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IPRO 336 Final Report

Developing Innovative Design Concepts for Airflow, Energy Sustainability & Fire Protection Safety in Buildings

April 26th, 2007

IPRO 336 It takes a team
INTERPROFESSIONAL PROJECTS PROGRAM

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Table of contents

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Introduction

The IPRO 336 team performed an original experimental study which helped to determine the consequences of the ~~effects of~~ stack effect phenomenon on ~~the~~ pressure distribution and ~~the~~ airflow movements within ~~high rise~~high-rise buildings. Specifically, the team was concerned with the effect that the phenomenon has on the movement of ~~the~~ smoke (in case of a fire) and pollutant gases, which are directly related to the safety of the building inhabitants. Besides the experimental study, a review of the smoke control design process in buildings has been performed through a~~the~~ series of interviews with experts in the Chicago area. Based on the experimental study, the information collected from the team's faculty advisor, Dr. Megri, and the interviews, a flowchart that depicts the innovative design process of smoke control in buildings has been developed.

As a part of this project, the team:

- Quantified the effect of pressure variation due to stack effect on airflow diffusers
- Characterized the airflow diffuser
- Performed the air-tightness measurement of the building envelope
- Measured the airflow, pressure difference, temperature, relative humidity and air velocity which helped to determine the thermal comfort indices (PMV, PPD and others)
- Delivered a descriptive report of consequences~~effects~~ that stack effect has in case of fire, and prescribed possible solutions
- Created an original flow chart that describes the design process of smoke control systems based on interviews with experts in the field~~.~~

Background

Glossary of nomenclature used in the project:

a:	atmospheric pressure (psi), (Pa)
A:	opening area (free area of inlet opening, which equals area of outlet opening) (ft^2), (m^2)
C:	0.0342 (SI unit), C= 0.0188 (PI, U.S. customary units)
Cd:	discharge coefficient (usually taken to be from 0.65 to 0.70)
g:	gravitational acceleration, 9.807 m/s^2, 32.17 ft/s^2
Q:	flow rate induced by the stack effect (stack effect draft/draught flow rate), (cfm), (m^3/s)
Ti:	average inside temperature, (°R), (K)
To:	absolute temperature, outside, (°R), (K)
ΔP_s:	available pressure difference, (psi), (Pa)

~~Following~~ The following paragraphs will provide background information on stack effect.

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Stack pressure (~~sometimes~~ also called chimney pressure) is caused by the difference in temperature (fluid density difference) between the ~~outside and the inside air of the buil~~air outside and inside of the building~~ding~~. This density difference produces an imbalance which results in a vertical pressure difference. At the height of the neutral pressure plane the air pressure ~~is equal~~ at the exterior and interior of the building is equal. Figure 1 illustrates this phenomenon, showing a negative pressure difference ΔP_s over the building envelope at the top (air is sucked out of~~from~~ the building), and a positive one at the bottom of the building (air is pressed into the building). That pressure difference ΔP_s is the driving force for the stack effect and it can be calculated with the equations presented below.

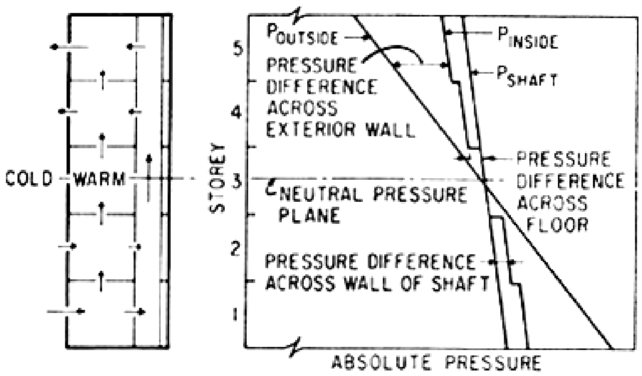

Figure 1: Stack pressure distribution on the two sides of the wall and the resulting pressure difference.

