An attic condensation: ventilation model

Handegord, G. O.; Giroux, G.

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AN ATTIC CONDENSATION - VENTILATION MODEL

G.O. Handegord and G. Giroux

INTRODUCTION

Most codes and guidelines for house construction specify ventilation openings for attic or roof spaces to control condensation. The values specified appear to be based on traditional practice and are regarded by many as being without experimental or analytical justification. This paper proposes a simple psychrometric model that could be used as a basis for roof space vent opening requirements. It was developed during the course of investigation of an attic condensation problem in flat wood-frame roofs of a low-rise row-housing condominium project in Canada.

THE PSYCHROMETRIC MODEL

A two-dimensional model of an insulated roof space and ceiling construction with equivalent soffit vent openings on either side is shown in Figure 1. Outside air will flow into and out of the roof space principally under tha action of wind. Unintentional openings will also exist through the ceiling, allowing air leakage to occur upward into the roof space from indoors under a pressure difference generated by stack effect or indirectly by wind action.

The outside air entering the vents on the windward side will mix with the air leaking upward through the ceiling, and the mixture will exit through the leeward side soffit openings.

The exiting mixture comes in contact with the underside of the roof sheathing, which will be at a temperature approximately equal to that of the outside air. If the dewpoint temperature of the mixture is above this value, condensation will occur on the sheathing surface and the air will exit at 100% rh at a temperature close to that of the outside air. If such condensation is to be avoided, the dewpoint temperature of the mixture must be below the roof sheathing temperature. The condition of the mixture will be on a line connecting the outside air condition and the indoor air condition.

For a given indoor condition and at the outdoor air conditions for the locality in question, the limiting mixture condition for no condensation can be established at the point of intersection of the mixture line and the dewpoint line corresponding to the temperature of the sheathing surface (outside air temperature).

APPLICATION

The ratio of flow into the soffit vents and through the ceiling leakage paths will be related to their respective areas and the pressure differences acting across them. If the pressure differences are similar, the ratio will be proportional to the areas of the openings.

At low outside temperatures, when condensation is more likely, the maximum pressure acting upward across the ceiling due to stack effect may approach that of the pressure due to the average winter wind acting across the inlet vent. As a first approximation, these pressure differences can be considered equal, and the mixing ratio will be proportional to the respective opening areas.

The ceiling leakage area can be estimated from a summation of individual leakage openings using methods such as in Chapter 22 of the ASHRAE Handbook of Fundamentals, or estimated from the Normalized Leakage Area (NLA) as measured or specified in codes or standards. The maximum value of the Normalized Leakage Area (NLA) specified in the requirements for the R-2000 Low Energy House Program of Energy Mines and Resources Canada is 0.7 cm^2/m^2. An NLA value of 3 cm^2/m^2 could represent an average value for traditional houses built in Canada during the 1960's and 1970's (ELA of 0.1 m^2).

As an example, the daily mean temperature for the coldest month for Toronto, Ontario is -6.5°C and the daily mean dewpoint temperature is -9°C. If it is assumed that an indoor relative humidity of 40% at 23°C is to be maintained indoors, the mixture line shown in Figure 2 represents the situation. The dewpoint line intersects the mixture line at about -3.8°C and the limiting mixture ratio is approximately 1/10. The minimum roof inlet vent opening required for the traditional house is thus 0.0003m^2 x 10/m^2 or 1/333 of the ceiling area and the total vent opening required will be twice this value or 1/167 of the ceiling area. For a house meeting the R-2000 requirements of 0.7 cm^2/m^2 NLA, the total roof vent opening required would be 1/714 of the ceiling area. The advantage of a tighter ceiling is apparent.

Figure 3 represents the situation for a house in the much colder climate of Saskatoon, Saskatchewan with average January conditions outdoors of -18°C dry bulb and -21°C dewpoint temperatures. The intersection of the dewpoint line with the mixture line occurs at about -17.0°C and the limiting mixture ratio is 1/40. The estimated vent area required for the traditional house would be 1/42 of the ceiling area and 1/179 for the R-2000 house. It should also be noted that fogging would be expected to occur if the ceiling leakage was higher than those considered.

OTHER CONSIDERATIONS

The model outlined assumes that the flow through the ceiling and roof space inlet vents is proportional to the respective vent areas. The flows will however be determined by the respective pressure differences and flow characteristics of the openings.

