ANL/NE-14/13

Computational Fluid Dynamics (CFD) Analyses of a Glovebox under Glove Loss Conditions

Nuclear Engineering

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prepared by
J.L. Bailey – NE Division
P. Strons – NE Division
A.A. Frigo – CSE Division

Nuclear Engineering Division, Argonne National Laboratory
Chemical Sciences & Engineering, Argonne National Laboratory

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1 CFD Analyses of a Glovebox under Glove Loss Conditions

1.1 INTRODUCTION

It is stated in the American Glovebox Society (AGS) publications AGS-G001-2007, *Guideline for Gloveboxes*, and AGS-G006-2005, *Standard of Practice for the Design and Fabrication of Nuclear-Application Gloveboxes*, that an inward-flowing face-velocity of 125 ± 25 linear ft/min be maintained when an access port is opened or if there is a credible breach of a glovebox (e.g., due to loss of a glove). This value for face velocity was chosen based on historical information (See Section 2, Appendix, for more details). Several users of the two AGS documents listed above have questioned this value. In particular, several users have asked if face velocities less than 100 linear ft/min are acceptable. As a result of these inquiries, the technical bases for this AGS-specified requirement were investigated. This investigation is summarized in the appendix.

The results of this investigation indicated, that although this face velocity requirement is cited in many standards, there is a need to provide more theoretically fundamental bases for the value given by this requirement. In order to meet this need, CFD analyses were performed considering several different open gloveport conditions. The following sections describe these analyses including results and conclusions.

1.2 CFD ANALYSIS DESCRIPTION

The commercial CFD computer program, ANSYS CFX (Version 14.5), was used to simulate the flow conditions for several different scenarios. A description of ANSYS CFX is provided in the appendix. A “standard” 36-in. glovebox with an 8-in. diameter open gloveport was modeled and used for all the scenarios. The overall model is shown in Figure 1. The room size was modeled as 12 ft x 12 ft x 12 ft high air space. Supply to the room was assigned 70 cfm and an exhaust boundary condition was set at atmospheric pressure. This pressure boundary assures a near atmospheric pressure in the room under all scenario flow conditions. Exhaust volume flow rate from the glovebox (Shown as 35 cfm) was adjusted in order to indirectly vary the face velocity at the open gloveport. The fluid was assumed to be air at ambient temperature and pressure conditions. All wall boundaries are modeled as “non-slip” conditions and the turbulence modeled used was CFX’s Shear Stress Transport (SST).

1.3 COMPUTER MODELING SCENARIOS AND RESULTS

Two bounding cases are summarized here.

The first is a high-flow case that bounds the maximum face velocity that would not produce back flow out of the open gloveport. The inputs for this case are shown in Figure 1. Note that the exhaust from the glovebox is assigned at 61 cfm in this figure. The velocity vector results at the vertical center plane of the gloveport opening are shown in Figure 2. These results show that, at an exhaust volume flow rate of 61 cfm from the glovebox, an average face velocity of 175 ft/min is produced. Further, that at this face velocity, a recirculation starts to occur in the glovebox and that, in turn, causes the onset of potential back flow out of the gloveport opening.

The second is a low-flow case that bounds the minimum face velocity that would not produce back flow out of the open gloveport. The inputs for this case are shown in Figure 3. A 3 mph cross flow is introduced across the open gloveport, as shown. This velocity is assumed to be the maximum flow disturbance that may be produced by either a person walking by the opening or by a room ventilation system. The velocity vector results at the vertical center plane of the gloveport opening are shown in Figure 4. These results show that, at an average face velocity of 90 ft/min, the cross flow starts to recreate the onset of potential back flow out of the gloveport opening.

1.4 CONCLUSIONS/RECOMMENDATIONS

The CFD analyses confirmed that there are no back-flow containment issues for a glove breach when the face velocity was between 100 and 150 linear ft/min. However, at face velocities of 90 ft/min and below, and at 175 ft/min and above, there are back-flow containment issues. Therefore, based on these CFD analyses, it is concluded that the AGS-specified face-velocity value of 125 ± 25 linear ft/min should continue to be used as a requirement in the event of the loss of a glovebox glove.