The pressure difference at the vertical distance z, in the downward direction, from the neutral pressure plane is:

$$\Delta P_s = z.(\rho_e - \rho_i).g$$

Here, ρ_e is the external air density, and ρ_i is the internal one. This can be expressed using temperatures and the ideal gas law as:

$$\Delta P_s = 3456.z.(\frac{1}{T_e} - \frac{1}{T_i})$$

Here, the exterior and interior temperatures Te and Ti shall be given in degrees Kelvin.

The vertical distance z, may be expressed as follow:

$$z = Hn - Hb$$

Hn is the height of "neutral pressure point" (for simple systems, assume 1/2 way between top and bottom openings) and Hb is the height of bottom opening.

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The equations apply only to buildings where air is both inside and outside the buildings. For buildings with one or two floors, *z* is the height of the building. For multi-floor, high-rise buildings, *z* is the distance from the openings at the neutral pressure level (NPL) of the building to either the topmost openings or the lowest openings. The pressure level in~~at~~ the building as a function of the vertical distance z is demonstrated in the Figure 2.

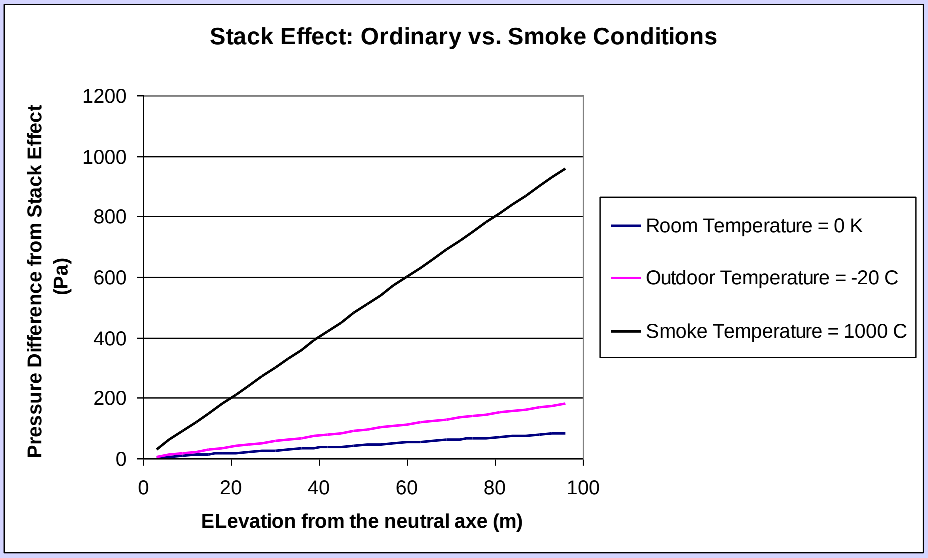

Figure 2: Stack effect for ordinary vs. smoke environments

Comment [KTH1]: In this chart, "ELevation" needs to be fixed and consistent units should be used in the legend.

The rate of air flow depends on several factors: the inside and the outside air temperatures, the area of the openings, and the vertical difference between the top and bottom openings. The equations presented in Table 1 may be used to determine the flow induced by the stack effect.

	ΔPs (pressure difference)	**Q (flow induced by the stack effect)**
Different formulation of pressure difference and flow	$\Delta P_s = z.(\rho_e - \rho_i).g$ $\Delta P_s = 3456.z.(\frac{1}{T_e} - \frac{1}{T_i})$ $\Delta P = C.a.z.\left(\frac{1}{To} - \frac{1}{Ti}\right)$ **(ASHRAE, 1997)**	$Q = k.\Delta P^n$ (COMIS and CONTAM Programs) K and n are determined experimentally $Q = 60.Cd.A.\sqrt{2.g.z.\frac{Ti - To}{Ti}}$

Table 1: Different formulation of pressure difference and flow

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Stack effect can also be used in positive ways. One common use for stack effect is the nighttime flushing of a building's interior, in order to~~of~~ cool~~ing~~ it for the next day. Stack effect can also be used to ventilate a building that has a temperature difference between the interior~~side~~ and ~~the~~ exterior~~outside~~. If the openings are properly placed (an opening high in the building and another low in the building) a natural flow will be initiated. If the air inside the building is warmer than the outside, this warmer air will flow~~oat~~ out of the top opening, and will be ~~ing~~ replaced with cooler air from outside through the bottom opening. If the air inside is cooler than that of the outside, the cooler air will drain out through the lower opening, while being replaced with warmer air from outside through the top opening.

