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Investigation of Pressure differences in the SNO Laboratory

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1 Introduction

The main goal of the SNO air system is to prevent dusty mine air from entering the Lab. This is accomplished by maintaining a positive pressure inside with respect to the drift just outside. A total of six air handler units (AHU's) filter, cool, and dehumidify, as well as providing the pressure drops across the Laboratory doors that keep the dirty air out. In addition, a set of exhaust fans remove some of the lab air (such as moist air from the car wash), and make-up air is provided from the only external AHU, AH5, which directly feeds four of the internal AHU's (1,2,3 and 4). The pressure drops from room to room have been adjusted so that the global pressure maximum is the deck and cavity. Figure 1 shows a schematic view of the SNO air system.

We investigated the pressures inside the Lab, both across specific doors and between the deck and the drift, under various test conditions that mimicked natural pressure fluctuations such as AHU downtime, power outages, and the opening and closing of doors. Although the pressures remained positive (with respect to the drift) for nearly all of the tests, two signifcant problems were found and recommendations are made here for their solution. In addition, visual inspection of doors and air handlers were made, and some suggestions are

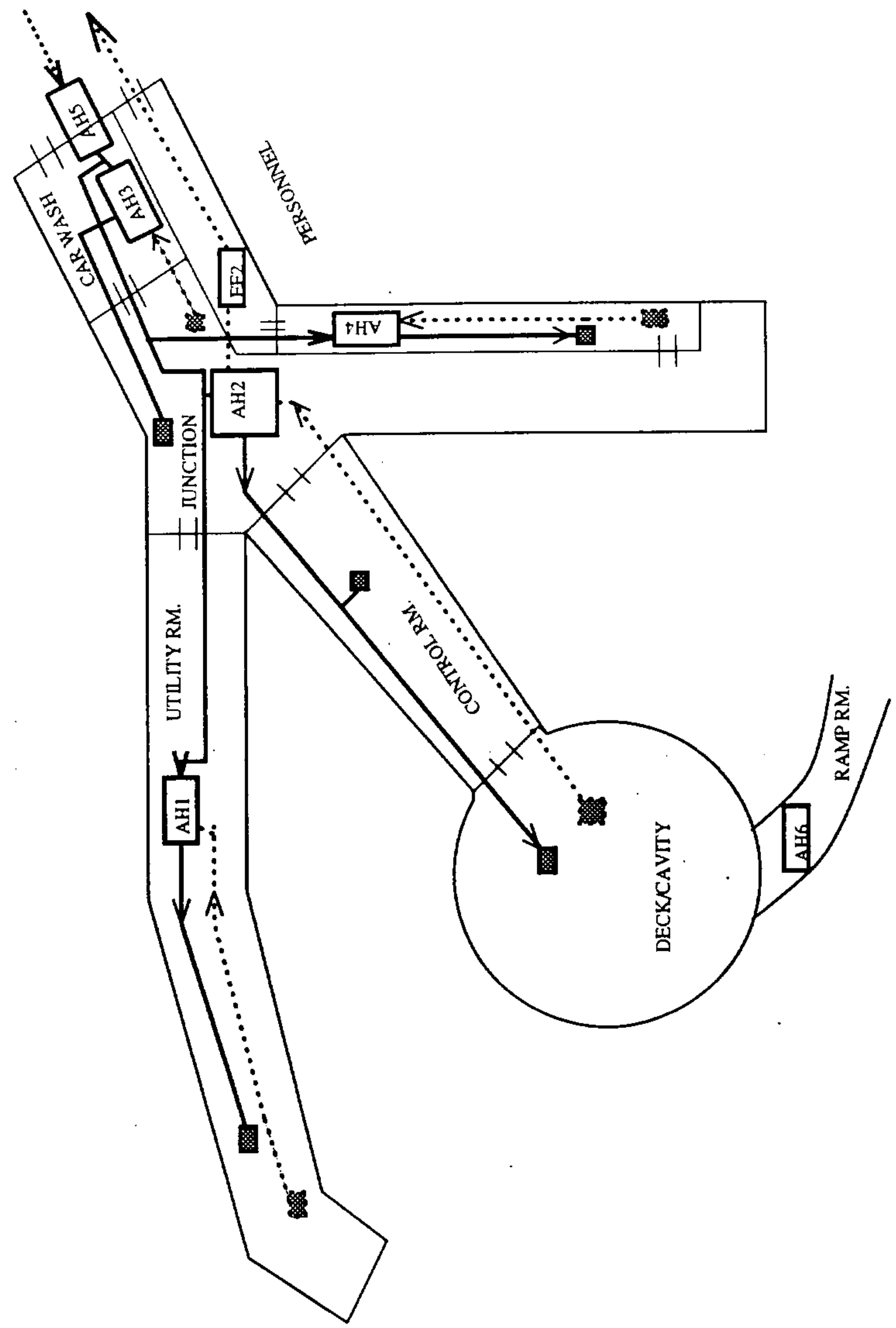

Figure 1: Schematic sketch of Air Handling System in SNO Laboratory.

also presented here for smaller improvements in pressure maintenance and monitoring based upon those inspections.

2 General Results