The action of the wind on the house model as described would not be expected to influence the sustained air pressure difference across the ceiling. For a two-dimensional model, such as an inner unit of a row-housing block, the pressures acting across each vent could be considered equal with one positive and one negative. This might also be approximately the case with a single detached unit with the wind blowing toward one corner. The value of pressure could be taken as the stagnation pressure of the average winter wind multiplied by the pressure coefficient associated with the specific geometry of the situation.

The pressure difference acting upward across the ceiling could be assumed equal to that resulting from buoyancy forces to be expected for the specific house (one storey, two storey, etc.) at the outdoor temperature chosen.

Ridge venting would be expected to create a negative pressure in the roof space with all soffit vents acting as outdoor air inlets. This negative pressure would also add to the pressure acting upward across the ceiling and could be taken into account.

CONCLUSION

The psychrometric model proposed offers a means by which the sizing of roof vents for condensation control can be related to winter weather conditions and house characteristics. Although refinements to the model could be employed, it is suggested that the assumption of flow rate based solely on vent or leakage area is adequate in view of the variations and influences in the real situation. Flexibility is best allowed for in the selection of the outdoor temperature to be utilized in the sizing determination.

It should also be recognized that in cold climates some roof space condensation is inevitable and that roof space venting is only effective in removing condensation in milder weather or under the action of solar radiation. The ability of the system to perform satisfactorily will depend on its ability to hold and remove moisture without damage or deterioration and this will be determined by many other factors, including material storage capacity, slope, drainage potential, and rate of accumulation. Clearly however, the tighter the ceiling construction is, the better the performance will be.