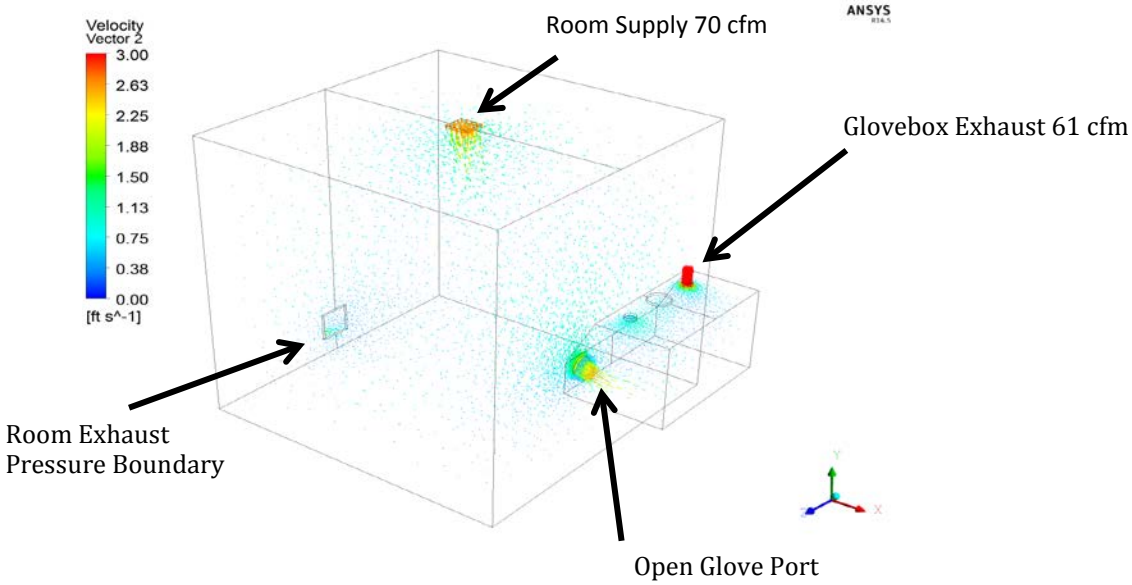

Figure 1, CFX Model Input for High Velocity Case

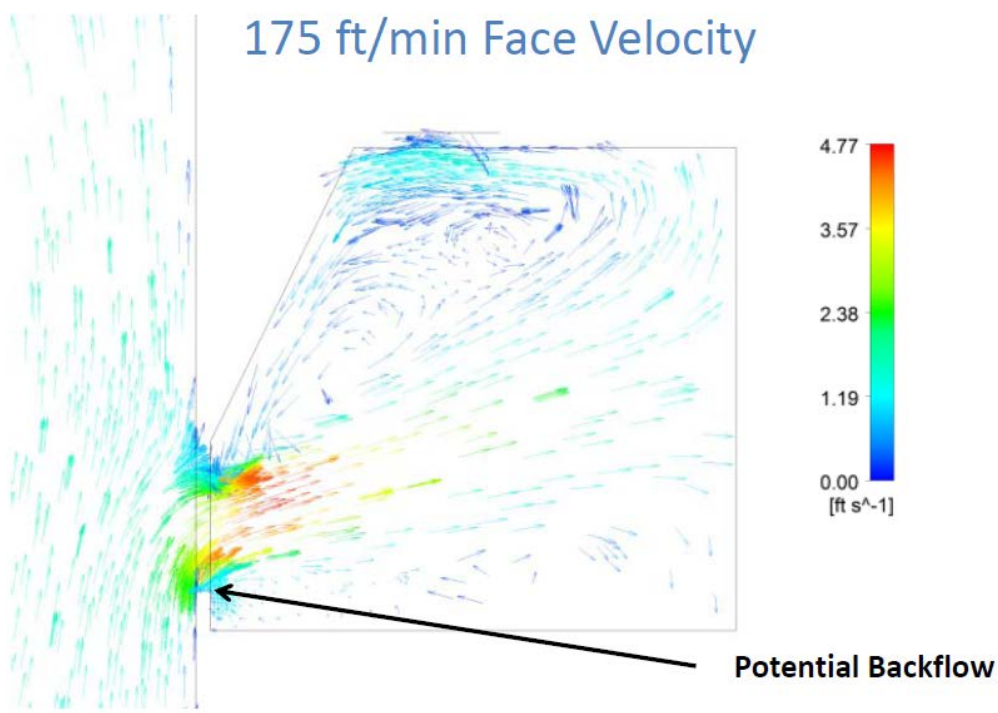

Figure 2, CFX Results for High Velocity Case

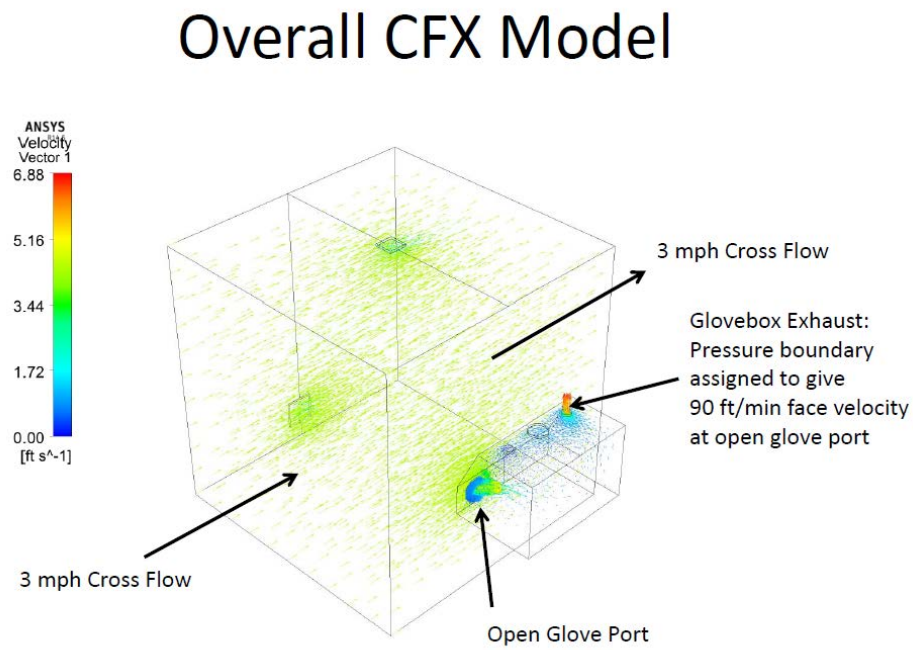

Figure 3, CFX Input for Low Velocity Case

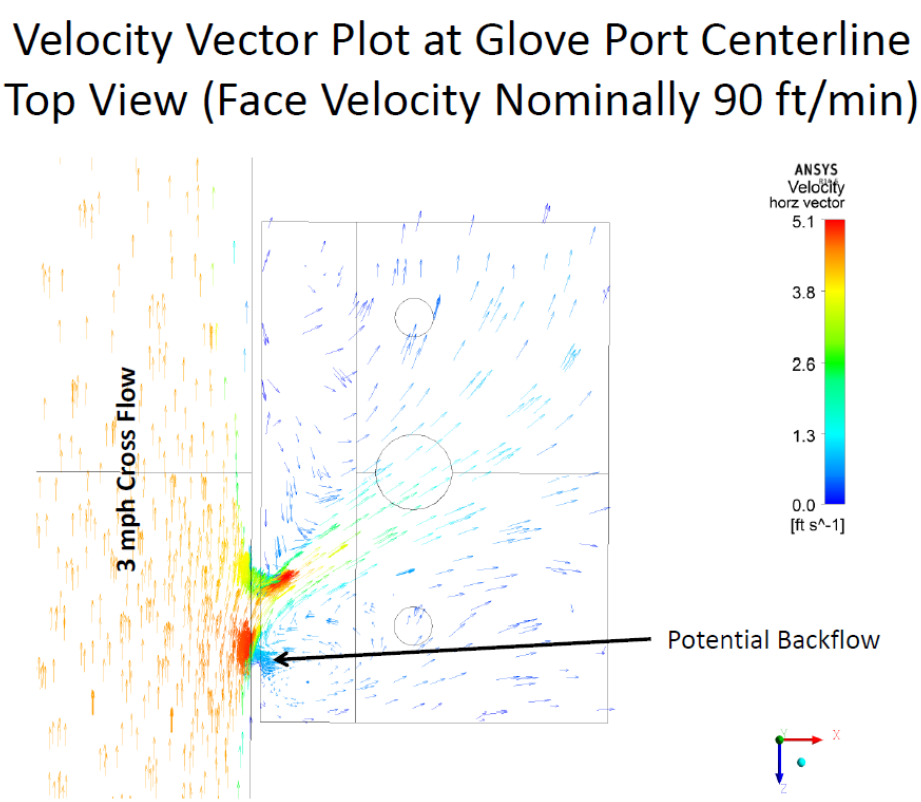

Figure 4, CFX Results for Low Velocity Case

2 Appendix

2.1 HISTORICAL PERSPECTIVE

W. Dean Shipley, former chairperson of the American Glovebox Society (AGS) Standards Development Committee (SDC), provided to the authors the historical basis for the selection of 125 ± 25 linear ft/min as the velocity range to be maintained when an access port is opened or if there is a credible breach of a glovebox.

In summary, Shipley refers to the work of Burchsted and Fuller (see Reference ORNL-NSIC-65). They worked at ORNL and conducted research on proper ventilation for nuclear-related applications. This work was used as the basis for DOE-HDBK-1169-2003, *Nuclear Air Cleaning Handbook*

- On Page 6.3 of ORNL-NSIC-65, relative to the issue of an open gloveport, it gives a value of 35 cfm (minimum) for a single open 8-in. diameter gloveport for a 3-ft long glovebox. For an 8-in. gloveport, this flow requires a face velocity of 100 linear ft/min.
- The AGS used this information to establish the minimum recommended face velocity through an open gloveport. Using the experience of the members of the SDC, it was agreed that the breach velocity should be 125 ± 25 linear ft/min.

