summarize their advantages and disadvantages.

b. 15 points

Calculate the diameters of sections AB, BC and CD of the duct system shown below. Assume a velocity of 6 m/s in section AB, and size sections BC and CD using static regain method. All ducts are circular. The pressure loss factor for the main duct at each junction may be taken as 0.1, applied to the velocity pressure in the main downstream of the branch.



PROBLEM 6. (20 POINTS)

The southwest wall of a school building in Toronto, Ontario, is 76 m by 2.7 m overall. It has 30 windows, each 2.0 m by 1.5 m. The wall is 200-mm heavyweight concrete with 25.4 mm ($R = 0.53\ K\ m^2 / W$) insulation. The windows are insulating glass (clear out, clear in, 6.4-mm glass, 13-mm airspace) with translucent roller shades.
Determine the cooling design load for the complete wall, assuming that this wall determines the design time for the whole building.

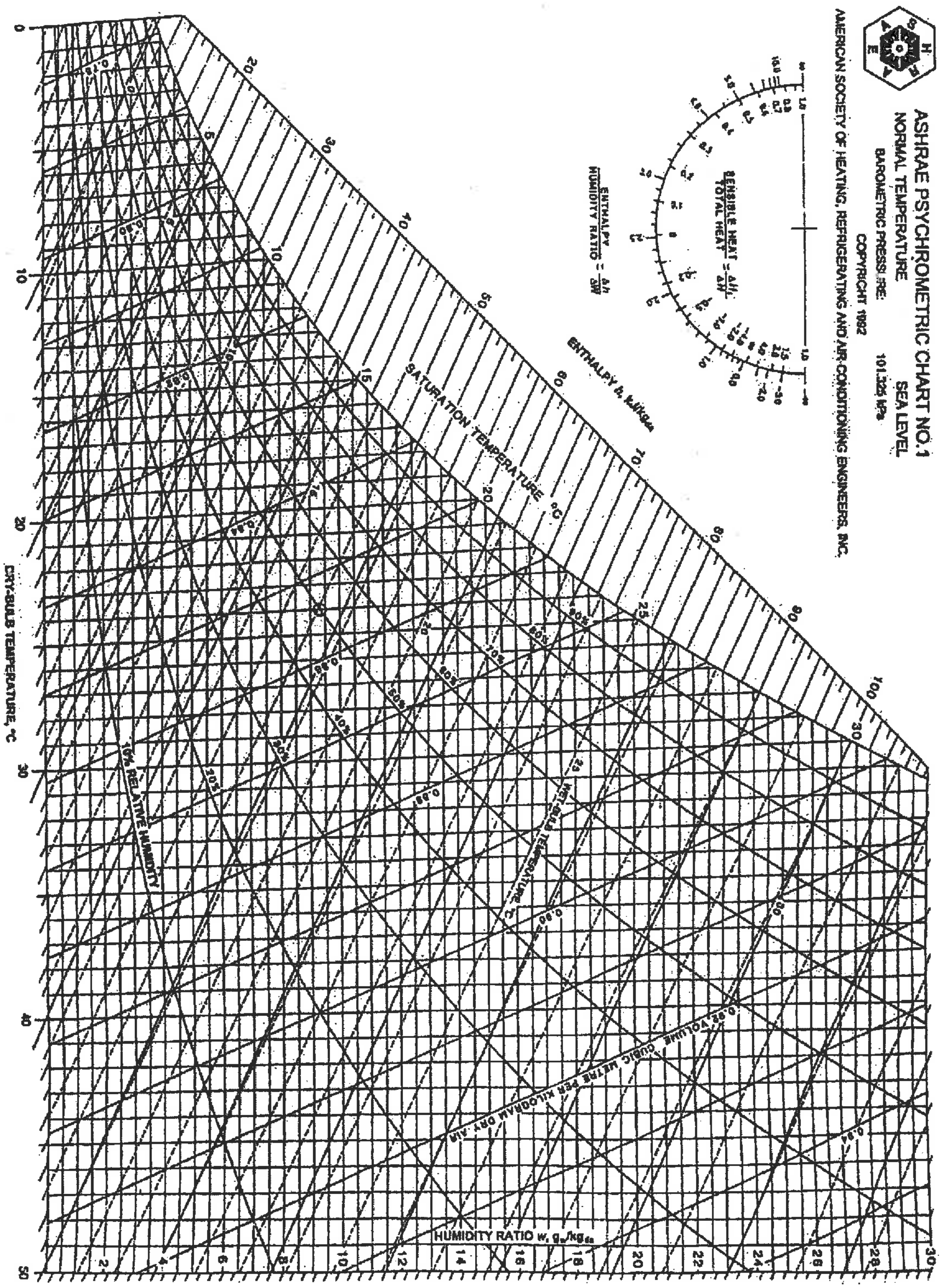
PROBLEM 7. (20 POINTS)