Table 1 compiles some of the measurements of changes in Δp (the pressure between the deck and the drift) made using the CMA system. Under normal conditions, Δp hovered around 0.85, with the opening and closing of doors (particularly the door opening between the deck and the control room) typically producing fluctuations as large as 20%. Turning off AH5 had the largest effect of any of the air handlers, bringing Δp down to roughly 0.07 inches of H_2O (see Figure 2), and AH2 (the AHU that directly feeds the deck and cavity) was a distant second bringing Δp to about 0.31 in. H_2O. This is not surprising, given that AH5 is in direct contact with the outside pressure and serves to offset the entire lab from the drift.

The time constant for pressure changes in the lab when AHU's were turned off or on fell between 30 and 40 seconds, with changes due to the deck door opening being somewhat smaller. The opening of the car wash door (to the drift) when all AHU's and EF's were on was a small effect ($< 10\%$), with a fall time characteristic of the lab.

Table 1 also shows two different endpoints for the final Δp when AH5 was turned off, 0.07 and 0.19. The difference in these two cases was a sticky damper between the line from AH5 to AH2. When AH5 is off, the damper should shut to prevent mine air from being drawn by AH2 through AH5. However, the damper occasianally stuck in the open position, producing a Δp somewhat higher than when closed. The damper was flaky enough that sometimes a door slamming could close it, with the subsequent drop in pressure seen on the CMA, and should be fixed if its use will continue.

3 Leaks and Doors

The best way to ensure that the Lab remains free of dift air during large drift pressure swings is to continue sealing the front entrance and ramp entrance. Visual (and tactile) inspection determined that air flows freely out of the lab through the open gutters, from below the doors, and around pipes. The current set of flaps on the gutters and surrounding

