IOWA STATE UNIVERSITY
Department of Mechanical Engineering

Frost and Ice Fog Formation and Heat Transfer in Supersaturated Freezer Air

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Abstract

Field observations of the operation of industrial freezers indicate that many are improperly designed as evidenced by large amounts of snow-like formations on the freezer coil and on the walls and ceiling of the freezer itself. These formations result from the presence of ice fog inside the freezer, which is tied to the presence of supersaturated air in the freezer. This condition is more likely to exist at lower air temperatures since the moisture carrying capacity of the air is significantly reduced at those temperatures. As the moisture level rises beyond the saturation amount, the excess moisture can only exist in the form of suspended liquid droplets or suspended ice crystals, depending on whether the temperature is above or below the freezing point of water, respectively. The significance of the presence of air-borne ice crystals in the vicinity of cold surfaces is that they tend to deposit on those surfaces in a predominantly convection-driven process and at a pace commensurate with the amount and speed of the suspended particles. This mechanism is usually coupled with a diffusion-driven mechanism due to the humidity ratio difference between the bulk air and the air in the vicinity of the cold surface. Formations resulting from the convection-driven mechanism have been observed to cause degradation in the coil heat transfer performance at significantly faster rates than those formations associated with the diffusion-driven mechanism. Experimental evidence also suggests a larger defrost energy penalty in the case of accumulations associated with suspended ice crystals. This lecture reports on results of a multiyear investigation at the Wayne K. and Lyla L. Masur HVAC Laboratory at the University of Florida of industrial freezer performance under ice foggy conditions. The lecture is supported by video and still images of formations of the types described above as well as of iced-up coils during defrosting. We wanted to determine the relationship between those formations and the prevailing freezer conditions. We also wanted to search for a demarcation line between snow-like formations and the more traditional formations and to correlate the findings with those predicted using psychrometric theory. We have developed new psychrometric charts that can be used for supersaturated moist air at freezer temperatures. The new body of data generated from this study should help the refrigeration engineer and the industrial freezer operator to avoid ice foggy freezer operation and thus reduce the frequency, duration, and energy penalty of the defrost cycle.

Dr. S.A. Sherif is a tenured Professor of Mechanical and Aerospace Engineering at the University of Florida. He is a Life Fellow of ASME, a Life Fellow of ASHRAE, a Fellow of the Royal Aeronautical Society (RAeS), an Associate Fellow of AIAA, a Member of Commission B-1 on Thermodynamics and Transfer Processes of the International Institute of Refrigeration, and a Member of the Advisory Board of Directors of the International Association for Hydrogen Energy. He is a Founding Member of the Board of Directors of the American Society of Thermal and Fluids Engineers (ASTFE). He served as the 2013-2014 Chair of the ASME Heat Transfer Division and as the 2002-2003 Chair of the ASME Advanced Energy Systems Division. He is Technical Editor of the ASME Journal of Thermal Science and Engineering Applications (2014-2019) and is on the editorial boards of 22 other archival journals. He has 300 refereed publications, 22 book chapters, 20 edited bound volumes, 130 technical reports and two US patents and is the primary editor of the Handbook of Hydrogen Energy.

This seminar counts towards the ME 600 seminar requirement for Mechanical Engineering graduate students.

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