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Technical Design Procedure for the "Haram Tawaf" Using Cold Air Nozzle Ejection

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Abstract: Using an interactive microcomputer package spot cooling system may be designed. The package satisfies the needs imposed by the ambient conditions of the Tawaf environment and the parameters for the Tawaf Activity region. This procedure has published for similar conditions. [1] An interactive computer package for spot cooling system design has been developed, The package offers the designer four aspects of interactive dialogue. The first satisfies the needs imposed by ambient conditions of the Tawaf environment, namely:

i. Ambient dry bulb temperature,
ii. Relative humidity,
iii. Mean radiant temperature, and
iv. Relative humidity of the cooling air delivered to the Jet's outlet.

The second considers the parameters required by the Tawaf Activity, namely:

i. Metabolic heat production of the person performing Tawaf.
ii. Closing insulation value,
iii. and Target area.

The third level is concerned with jet angle as well as the target distance from the Jet's outlet.
The fourth level and last is the desired maximum and minimum velocity of the conditioned air at the target area.
The results are displayed on the screen as well as stored in an output file to give the designer opportunities of both direct selection and documented results. The results have been compared with available data in literature and a good agreement with which has been achieved.

Introduction

Spot cooling systems can be the best air conditioning alternative for many open areas, where there are large areas are exposed to the outdoor atmosphere. It is' also effective where process loads are very high and cannot be removed economically using traditional air conditioning systems.

The two other candidates, total volume system and stratified system, are not capable of reducing the energy burden in the above described circumstances as effectively as the spot cooling system.

Recently, a design procedure for spot cooling systems [2-3] has been offered. A condensed step-by-step version, for the designer of spot cooling systems, has been introduced.[4] However the calculations needed, to evaluate the possible permutations of working parameters to achieve an acceptable physiological stress, is tedious and time consuming.

In this work an interactive computer package for micros has been developed.

Spot jet cooling model

The selected model is that developed by Azer, [2-4] which is in turn based on the jet model developed by Koestel.[5] Figure 1 gives a schematic presentation of a jet of cold conditioned air supplied vertically downwards on a hot working station. Since all equations,[1] only the Mathematical Model, package structure, design selections and the flow chaff will be given here. It is worth mentioning that all interpolations are utilizing a modified LaGrange technique in three-dimensional domain, which is rather accurate than linear interpolations used in.[2] Also, the designer may specify the surrounding environment and Jet's outlet condition using dry bulb temperature and relative humidity, or dry bulb temperature and wet bulb temperature. The package will derive all air properties based upon either combination of input variables.

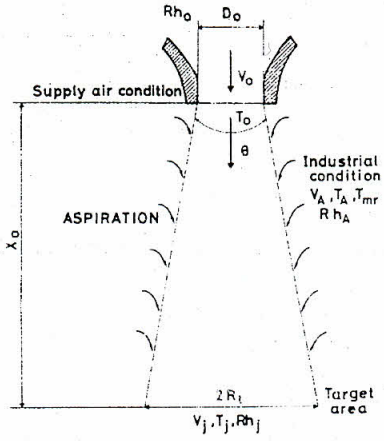

Fig. 1: Jet model used for cold air spot cooling.

Package structure

The package consists of a main program, 22 subroutines and three data files. The main program has the steering function among all subroutines. The subroutines take care of all mathematical formulas, equation solution, interpolations, basic data reading and output writing and display.

Sample results

In order to verify the package, a preliminary version has been developed to recalculate all results given by Azer.[4]
Tables 2, 3, 4, 5 and 6 by Azer[4] have been recalculated and a good agreement has been achieved. Some minor discrepancies have been observed; mainly because of the accurate air properties equations used in this work.[5] Figures 2-5 show[2] the effect of the environmental dry bulb temperature on the target dry bulb temperature and relative humidity as well as at jet outlet. It is clear that the supply air dry-bulb temperature at the jet outlet should be decreased steeply in order to overcome the hot environmental dry bulb temperature.