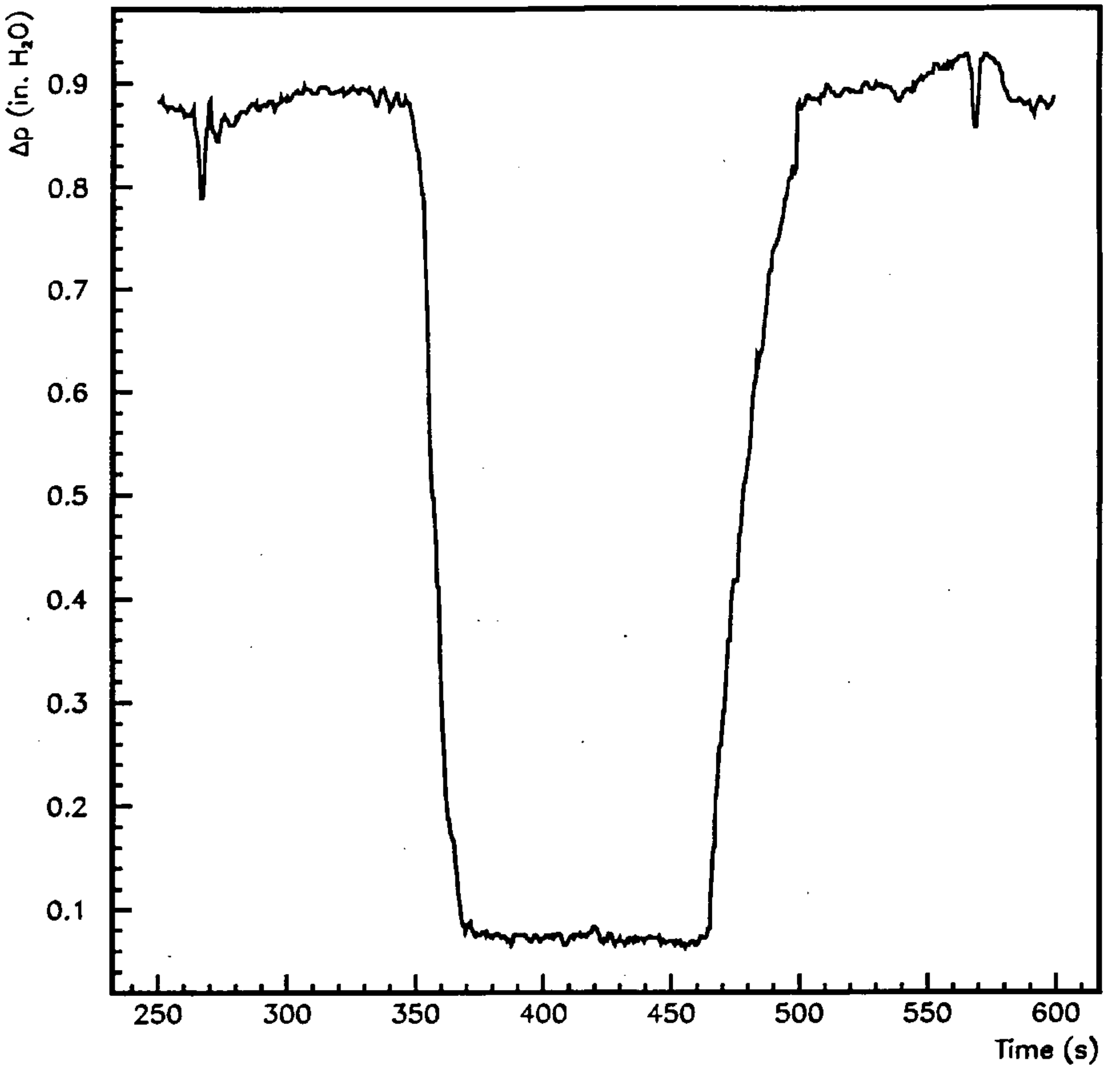

Figure 2: Fall and rise of Δp with AH5 turned off and on.

Table 1: Data Taken in Lab for Studies of Δp.

Condition	Δp_i (in. H_2O)	Δp_f(in. H_2O)	Rise/Fall (s)
All AHU's On	0.85 ± 0.03	0.85 ± 0.03	—
Deck Door Open	0.85 ± 0.03	0.69 ± 0.03	15 ± 5
AH5, EF's Off	0.85 ± 0.03	0.07 ± 0.03	27 ± 1
AH5, EF's Back On	0.07 ± 0.01	0.08 ± 0.03	44 ± 5
Just EF's Off	0.88 ± 0.03	1.15 ± 0.05	40 ± 3
EF's Off, AH5 Off	1.13 ± 0.05	0.07 ± 0.03	53 ± 5
AH5, EF's Off	0.87 ± 0.03	0.19 ± 0.03	26 ± 1
AH5, EF's Back On	0.18 ± 0.01	0.88 ± 0.03	50 ± 2
Car Wash Door Open	0.87 ± 0.03	0.76 ± 0.04	40 ± 2
AH2 Off	0.85 ± 0.03	0.31 ± 0.03	30 ± 5
All AHU's Off	0.85 ± 0.03	0.02 ± 0.01	42 ± 1
All AHU's Back On	0.02 ± 0.01	0.92 ± 0.05	35 ± 5
AH 1,2,3,4 Off	0.78 ± 0.03	0.60 ± 0.1	31 ± 8
AH 1,2,3,4 Off, 5 Off	0.59 ± 0.06	0.014 ± 0.005	36 ± 3