Purpose

Stack effect is a dilemma commonly found in all high rise buildings. This dilemma a~~e~~ffects the distribution of pressure and air flow within the building. Stack effect ~~also has negative effects consequently~~ can caus~~eing~~ life safety concerns in the event of a fire erupting in a tall building. With the understanding of stack effect, a more sufficient mechanical design of ~~, including the~~ fire protection and smoke control systems ~~,~~ can be prepared.

With the devise of two independent experimental studies, the IPRO 336 group ~~expected to~~ accomplished the understanding of stack effect and how it affects the air flow sustainability in buildings. Using Mathcad 13, a program was~~will be~~ developed to establish the location of the neutral axis in a building based upon the building's parameters. The use of CONTAMW was ~~would be~~ suitable for the modeling ~~of~~ the test scenarios used in our experiments, which was ~~would~~ served as a validation component. For the first hand understanding of stack effect, the group had performed two experiments. From t~~T~~he first experiment we performed ~~was to obtain data a~~study under normal building conditions. ~~s the control experiment from the control volume.~~ The second experiment we ~~was going to be~~was used ~~as a validation experiment from a~~ the same building, but sealed~~well sealed control volume which then would~~was ~~be compared to the original results~~. CONTAMW simulation software ~~modeling~~ was ~~also going to be~~ used ~~as additional comparison for~~for ~~both experiments~~for validation purposes. ~~scenarios. The objectives of each experiment were listed above in the objectives.~~

Comment [KTH2]: This is a repetition of the first line of the paragraph. Consider deleting this sentence.

Comment [KTH3]: I don't understand what was trying to be said here.

Research Methodology

At the beginning of the IPRO, the objectives of the semester were presented by the instructor. However, before any work could be done, the team had to be ~~first~~ introduced to the topics that were to be covered. The first couple of sessions were small lessons on the need for smoke control and a brief explanation on the phenomenon of stack effect. After having understood this, the class was broken up into different groups. In order to accomplish the goals of this IPRO, breaking into groups was necessary since each individual group was to cover different assignments. The groups were divided as such:

- CONTAMW Software Development
- ASCOS Software Development
- STACK Software Development
- ~~Fire Protection Research~~

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- Smoke Control interviews ~~Research~~
- Case Study

Each team was either dedicated to a software program or to research on certain topics. Those involved with the software were required to learn and understand their specific software so that their software could be used later in IPRO experiments. Those individuals involved in the research were required to speak with ~~working~~ practicing professionals ~~in practice~~ and conduct~~make~~ interviews to obtain the knowledge needed to create a good foundation for the research objectives of the IPRO.

To accomplish the research goals of the IPRO, selected team members needed to contact different professional engineers specializing in smoke control. Team members interviewed these engineers, asking them questions on smoke control design methods and considerations. This was not so easy to accomplish since there are only a handful smoke control professionals within the Chicago area, and these professionals are busy people working in major engineering corporations. The knowledge to be obtained would prove to be vital and very valuable to the IPRO. Along with design methods, equipment used and building code criteria were also discussed. From the collective knowledge obtained by the different team members of the IPRO, a flow chart was created that explained the design process of a smoke control system that included all considerations, equipment, codes, and other aspects shared by the different individuals. The flow chart serves as a good guide for ~~going about the design of~~ designing a smoke control system.

With the knowledge obtained from these interviews, a case study was performed. ~~This particular case study had the subject~~The subject of this particular case study was ~~of~~ McCormick Place, Chicago's very own premier convention facility. This case study involved the team members going inside the building and having the design engineers of the smoke control system actually go through and explain how it worked~~ inside the building~~. However, those engineers first had to be contacted, and the actual tour of the building had to be scheduled. From the tour of the building, the placement of equipment and the techniques used were explored. This was an excellent demonstration of how all of the theory behind smoke control is actually applied in the real world. ~~The~~ McCormick Place is an excellent case study since the building is mainly comprised of very large open spaces and the smoke control system would be quite complicated for such a massive structure.