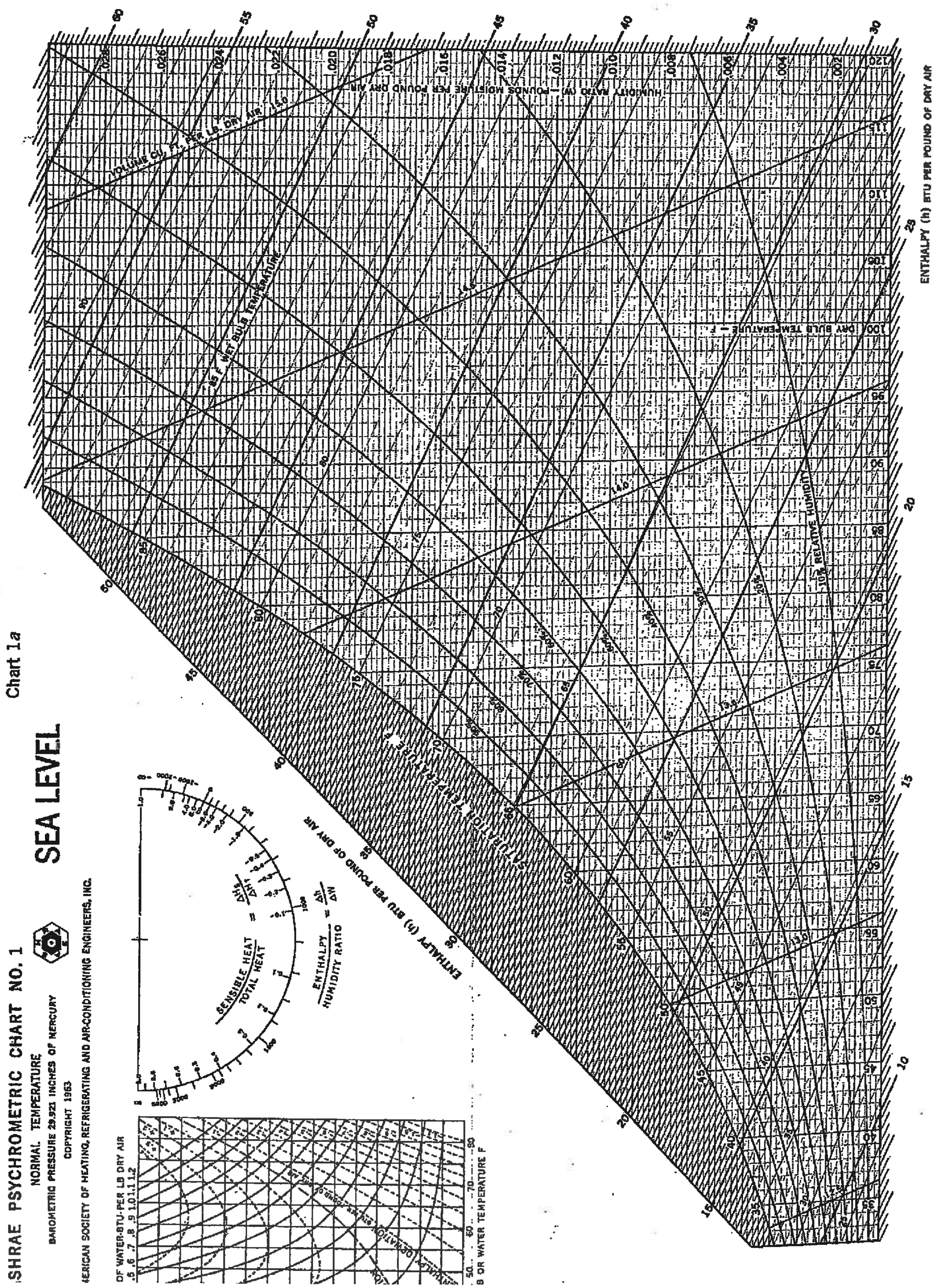
Sketch an induced draft counter-flow cooling tower, showing how it may be regulated to control the operation of a refrigeration plant.