ERDA 76-21 further supports the 125 ± 25 linear ft/min recommendation. This reference also provides part of the basis for the choice of the AGS requirement of 0.5% of glovebox volume per hour allowable leak rate that is recommended in AGS-G001 (a 2x safety factor relative to ERDA 76-21). In AGS-G006-2005, the safety factor was increased, requiring a leak rate of less than 0.3% of the glovebox volume.

The AGS documents provide guidance and requirements that the AGS SDC believe will provide protection in the event of a glove breach. Anyone with special needs can conduct research to justify different requirements.

Additional background information is provided in the following references:

- L. R. Kelman, W. D. Wilkinson, A. B. Shuck, and R. C. Goertz, Argonne National Laboratory, The Safe Handling of Radioactive-Pyrophoric Materials, ANL-5509, December, 1955
  - Pg. 41: Discusses window removal only (not open gloveport); states that a velocity of 150 ft/min is the minimum value to prevent the outward diffusion of contaminated particles.

- United Kingdom Atomic Energy Authority, Glove Boxes and Shielded Cells for Handling Radioactive Materials, Proceedings of the Symposium on Glove Box Design and Operation held in the Cockcroft Hall, A.E.R.E, Harwell, February 19-21, 1957 (Note: This is the “textbook” about gloveboxes)

- Pg. 173: L. R. Kelman, "Procedure at Argonne National Laboratory" (This paper presents the same information as given in ANL-5509.)

- C. A. Burchsted and A. B. Fuller, Oak Ridge National Laboratory, Design, Construction, and Testing of High-Efficiency Air Filtration Systems for Nuclear Application, ORNL-NSIC-65, January 1970
  - Pg. 2.7: 150 ft/min and may be 200 ft/min for hazardous operations
  - Pg. 2.8: Capacity of exhaust system shall be sufficient …… to maintain a face velocity of at least 100 to 150 ft/min through one open gloveport … in the event of a glove rupture to prevent escape of contaminants.

- C. A. Burchsted, J. E. Kahn, and A. B. Fuller, Oak Ridge National Laboratory, *Design, Construction, and Testing of High-Efficiency Air Filtration Systems for Nuclear Application*, ERDA 76-21, March, 1976
  - Pg. 16: For gloveboxes, airflow shall be sufficient to provide at least 5 scfm to the glovebox and to maintain an inward velocity of at least 100 linear ft/min through one open gloveport...in the event of glove failure.
  - Pg 16: For chemical fume hoods, a face velocity of 100 linear ft/min is recommended for operations with radioactive materials; 150 ft/min is desirable.

- U. S. DOE, DOE Handbook, *Nuclear Air Cleaning Handbook*, DOE-HDBK-1169-2003, November, 2003
  - Table 2.7: Airflow must be sufficient…to maintain an inward velocity of at least 125 ft/min (with higher velocities mandated by some operators for gaseous effluents) through one open gloveport in every five gloveboxes in the system. **(Note: The selection of this value is based on AGS-G001-2007)**
  - Section 7.2: Airflow of 125 ± 25 linear ft/min through a breached (8-inch diameter) gloveport will maintain confinement. **(Note: The selection of this value is based on AGS-G001-2007)**

Argonne National Laboratory conducted infrared imaging studies of air currents in 2001. These studies focused on fume hoods and vacuum frame hoods. It was determined that a face velocity of 100-150 ft/min is required to maintain containment; values higher than 150 ft/min could cause backflow towards the operator. This study referenced the ANSI Z9.5 laboratory ventilation standard. Argonne National Laboratory currently requires a value of 125 ± 25 ft/min for face velocity of an open gloveport, which is based on experience and tests performed at various laboratories and glovebox manufacturing facilities. This requirement references American Glovebox Standard of Practice AGS-G006-2005.

2.2 ANSYS CFX SOFTWARE DESCRIPTION

ANSYS CFX software is a high-performance, general purpose fluid dynamics program that has been applied to solve wide-ranging fluid flow problems for over 20 years. At the heart of ANSYS CFX is its advanced solver technology, the key to achieving reliable and accurate solutions quickly and robustly. The modern, highly parallelized solver is the foundation for an abundant choice of physical models to capture virtually any type of phenomena related to fluid flow. The solver and its many physical models are wrapped in a modern, intuitive, and flexible Graphical User Interface (GUI) and user environment, with extensive capabilities for customization and automation using session files, scripting and a powerful expression language.

Nuclear Engineering Division
Argonne National Laboratory
9700 South Cass Avenue, Bldg. 362
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