The IPRO team performed two experiments to demonstrate the pressurization considerations involved in smoke control. The experiments revolved around a procedure that measured pressure differences between rooms. The experiment was conducted in a room with adjacent rooms. The~~is~~ room being tested contained air diffusers. The first experiment was carried out as such:

Comment [KTH4]: Be more specific about the actual rooms tested???

- Set up blower door
- Set up measuring devices
- Pressure meter
- Flow meter
- Cover the air diffuser
- Activate the blower door fan
- Measure the pressure difference between rooms and velocity of air flow
- Measure airflow and temperature from air diffuser with the balometer
- Repeat steps for different air velocities

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- Repeat steps for different scenarios of how air diffuser is covered

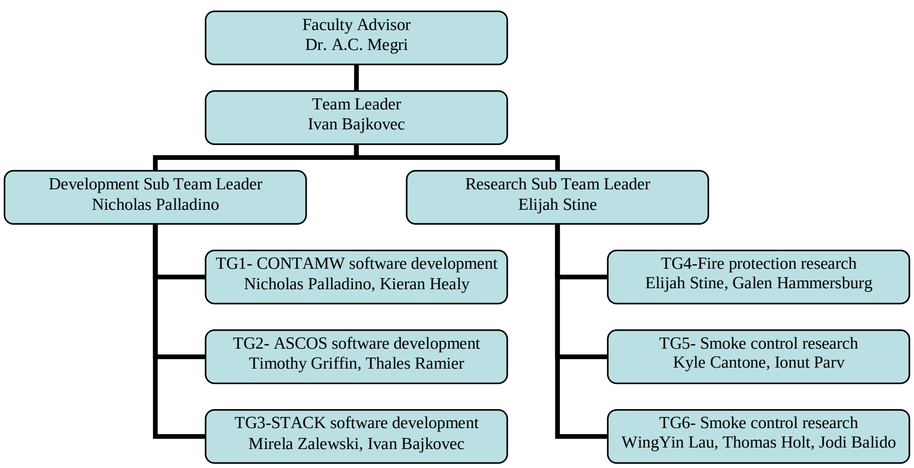
Comment [KTH5]: Procedure should be a little more specific???

From this procedure, results were obtained which allowed for data analysis.

A second experiment was performed to serve as a validation of the first experiment. The second experiment was very similar to the first experiment but the difference was that ~~the~~ all airflow cracks were sealed ~~giving~~ to create an airtight room. Here, the return of the airflow of the HVAC system was tested. The same procedure was followed for the second experiment. Results from this experiment also allowed for data analysis. In addition, the software that was learned earlier was applied as to validate the experiments. ~~The software is a good source and is already validated. The software was now used to validate the experiment and to determine whether or not the experiments could be a good source as well.~~

Assignments

IPRO 336 - Developing Innovative Design Concepts for Airflow, Energy Sustainability & Fire Protection Safety in Buildings – required a numerous number of tasks to be completed. In order to get the best results possible, these tasks were assigned to each person from the team. At the beginning of the semester, a group leader and two sub-leaders were chosen, while the rest of the group completed the work that was assigned to them.



For the actual experimentation, which had two sessions, the teams worked together, so that there were research and software development people in each experimentation group. The experimentation teams were made as follows:

Experiment Group 1 :

Experiment Group 2 :

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Ivan Bajkovec
Elijah Stine
Timothy Griffin
Thales Ramier
Jodi Balido
Wing Yin Lau

Nicholas Palladino
Galen Hammersburg
Kyle Cantone
Ionut Parv
Mirela Zalewski
Thomas Holt
Kieran Healy

