RESEARCH TOPIC ACCEPTANCE REQUEST (RTAR)

Title: ***The Design of Displacement Ventilation Systems Within Industrial Facilities***

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Research Category:	**Research Classification:**
TC/TG Priority:	1st
Estimated Cost & Duration:	$200,000 & 24 months.
Other Interested TC/TGs:	Search for TC/TGs in progress, TC 4.10?
Possible Co-funding Organizations:	None currently identified

Handbook Chapters to be Affected By Results of this Project: Chapters 28 & 29

State-of-the-Art (Background):

The merits of displacement ventilation for industrial premises are well understood. By arranging the ventilation flow paths to be unidirectional, usually upwards, contaminants are efficiently flushed from the occupied space. This increased efficiency leads to a combination of better air quality at a lower cost. The relative improvements of these factors depends on the configuration of the system installed.

As it stands now, most of the research that is been published on displacement ventilation deals with the steady behaviour of a controllable occupied space. The heat loads and air flows are constant. The majority of the work available has been for office or commercial spaces. For instance, one of the results from ASHRAE Research Project (RP 949) was a design methodology for ventilation professionals to use when designing ventilation systems for occupied spaces (Yuan et al., 1999a).

Displacement ventilation has become a popular means for contaminant control in European industrial facilities. Both horizontal (Skistad, 1994) and vertical systems (Akimoto, 1999) are used. Their advantage is that they can maintain an appropriately high level of air quality in the occupied zone while reducing the ventilation costs of more traditional mixing ventilation systems. Despite this, detailed design literature on industrial displacement ventilation systems is scarce.

With few exceptions, the spaces modelled, measured and analyzed in the literature have had static conditions and more or less ideal flow systems. That said, the use of current design guides that assumes static conditions may not provide for a sufficient margin of safety should "off-design" conditions occur. Furthermore, the design guides do not provide any information regarding the ability of a displacement ventilation flow pattern to re-establish itself after being upset.

The studies that have reviewed the transient nature of displacement ventilation and disturbances have identifed some of the issues but not necessarily solutions. For example, in a study of a displacement system in an industrial facility, Niemelä & Koskela (1996) discovered that the establishment of a vertical displacement air patterns in an industrial hall was problematic first thing in the morning when the air temperatures were not favourable to the flow system. In this case, the supply was at the floor and the exhaust at the roof. In addition, the results varied depending on the contaminant. A gaseous contaminant was effectively drawn out of the breathing zone while larger particles were not. Mundt (1994) presents the results of a study of displacement ventilation in a room. The work shows the effect of a disturbance on the breakdown of the displacement pattern and the delay before it re-establishes itself. While the disturbance might not be typical of that in an office, large changes to the flow patterns are observed in industrial facilities from processes and operations within the ventilated environment. Mattson & Sandberg (1994) show that movement within a room, similar to that of a human walking, can have a strong influence on the ventilation flows, and thus effectiveness, within a displacement ventilated room. In a

review of natural ventilation, Linden (1999) includes a discussion on the requirements of a wind driven flow that would be able to break down a stably stratified flow - e.g. displacement ventilation. While he suggests that the level of wind flow is too high to be permitted in a building designed for comfort, it may not necessarily be true for an industrial facility that has large openings.

Thus the state of the art at the moment can be summarized as follows:

1) We understand how displacement ventilation can contribute to energy savings and indoor air quality improvements.

2) There is a far amount of literature on office and commercial spaces, but a lack of specifics on industrial facilities.

3) The studies conducted usually concentrated on the static, or well developed, flow conditions as well as an environment that did not change - e.g. heat loads were constant, no upsetting forces due to process or people movement.

4) The design documents that exist do not provide a means to establish how robust the flow pattern is (e.g. can it be upset by a temporary change in the environment) nor does it provide for factors of safety should "off-design" environmental conditions exist.

Advancement to the State-of-the-Art:

The purpose of this research project will be to focus on the industrial ventilation environment and provide clear direction on that listed below. While it is anticipated that one of the deliverables is a design guide, there is significant work that needs to be done to fill in the missing information. The research project should:

1) Provide a means to identify when displacement ventilation systems will work and when they will not: identify the limitations.

2) Identify the permissible range of operating variability that will permit the system to continue to operate efficiently.

3) Evaluate the ability of the system to recover from a driving force (e.g. conveyor movement, opening of doors, process changes) that causes an adverse disturbance to the flow field.

4) Evaluate the critical system factors to ensure that the occupied zone remains clear of heat and contaminants. These shall include heat loads, contaminant generation rates and building envelope types as a minimum.

Justification and Value to ASHRAE

As it stands now, there are tens of thousands of industrial facilities in North America. This research could impact a significant proportion of these facilities. The ASHRAE membership will benefit from the availability of design proceedures that address both variability and margins of error. In terms of the impact on general society, if a refined ventilation system can address both indoor air quality and energy efficiency at the same time, then there is a clear advantage to the design. However, the research project will also identify conditions underwhich displacement ventilation will not be appropriate.

Objective

The research project deliverables will provide the following:

1) A design guide for displacement ventilation
2) Enhancements in the form of details to Chapters 28 & 29.