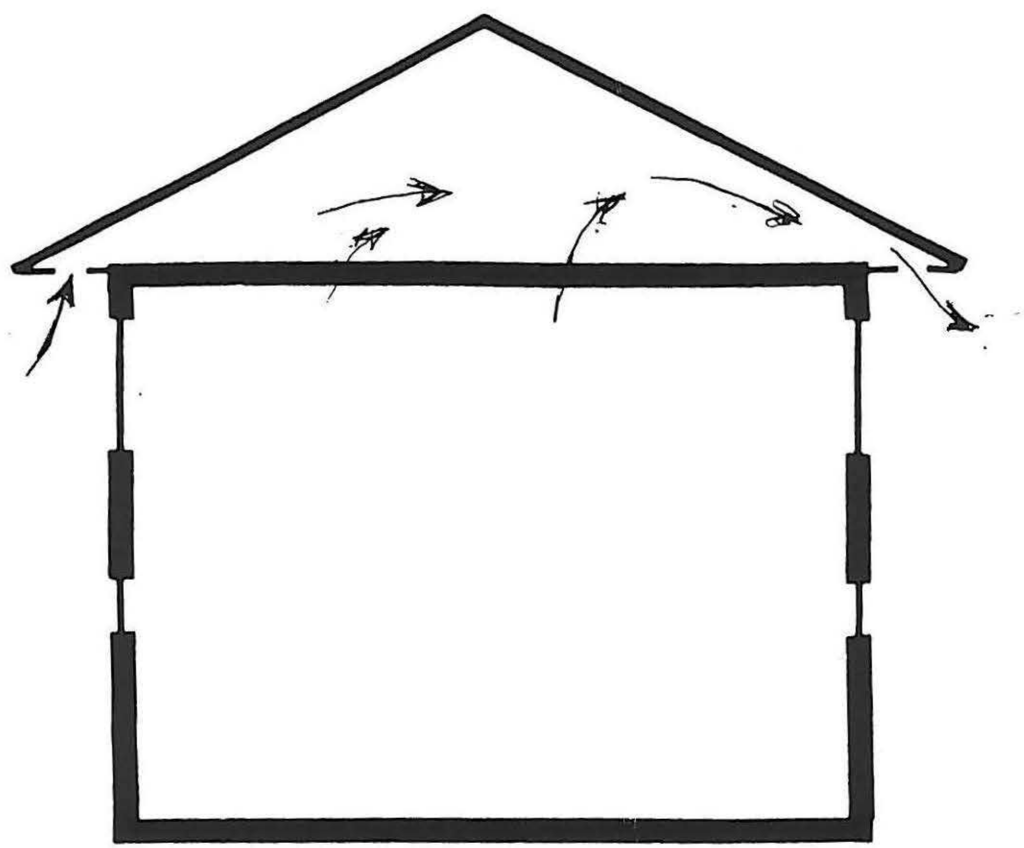


FIGURE 1 PHYSICAL MODEL

FIGURE 2
PSYCHROMETRIC MODEL