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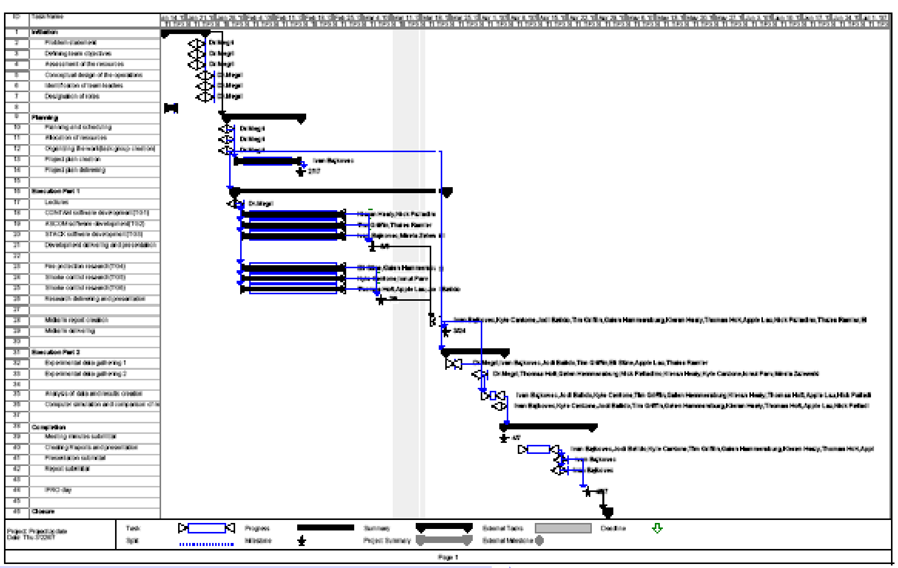
The data analysis was divided between each member of the team, in such a way that everyone contributed to the reports of the experimentations.

The last assignments were attributed for finalizing the tasks of the IPRO. At this point, people were assigned to work on the final report and the presentation of the results.

Each of the IPRO tasks required an enormous amount of work, so the team members tried to work together as much as possible. There was some confusion about each person's duties, but because the group was meeting as often as possible, they were quickly clarified, so everyone knew exactly what needed to be done.

Comment [KTH6]: "enormous" isn't the best word to be used here

Comment [KTH7]: maybe add something about email or Igroups here



Project Workflow Diagram

Comment [KTH8]: This diagram isn't legible and should have a better label e.g. Figure 3: Project Workflow Diagram. The formatting of all labels throughout the report should be the same.

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List of individual member assignments can be found below (please refer to the attached MS Project file in order for a complete examination):

1 Ivan Bajkovec 110 hrs

ID	Task Name	Units	Work	Delay	Start	Finish
13	Project plan creation	100%	20 hrs	0 days	Thu 2/1/07	Sat 2/17/07
20	STACK software development(TG3)	100%	30 hrs	0 days	Sat 2/3/07	Tue 2/27/07
21	Development delivering and presentation	100%	2 hrs	0 days	Tue 3/6/07	Tue 3/6/07
14	Project plan delivering	100%	1 hr	0 days	Sat 2/17/07	Sat 2/17/07
28	Midterm report creation	100%	4 hrs	0 days	Tue 3/20/07	Thu 3/22/07
32	Experimental data gathering 1	100%	4 hrs	0 days	Sat 3/3/07	Sat 3/3/07
35	Analysis of data and results creation	100%	10 hrs	0 days	Tue 3/27/07	Tue 4/3/07
36	Computer simulation and comparison of results	100%	4 hrs	0 days	Thu 4/5/07	Fri 4/6/07
40	Creating Reports and presentation	100%	25 hrs	0 days	Tue 4/10/07	Tue 4/24/07
41	Presentation submittal	100%	1 hr	0 days	Wed 4/25/07	Wed 4/25/07
42	Report submittal	100%	1 hr	0 days	Thu 4/26/07	Thu 4/26/07
44	IPRO day	100%	8 hrs	0 days	Fri 4/27/07	Fri 4/27/07