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[1] The detailed procedure and their development are given in reference [1-4]

[2] For ICL = 0.3 AND M = 87 W/m^2 for these curves.

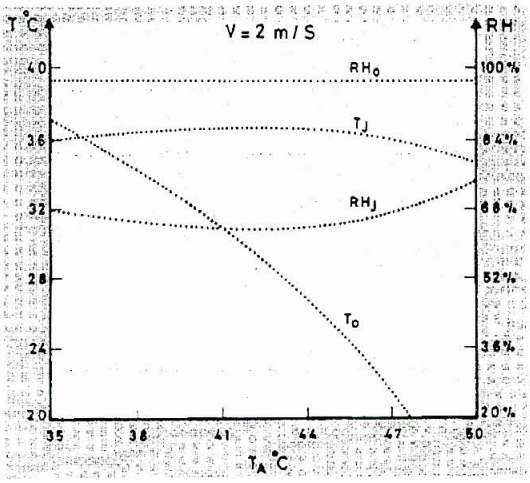

Fig. 2: Dry bulb temperature and relative humidity at target and jet outlet at a target velocity of 2 m/s.

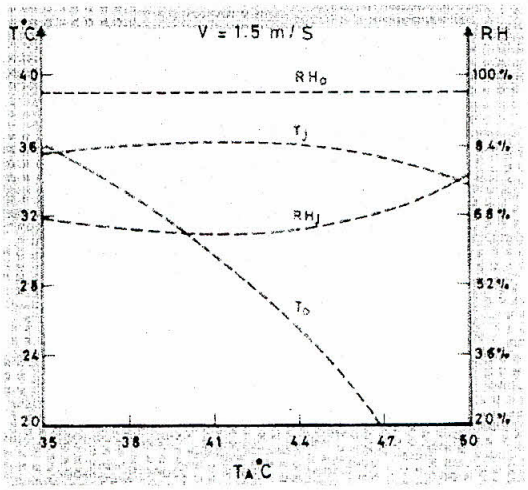

Fig. 3: Dry bulb temperature and relative humidity at target and jet outlet at a target velocity of 1.5 m/s.

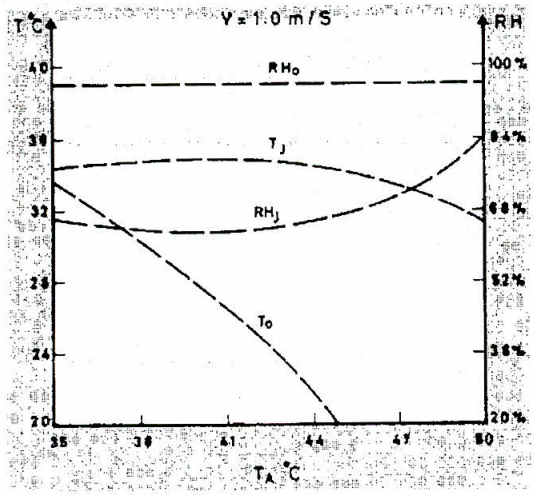

Fig. 4: Dry bulb temperature and relative humidity at target and jet outlet at a target velocity of 1 m/s.

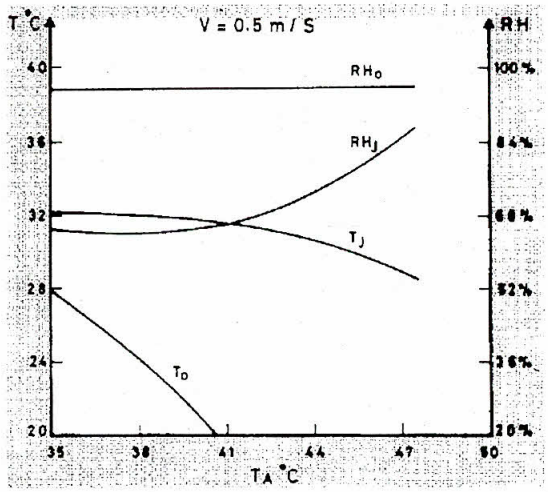

Fig. 5: Dry bulb temperature and relative humidity at target and jet outlet at a target velocity of 0.5 m/s.