TORONTO ONTARIO

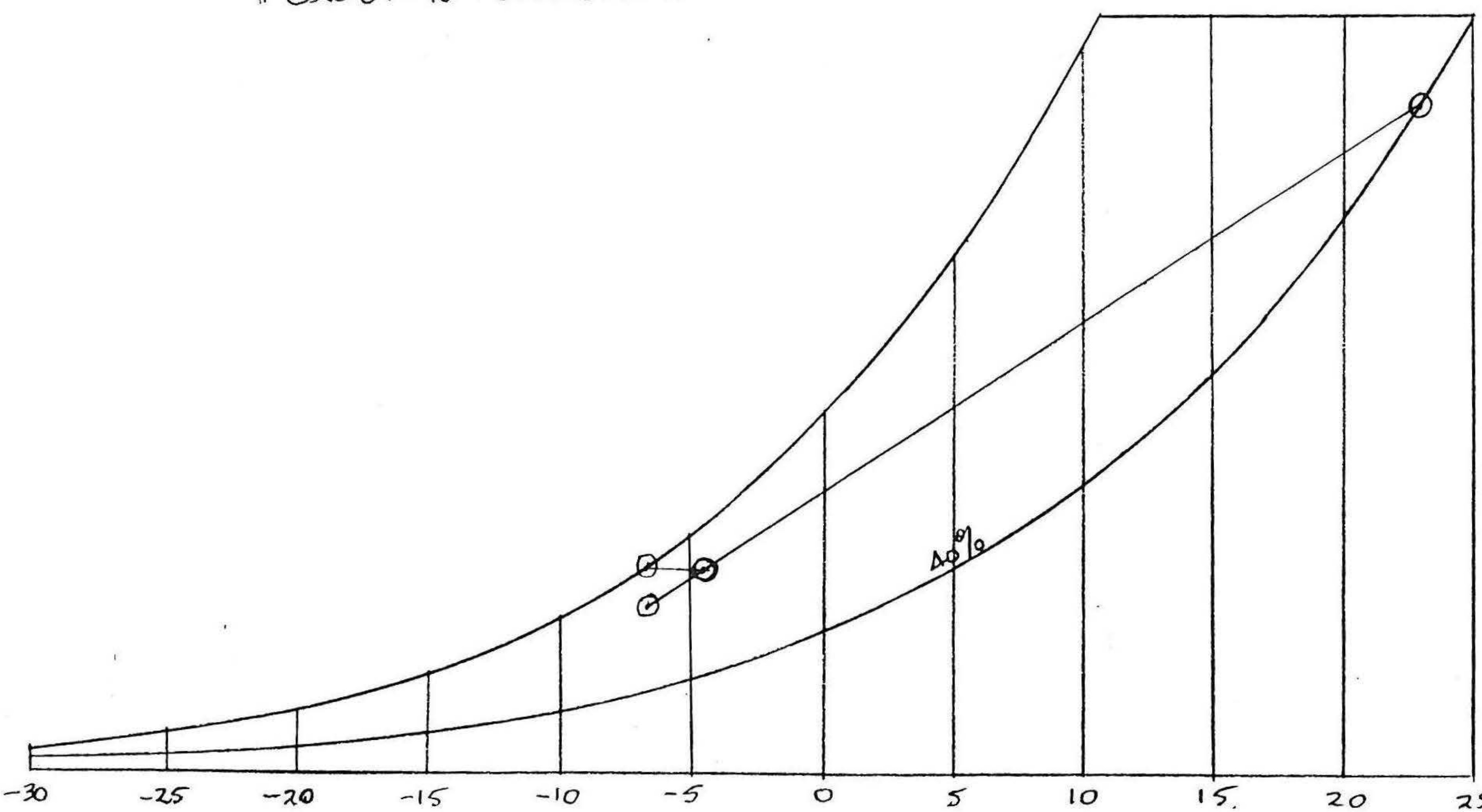
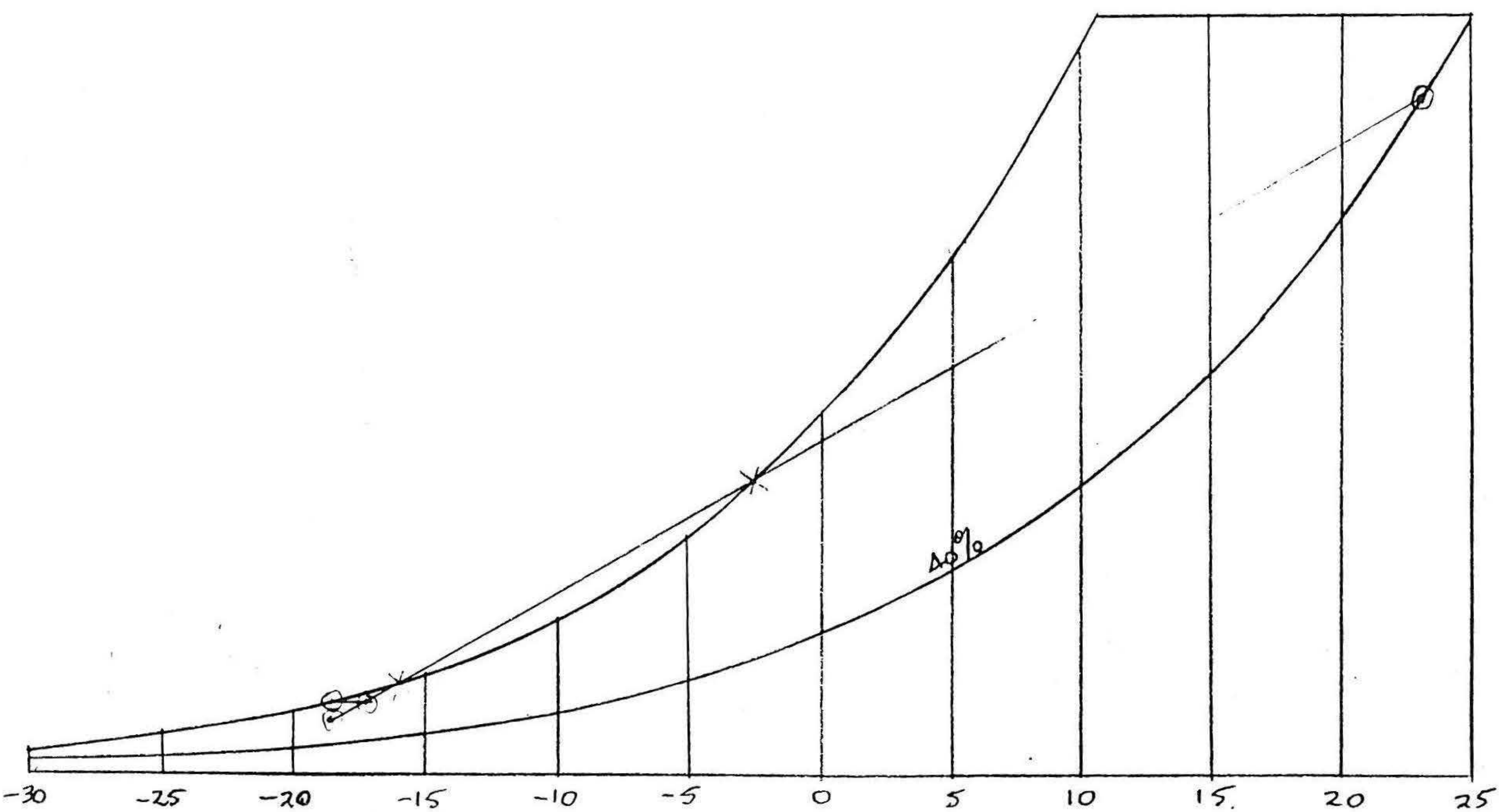