2 Dr.Megri 35 hrs

ID	Task Name	Units	Work	Delay	Start	Finish
2	Problem statement	100%	0.5 hrs	0 days	Tue 1/23/07	Tue 1/23/07
3	Defining team objectives	100%	0.5 hrs	0 days	Tue 1/23/07	Tue 1/23/07
4	Assessment of the resources	100%	0.5 hrs	0 days	Tue 1/23/07	Tue 1/23/07
5	Conceptual design of the operations	100%	0.5 hrs	0 days	Thu 1/25/07	Thu 1/25/07
6	Identification of team leaders	100%	0.5 hrs	0 days	Thu 1/25/07	Thu 1/25/07
7	Designation of roles	100%	0.5 hrs	0 days	Thu 1/25/07	Thu 1/25/07
10	Planning and scheduling	100%	2 hrs	0 days	Tue 1/30/07	Tue 1/30/07
11	Allocation of resources	100%	2 hrs	0 days	Tue 1/30/07	Tue 1/30/07
12	Organizing the work(task group creation)	100%	2 hrs	0 days	Tue 1/30/07	Tue 1/30/07
17	Lectures	100%	2 hrs	0 days	Thu 2/1/07	Thu 2/1/07
32	Experimental data gathering 1	100%	4 hrs	0 days	Sat 3/3/07	Sat 3/3/07
33	Experimental data gathering 1	100%	4 hrs	0 days	Sat 3/24/07	Sat 3/24/07
47	Final briefing and disitntegration	100%	2 hrs	0 days	Tue 5/1/07	Tue 5/1/07
36	Computer simulation and comparison of results	100%	4 hrs	0 days	Thu 4/5/07	Fri 4/6/07
35	Analysis of data and results creation	100%	10 hrs	0 days	Tue 3/27/07	Tue 4/3/07

3 Jodi Balido 87 hrs

ID	Task Name	Units	Work	Delay	Start	Finish
25	Smoke control research(TG6)	100%	30 hrs	0 days	Sat 2/3/07	Tue 2/27/07
26	Research delivering and presentation	100%	2 hrs	0 days	Thu 3/8/07	Thu 3/8/07
28	Midterm report creation	100%	4 hrs	0 days	Tue 3/20/07	Thu 3/22/07
32	Experimental data gathering 1	100%	4 hrs	0 days	Sat 3/3/07	Sat 3/3/07
35	Analysis of data and results creation	100%	10 hrs	0 days	Tue 3/27/07	Tue 4/3/07
36	Computer simulation and comparison of results	100%	4 hrs	0 days	Thu 4/5/07	Fri 4/6/07
40	Creating Reports and presentation	100%	25 hrs	0 days	Tue 4/10/07	Tue 4/24/07
44	IPRO day	100%	8 hrs	0 days	Fri 4/27/07	Fri 4/27/07

4 Kyle Cantone 87 hrs

ID	Task Name	Units	Work	Delay	Start	Finish
24	Smoke control research(TG5)	100%	30 hrs	0 days	Sat 2/3/07	Tue 2/27/07
26	Research delivering and presentation	100%	2 hrs	0 days	Thu 3/8/07	Thu 3/8/07
28	Midterm report creation	100%	4 hrs	0 days	Tue 3/20/07	Thu 3/22/07
32	Experimental data gathering 1	100%	4 hrs	0 days	Sat 3/3/07	Sat 3/3/07
35	Analysis of data and results creation	100%	10 hrs	0 days	Tue 3/27/07	Tue 4/3/07
36	Computer simulation and comparison of results	100%	4 hrs	0 days	Thu 4/5/07	Fri 4/6/07
40	Creating Reports and presentation	100%	25 hrs	0 days	Tue 4/10/07	Tue 4/24/07
44	IPRO day	100%	8 hrs	0 days	Fri 4/27/07	Fri 4/27/07