the pipes on the front entrance are inadequate and should be replaced with stiff hinged flaps where possible to allow some flow of air outwards but preventing any from flowing back in during negative pressure swings from blasts or power failures. On the door to the ramp clean room, a simple flap on the drift side blocking the crack between the doors would accomplish the same thing there.

Within the lab, the door from the control room to the deck must be fixed. Currently, it will not close by itself, and therefore is often left open accidentally. Since this door has the largest effect on the differential pressure between the deck and the drift—roughly 20%—keeping it closed should improve air quality in the cavity.

4 Car Wash

The car wash is the most vulnerable spot for SNO in terms of the potential for dirty air to enter the Lab. As described in Section 2, when AH5 is turned off for maintenance (such as filter changes), a damper in the make-up line connecting AH5 and AH2 (the AHU which feeds the deck and cavity) closes to prevent drift air from being pulled passively through AH5. In this situation, the pressure on the deck relative to the drift (Δp) drops from an average of 0.85 ± 0.05 to 0.07 ± 0.03, reflecting a drop in the pressure of the lab as a whole. When this is the case, opening the car wash doors becomes particularly dangerous since the differential pressure between the car wash and the drift at that time is very low (< 0.01 in. H_2O). However, opening the door to the junction raises the pressure in the car wash, indicating that there is enough presure in the lab (probably due here to AH3) to force air out of the car wash even when AH5 is down. Alternatively, when the damper from AH5 to AH2 is not closed, the pressure in the car wash does remain positive (~ 0.2 in. H_2O), indicating that drawing air from the drift into the lab allows some pressure to remain.

At the very least, a procedural change must be implemented, requiring that the car wash doors to the drift not be opened during AH5 downtime. However, a much better solution would be to have ducting from AH3 routed into the car wash to allow it to remain postive during AH5 downtime, just as the junction remains somewhat positive. Currently, no supply air feeds the car wash, although an exhaust fan does remove some of the dirty air when the doors to the drift are closed. The alternative to ducting AH3 in to the car wash would be to allow the door from car wash to the junction to remain leaky, but this runs the obvious risk of allowing dirty air from the wash to enter the junction during large pressure swings.

5 Exhaust Fan 2

The most significant problem found in the system was the intake of air through the fan intended to exhaust the deck and cavity (EF2). Currently, EF2 is ducted directly into the return of AH2. During normal operation, there is enough air from the cavity return and AH5 to allow EF2 to steal some to exhaust into the drift. However, with AH5 off (EF2 turns off when AH5 is off), the pull from AH2 is enough to draw air through the ducting of EF2 directly from the drift. This air has not had the benefit of any filtering (as has the make-up air that travels through AH5) and therefore the filters and interior of AH2 can become dirty quickly, running the risk that the pressure in the cavity and deck area will drop. The solution to the problem is to duct EF2 directly to the deck area, where it will not be in direct conflict with the intake of AH2. This may reduce the pressure on the deck area by a very small amount, but will help exhaust air which may become dirty due to construction in the cavity or deck.

6 Return for AH3

Air handler 3 (AH3), the AHU which feeds the junction, currently has no ducted return but instead has open dampers which intake air directly from the air handler's surrounding environment. Unfortunately, AH3 is contained in a fairly cramped space, directly behind a wall separating the lab from the (very leaky) space containing AH5. Therefore, the large negative draw of air into AH3 will produce a locally negative pressure drop with respect to the drift, which in turn can draw drift air in through cracks and leaks in the wall. The recent caulking of the cracks in this area is a step in the right direction, but a better solution would be to duct the return of AH3 so that it draws from the Junction instead of from the area directly adjacent to the air handler. Without this re-ducting, more care will have to be taken to ensure that the wall between AH3 and AH5 remains sealed.