The target temperatures however are almost at the same level. Decreasing the air velocity however minimizes the mixing of the cold supply air with hot environment. The relative humidity, of the air at the target area, increases to a level far away from the comfort zone. *Also, as the air speed decreases, water droplets are formed in the supply air; even ice particles may be found.* The program stops the calculation in such circumstances. In Figure 6, the air velocity effect on the target dry bulb and relative humidity is displayed. This effect diminishes as the velocity increases. It is also clear that a velocity increase has only a very small effect on the air relative humidity at the target area for environmental air dry-bulb temperatures between 35C° and 43C°. For higher temperatures, however the velocity effects are more significant. Figure 7, summarizes the required supply air condition at the jet outlet for different dry bulb temperatures of the Tawaf environmental area. As the velocity increases the supply air dry bulb may be increased since less hot aspirated air will be mixed with the cold air stream. This effect diminishes as the velocity increases because of the turbulent mixing power.

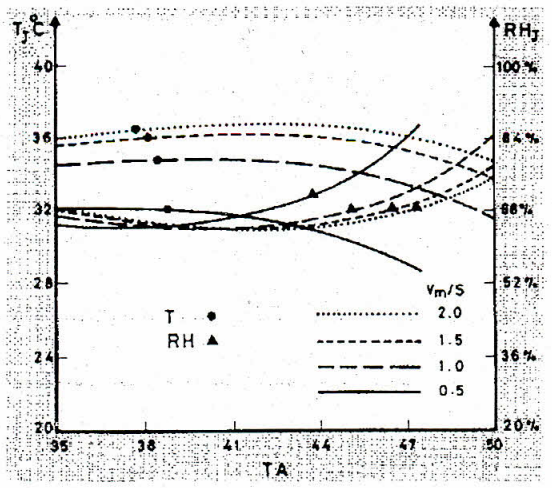

Fig. 6: Target dry bulb temperature and relative humidity at different air velocities.

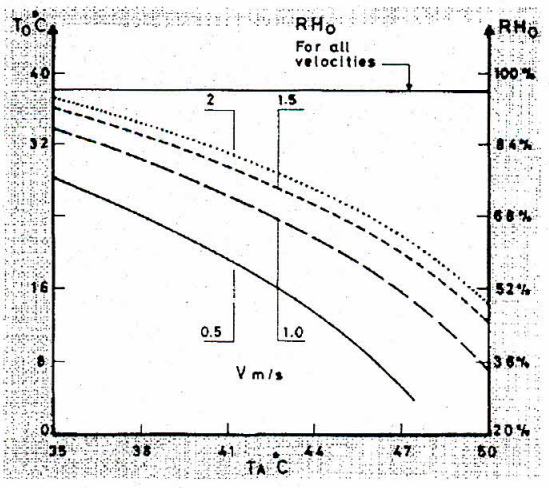

Fig. 7: Jet outlet dry bulb temperature and relative humidity at different air velocities.

References

[1] Sofrata, H. and Al-Hukail, Y., *Spot Cooling System Design.* ASHRAE Journal, pp. 38-42, January 1987.

[2] Azer N. Z., *Design Guidelines for Spot Cooling Systems: Part 1 - Assessing the Acceptability of the Environment.* ASHRAE transactions Vol. 88, Part 1, 1982.

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[5] Koestel, A., *Computing Temperatures and Velocities in Vertical Jets of Hot or Cold Air.* ASHRAE Transactions, Vol. 60, 385.410, 1954.

[6] Sofrata, H., *An Interactive Program Yields Thermodynamical Properties of Moist Air.* Proceedings of 7th Miami International Conference on Alternative Energy Sources, 9-11, Miami Beach, Florida, USA, December 1985.