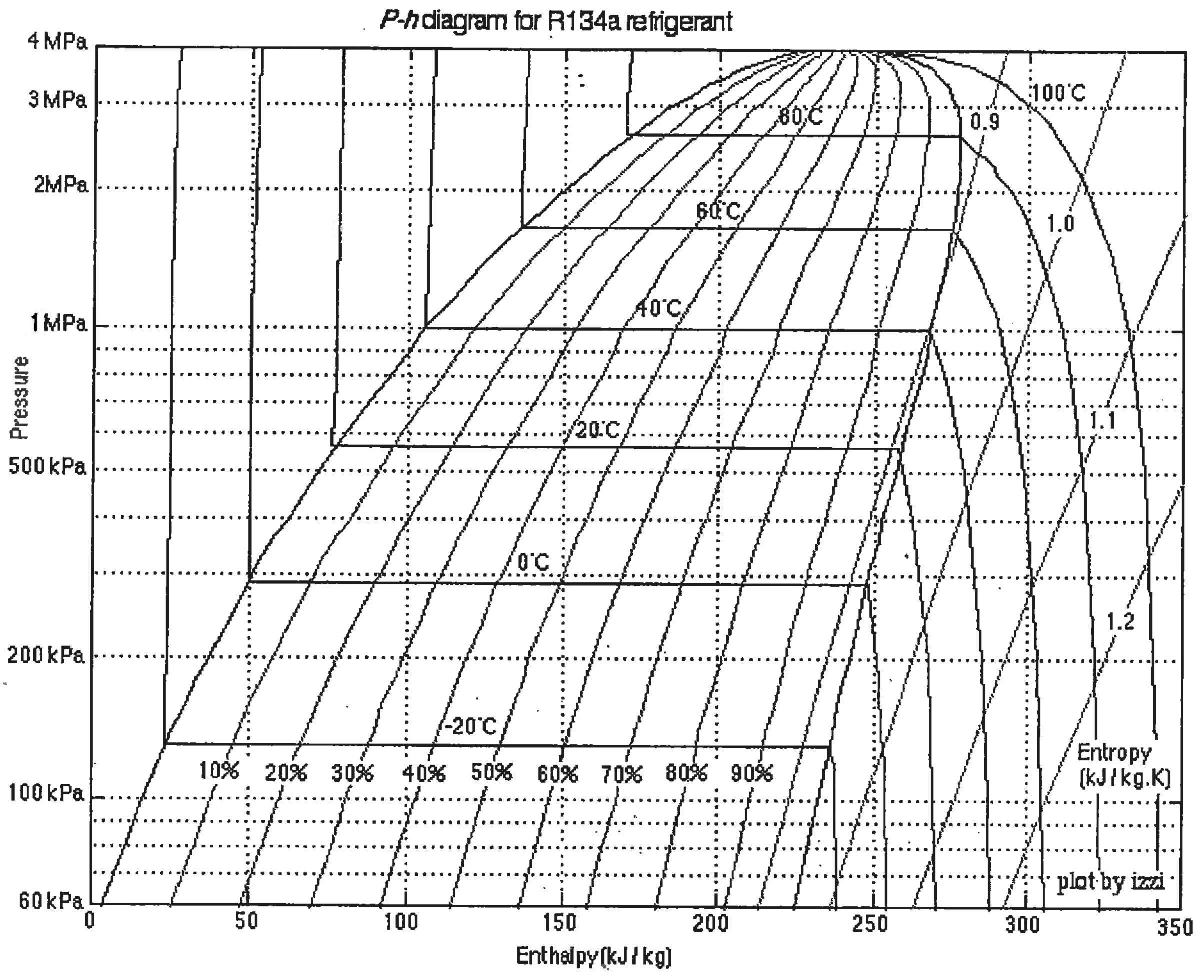
A cooling tower operating in atmospheric conditions of 65°F db (dry bulb), 58°F wb (wet bulb), cools 4500 lb/min of water from 100°F through a range of up to 30°F. The air is assumed to leave the top of the tower at 90°F db, 95% RH.

a. **Calculate the enthalpy, specific volume and relative humidity of the air entering the tower.**
b. **Find the air volumetric flow at the tower inlet (ft^3/min)**
c. **Find the evaporative loss (%).**
d. **Find the make-up water required, taking into account that some moisture is gained by the cooling air and also that there is a drift of 0.3% of the total water flow**

Fig. 1 ASHRAE Psychrometric Chart No. 1




SHRAE PSYCHROMETRIC CHART NO. 1
NORMAL TEMPERATURE
BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY
COPYRIGHT 1963
ERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.
SEA LEVEL
Chart 1a
SENSIBLE HEAT / TOTAL HEAT
ENTHALPY / HUMIDITY RATIO
ENTHALPY (h) BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE
WET BULB TEMPERATURE
VOLUME CU. FT. PER LB. DRY AIR
HUMIDITY RATIO (W) - POUNDS MOISTURE PER POUND DRY AIR
DRY BULB TEMPERATURE - F
10% RELATIVE HUMIDITY
ENTHALPY (h) BTU PER POUND OF DRY AIR


P-h diagram for R134a refrigerant
4 MPa
3 MPa
2MPa
1 MPa
500 kPa
200 kPa
100 kPa
60 kPa
Pressure
0
50
100
150
200
250
300
350
Enthalpy (kJ / kg)
80°C
60°C
40°C
20°C
0°C
-20°C
100°C
10%
20%
30%
40%
50%
60%
70%
80%
90%
0.9
1.0
1.1
1.2
Entropy (kJ / kg.K)
plot by izzi