5 Tim Griffin 87 hrs

ID	Task Name	Units	Work	Delay	Start	Finish
19	ASCOM software development(TG2)	100%	30 hrs	0 days	Sat 2/3/07	Tue 2/27/07
21	Development delivering and presentation	100%	2 hrs	0 days	Tue 3/6/07	Tue 3/6/07
28	Midterm report creation	100%	4 hrs	0 days	Tue 3/20/07	Thu 3/22/07
32	Experimental data gathering 1	100%	4 hrs	0 days	Sat 3/3/07	Sat 3/3/07
35	Analysis of data and results creation	100%	10 hrs	0 days	Tue 3/27/07	Tue 4/3/07
36	Computer simulation and comparison of results	100%	4 hrs	0 days	Thu 4/5/07	Fri 4/6/07
40	Creating Reports and presentation	100%	25 hrs	0 days	Tue 4/10/07	Tue 4/24/07
44	IPRO day	100%	8 hrs	0 days	Fri 4/27/07	Fri 4/27/07

6 Galen Hammersburg 87 hrs

ID	Task Name	Units	Work	Delay	Start	Finish
23	Fire protection research(TG4)	100%	30 hrs	0 days	Sat 2/3/07	Tue 2/27/07
26	Research delivering and presentation	100%	2 hrs	0 days	Thu 3/8/07	Thu 3/8/07
28	Midterm report creation	100%	4 hrs	0 days	Tue 3/20/07	Thu 3/22/07
32	Experimental data gathering 1	100%	4 hrs	0 days	Sat 3/3/07	Sat 3/3/07
35	Analysis of data and results creation	100%	10 hrs	0 days	Tue 3/27/07	Tue 4/3/07

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"Galen Hammersburg" continued

ID	Task Name	Units	Work	Delay	Start	Finish
36	Computer simulation and comparison of results	100%	4 hrs	0 days	Thu 4/5/07	Fri 4/6/07
40	Creating Reports and presentation	100%	25 hrs	0 days	Tue 4/10/07	Tue 4/24/07
44	IPRO day	100%	8 hrs	0 days	Fri 4/27/07	Fri 4/27/07

7 Kieran Healy 87 hrs

ID	Task Name	Units	Work	Delay	Start	Finish
18	CONTAM software development(TG1)	100%	30 hrs	0 days	Sat 2/3/07	Tue 2/27/07
21	Development delivering and presentation	100%	2 hrs	0 days	Tue 3/6/07	Tue 3/6/07
28	Midterm report creation	100%	4 hrs	0 days	Tue 3/20/07	Thu 3/22/07
32	Experimental data gathering 1	100%	4 hrs	0 days	Sat 3/3/07	Sat 3/3/07
35	Analysis of data and results creation	100%	10 hrs	0 days	Tue 3/27/07	Tue 4/3/07
36	Computer simulation and comparison of results	100%	4 hrs	0 days	Thu 4/5/07	Fri 4/6/07
40	Creating Reports and presentation	100%	25 hrs	0 days	Tue 4/10/07	Tue 4/24/07
44	IPRO day	100%	8 hrs	0 days	Fri 4/27/07	Fri 4/27/07

8 Thomas Holt 87 hrs

ID	Task Name	Units	Work	Delay	Start	Finish
25	Smoke control research(TG6)	100%	30 hrs	0 days	Sat 2/3/07	Tue 2/27/07
26	Research delivering and presentation	100%	2 hrs	0 days	Thu 3/8/07	Thu 3/8/07
28	Midterm report creation	100%	4 hrs	0 days	Tue 3/20/07	Thu 3/22/07
33	Experimental data gathering 1	100%	4 hrs	0 days	Sat 3/24/07	Sat 3/24/07
35	Analysis of data and results creation	100%	10 hrs	0 days	Tue 3/27/07	Tue 4/3/07
36	Computer simulation and comparison of results	100%	4 hrs	0 days	Thu 4/5/07	Fri 4/6/07
40	Creating Reports and presentation	100%	25 hrs	0 days	Tue 4/10/07	Tue 4/24/07
44	IPRO day	100%	8 hrs	0 days	Fri 4/27/07	Fri 4/27/07