7 Negative Excursions

Two conditions can naturally produce negative excursions in Δp—power failures in the mine and the lab, and blasts. Both of these have been recorded by the current CMA system and appear to behave as one would expect given the different time constants for pressure changes of lab and drift. The only way to decrease the effects on cleanliness of such events is to further seal the lab entrance in the hopes that air coming in will travel through the filters of AH5 rather than through unfiltered leaks and holes. In the case of blasts, where the pressure changes are short-lived, this may prevent a significant amount of dirty air from entering the lab.

However, at least one example exists of Δp going negative with no change at all in the absolute pressure in the drift. Through exhaustive tests with various air handlers and exhaust fans turned on and off, we were only able to produce such an excursion when the entire system was being turned on after having been off. Figure 3 shows this negative event, and the delays in various AHU's turning on can be seen in the distinct peaks in the turn-on curve. The most likely explanation for such an excursion is a delay in the turn on of the air handlers with respect to the exhaust fans—perhaps due to the slow opening of dampers, for example. The fact that we were unable to reproduce the effect in subsequent trials indicates that it only occurs when the system is in a particular state and is not a general feature of the turn-on curve. In any case, the excursions seem to be brief and rare events. Maintaining good seals (closed doors) between the rooms within the lab will minimize the effects of these short-lived events.

In addition, the planned control of the exhaust fans through a feedback from a Δp measurement between the junction and the drift may eliminate the problem. With Δp low, the exhaust fans would remain off until the air handlers raised the pressure, at which point the chance of a negative excursion would be very small.

8 Inspection, Maintenance, and Monitoring

Visual inspection inside and around the air handlers uncovered the potential for future problems which should be inspected and in some cases fixed. AHU's 1, 2, and 3 had intake dampers set so that no air flowed through the condensers and therefore the air was not

