Using CFD to Determine the Impact of a Propeller Fan on Exhaust Hood Performance

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ABSTRACT

Using CFD to Demonstrate the Impact of Propeller Fan on Exhaust Hood Performance

IH and safety professionals know that propeller fans can significantly disrupt the capture efficiency of an exhaust hood. Despite this knowledge, propeller fans directed at exhaust hoods are still commonly seen in many work settings.

In the present case, high exposure levels were detected during a thermal cutting operation. CFD analysis is used to demonstrate the significant impact the propeller fan has on hood performance and the improvements possible if the fan is eliminated or replaced. The analysis was validated using exposure monitoring data.

The CFD output in the form of easily understandable graphical images may be helpful to educate operators, supervisors, facility engineers and managers about propeller fans so that work practices and process setups will be modified. Significant reductions in exposure levels are possible.

BACKGROUND

During an IH survey, a thermal cutting operation (air-carbon arc) was observed. No visible fume was apparent, but a 30" diameter, wall-mounted propeller fan located ~20' away and directed at the exhaust hood was very noticeable. The operator said that the propeller fan was needed to control the fumes and to provide cooling.

A personal sample was collected during the normal process, i.e. with the propeller fan on. After an hour, the filter had significant discoloration. The operator was asked to conduct the process with the propeller fan off. A new sampling filter was put in place. Two hours later, much less filter discoloration was observed – suggesting that use of the propeller fan significantly increased exposure. The operator and the supervisor were notified of the initial findings and advised to consider options to eliminate the propeller fan. In the interim, the operator preferred to continue using the fan.

The sample results were as follows:

	Fan On	Fan Off	TLV
Total Particulate (mg/m^3)	20	3	3 – 10 (depends on particle size)
Copper (mg/m^3)	0.2	0.03	0.2
Sample Time (hr)	2	2	

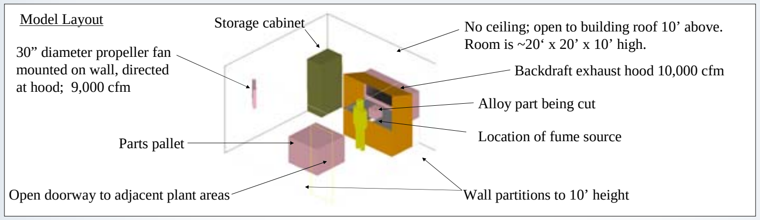
The sample results confirmed the initial conclusions – use of the propeller fan significantly increased exposure. However, even with the fan off, exposure levels could exceed the TLV. A formal recommendation to eliminate the propeller fan and to reduce exposure levels was presented.

PROBLEM

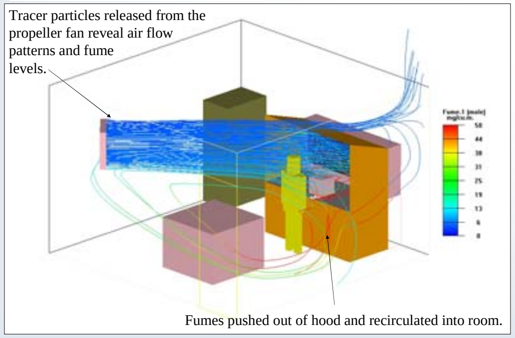
- Can CFD analysis be used to help operators and supervisors visualize the impact of the propeller fan?
- Can alternative setups be shown to be more effective?

ANALYSIS

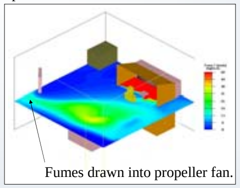
A computational fluid dynamic (CFD) model of the process area was constructed using a commercially available software package. The general layout of the model is shown in the figure below. The process area is enclosed by 10' high walls to protect adjacent work areas, but the ceiling is open up to the building roof to allow replacement air to enter from adjacent areas. Though not shown in the figures to save space, the modeled area includes this open space above the room. The model also includes a point source that releases a continuous flow of fumes and heat energy to simulate the thermal cutting process. The model was solved to produced steady state solutions for the Propeller Fan-On and the Propeller Fan-Off conditions. The dimensions and flowrates for some of the components were estimated because data from the site were not available; hence the model is similar to but not an exact representation of the actual conditions. The objective of this project was to demonstrate the impact of the propeller fan, not to perform definitive work on exposure control for this particular thermal cutting process.