FIGURE 3
PSYCHROMETRIC MODEL
SASKATOON SASK., A



$\frac{2.7}{26.8} \simeq \frac{1}{10}$

TORONTO $(-6.5-(-9.8)) = 2.7$
$(23-(-3.8)) = 26.8$

Carrier

PSYCHROMETRIC CHART

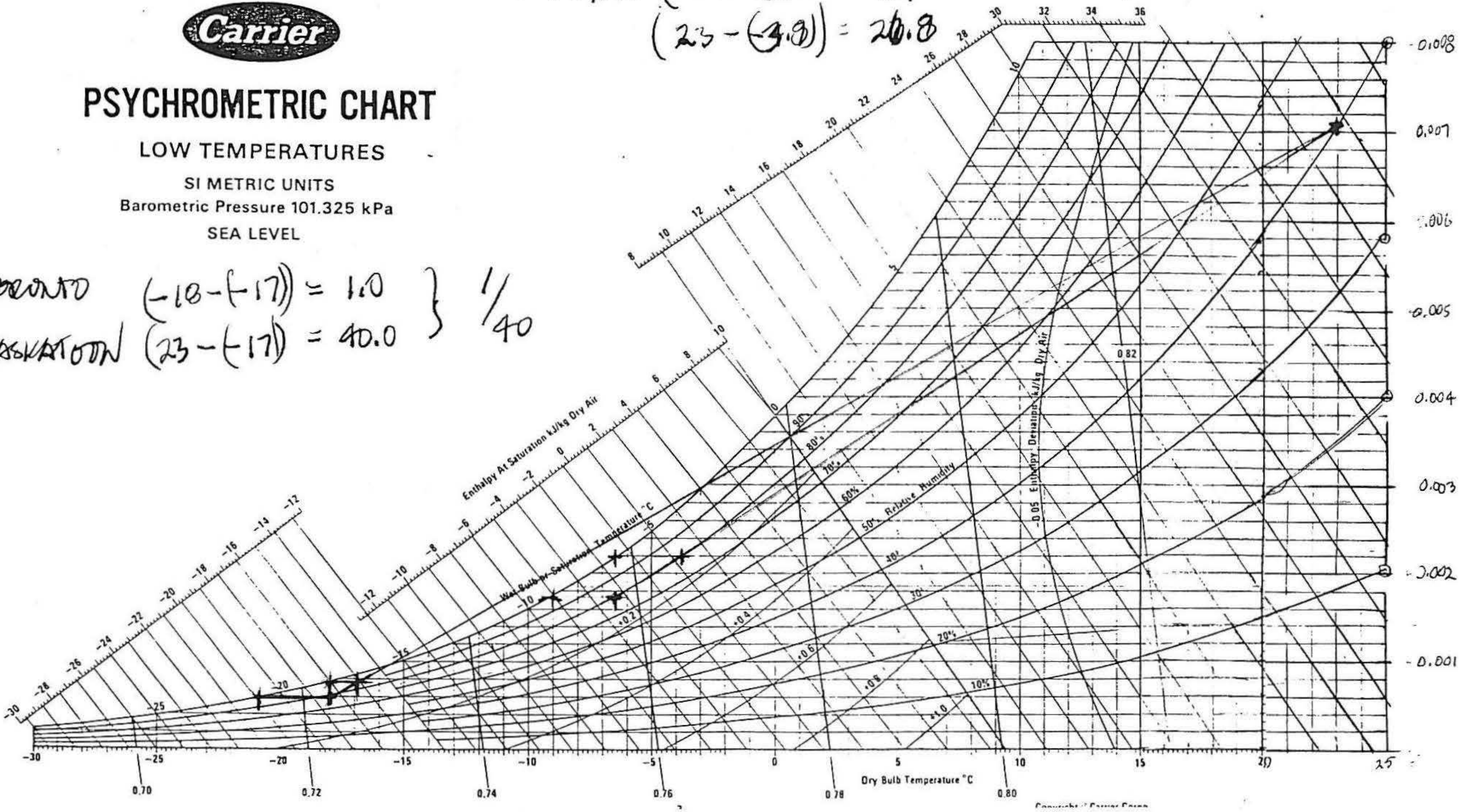
LOW TEMPERATURES

SI METRIC UNITS

Barometric Pressure 101.325 kPa

SEA LEVEL

TORONTO $(-18-(-17)) = 1.0$
SASKATOON $(23-(-17)) = 40.0$ } $1/40$



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