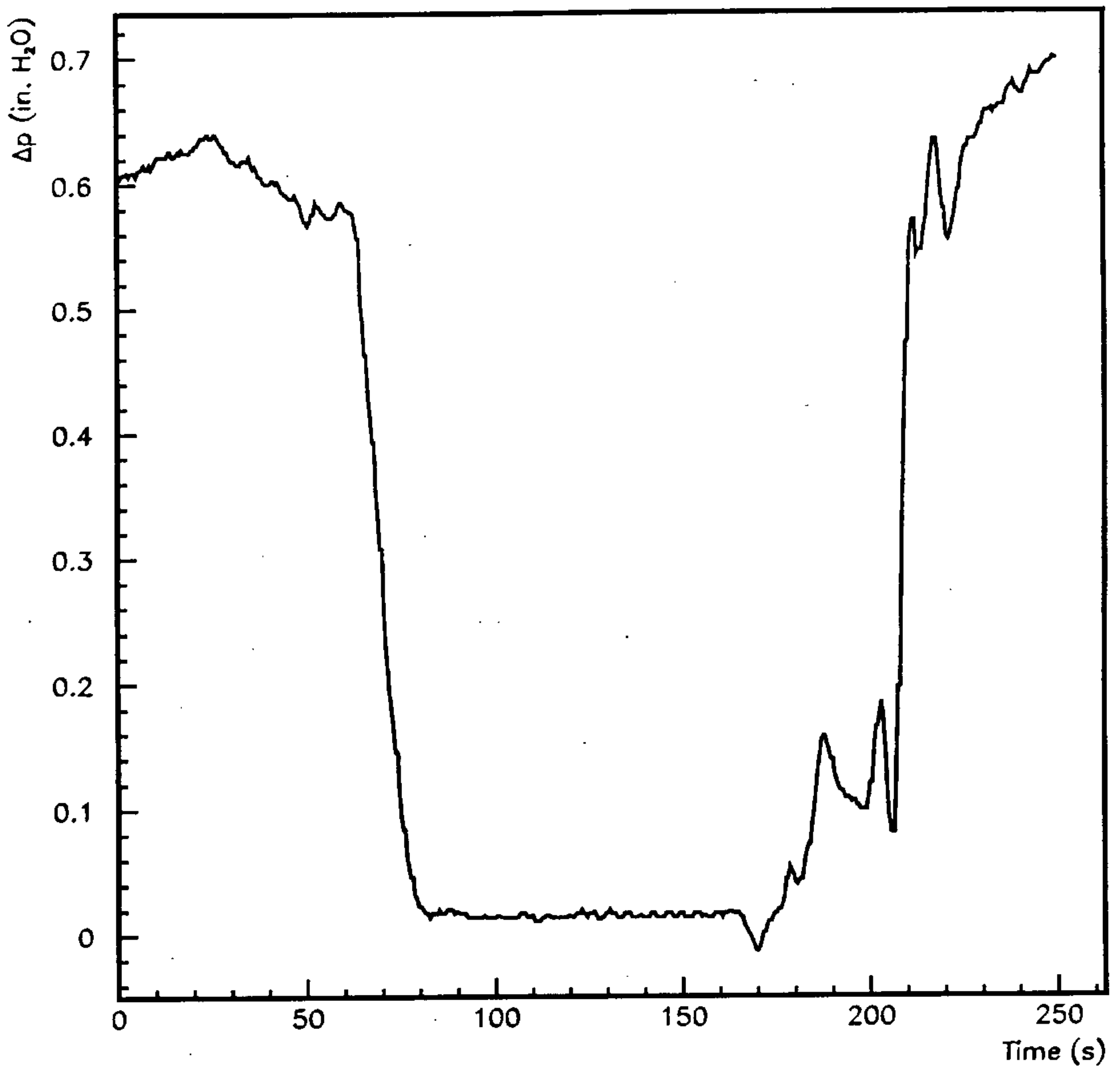

Figure 3: Negative Excursion Produced with Turn On of Air System.

being dehumidified or cooled with these units. While the humidity and temperature of the lab have been measured to be within the design range despite this condition, the current setting of these intake dampers should be checked and understood to ensure that they are operating properly. In addition, if not already planned, a monitor of laboratory humidity and temperature should be added to the CMA system to study ther daily fluctuations in correlation with each other and with the pressure inside the lab.

The interior of the air handlers is also very dirty (AH2 in particular due to the problem with EF2 mentioned earlier). Although in principle the dirt will stay inside the unit or be caught in the filters, during maintenance the doors to the housing are opened and the dirt may enter the lab. Therefore, if not already done, regularly scheduled inspections and cleanings of the AHU's interiors should be undertaken, concentrating on the output end of each unit. In addition, although particle counts are taken near the supply outputs of the air handlers to determine air quality, a continuous monitor of particle counts should be added to the CMA system if possible. A small piece of filter paper should also be placed in the output of each air handler to collect dirt and act as a 'common sense' monitor of air quality. In this way we can monitor the integral of the particle count, a quantity much more important for SNO than an instantaneous measurement.

Lastly, the caulking and welds of the AHU housings should be inspected to ensure that there are no leaks. AH1, for example, appeared to have several holes in the base of its housing, potentially allowing dirty air to escape into the utility room.

9 Summary of Recommedations

I would like to thank several people for their help in this project: Reg Michaud, Jon Hykawy, Dennis Kowalski, Rob Price and Duncan Hepburn.

The following is a list of the recommendations made in the text:

- Seal entrances to the lab using 'check-valve' type flaps.
- Fix door from control room to deck so that it closes by itself.
- Fix/inspect flaky damper in line from AH5 to AH2.
- Duct AH3 into car wash to maintain positive pressure with AH5 off.

- Re-duct EF2 to exhaust directly from deck, not AH2.
- Add ducting to take return of AH3 from junction.
- Add continuous monitors of humidity, temperature, and particle count to CMA.
- Add passive filter as monitor to supply air from AHU's.
- Inspect welds and caulking on AHU housings and fix leaks and cracks.