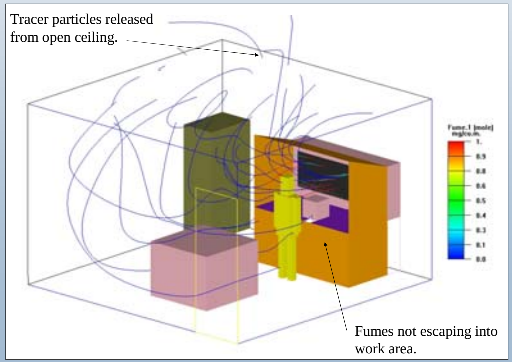
Model Output – Fan On Condition



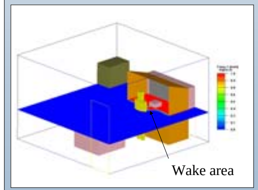
Horizontal cut plane showing predicted fume levels.



Model Output – Fan Off Condition



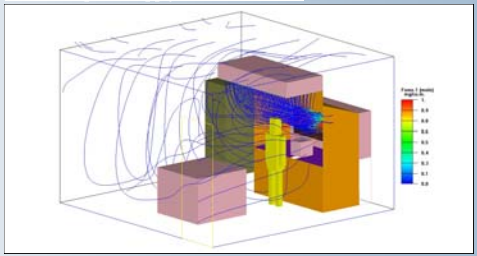
Low fume levels in room except in wake area in front of worker.



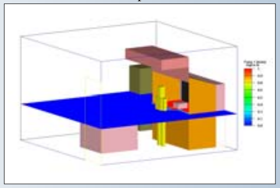
SOLUTIONS

The sampling data and the CFD modeling clearly show that exposure levels are significantly lower during the Fan Off condition. However, the operator was reluctant to accept the Fan Off condition stating that a more direct flow of cooling air was needed because of the heat and fumes produced. To evaluate a possible alternative, a supply air plenum was added to the CFD model directly over the operator's working position. All other components in the model were held constant. The width of the plenum extending out from the hood and the quantity and temperature of supply air were varied in an attempt to achieve an optimum configuration.

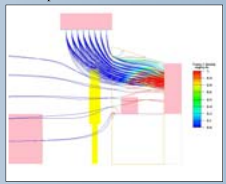
Model Output – Supply Air Plenum - On



Low fumes level except in wake area.



Flow patterns and fume levels.



CONCLUSIONS

- Significantly higher fume levels in the room were predicted by the CFD modeling during the Propeller Fan – On condition compared to the Fan-Off condition. (Monitoring data showed a similar pattern.)
- CFD model output reveals that fumes are pushed out of the hood, drawn toward the propeller fan and recirculated in the room. (Fumes were not visible in the room nor was the worker aware of the problem until air monitoring was conducted.)
- Model output shows that a supply-air plenum mounted over the worker would provide the desired direct flow of cool air on the worker without increasing exposure.
- Elevated fume levels are predicted by the model in the wake area in front of the worker in all cases. Fumes in this zone likely cause worker exposure. Modifications to the exhaust hood configuration would have to be considered to reduce these concentrations.
- Full-page color printouts of the model output can be used to help operators, supervisors and plant engineers visualize the impact of the propeller fan and understand how a supply-air plenum would improve conditions. Brainstorming could lead to other configurations.
- Additional CFD modeling could be performed to optimize the designs of the exhaust hood and the supply-air plenum to minimize exposure and to achieve the desired working conditions.

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