9 Apple Lau 87 hrs

ID	Task Name	Units	Work	Delay	Start	Finish
25	Smoke control research(TG6)	100%	30 hrs	0 days	Sat 2/3/07	Tue 2/27/07
26	Research delivering and presentation	100%	2 hrs	0 days	Thu 3/8/07	Thu 3/8/07
28	Midterm report creation	100%	4 hrs	0 days	Tue 3/20/07	Thu 3/22/07
33	Experimental data gathering 1	100%	4 hrs	0 days	Sat 3/24/07	Sat 3/24/07
35	Analysis of data and results creation	100%	10 hrs	0 days	Tue 3/27/07	Tue 4/3/07
36	Computer simulation and comparison of results	100%	4 hrs	0 days	Thu 4/5/07	Fri 4/6/07
40	Creating Reports and presentation	100%	25 hrs	0 days	Tue 4/10/07	Tue 4/24/07
44	IPRO day	100%	8 hrs	0 days	Fri 4/27/07	Fri 4/27/07

10 Nick Palladino 87 hrs

ID	Task Name	Units	Work	Delay	Start	Finish
18	CONTAM software development(TG1)	100%	30 hrs	0 days	Sat 2/3/07	Tue 2/27/07
21	Development delivering and presentation	100%	2 hrs	0 days	Tue 3/6/07	Tue 3/6/07
28	Midterm report creation	100%	4 hrs	0 days	Tue 3/20/07	Thu 3/22/07
33	Experimental data gathering 1	100%	4 hrs	0 days	Sat 3/24/07	Sat 3/24/07
35	Analysis of data and results creation	100%	10 hrs	0 days	Tue 3/27/07	Tue 4/3/07
36	Computer simulation and comparison of results	100%	4 hrs	0 days	Thu 4/5/07	Fri 4/6/07
40	Creating Reports and presentation	100%	25 hrs	0 days	Tue 4/10/07	Tue 4/24/07
44	IPRO day	100%	8 hrs	0 days	Fri 4/27/07	Fri 4/27/07

11 Thales Ramier 87 hrs

ID	Task Name	Units	Work	Delay	Start	Finish
19	ASCOM software development(TG2)	100%	30 hrs	0 days	Sat 2/3/07	Tue 2/27/07
21	Development delivering and presentation	100%	2 hrs	0 days	Tue 3/6/07	Tue 3/6/07
28	Midterm report creation	100%	4 hrs	0 days	Tue 3/20/07	Thu 3/22/07
33	Experimental data gathering 1	100%	4 hrs	0 days	Sat 3/24/07	Sat 3/24/07
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36	Computer simulation and comparison of results	100%	4 hrs	0 days	Thu 4/5/07	Fri 4/6/07
40	Creating Reports and presentation	100%	25 hrs	0 days	Tue 4/10/07	Tue 4/24/07
44	IPRO day	100%	8 hrs	0 days	Fri 4/27/07	Fri 4/27/07

12 Eli Stine 87 hrs

ID	Task Name	Units	Work	Delay	Start	Finish
23	Fire protection research(TG4)	100%	30 hrs	0 days	Sat 2/3/07	Tue 2/27/07
26	Research delivering and presentation	100%	2 hrs	0 days	Thu 3/8/07	Thu 3/8/07
28	Midterm report creation	100%	4 hrs	0 days	Tue 3/20/07	Thu 3/22/07
33	Experimental data gathering 1	100%	4 hrs	0 days	Sat 3/24/07	Sat 3/24/07
35	Analysis of data and results creation	100%	10 hrs	0 days	Tue 3/27/07	Tue 4/3/07
36	Computer simulation and comparison of results	100%	4 hrs	0 days	Thu 4/5/07	Fri 4/6/07
40	Creating Reports and presentation	100%	25 hrs	0 days	Tue 4/10/07	Tue 4/24/07
44	IPRO day	100%	8 hrs	0 days	Fri 4/27/07	Fri 4/27/07

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13		Mirela Zalewski		88 hrs			
	ID	Task Name	Units	Work	Delay	Start	Finish
	20	STACK software development(TG3)	100%	30 hrs	0 days	Sat 2/3/07	Tue 2/27/07
	21	Development delivering and presentation	100%	2 hrs	0 days	Tue 3/6/07	Tue 3/6/07
	28	Midterm report creation	100%	4 hrs	0 days	Tue 3/20/07	Thu 3/22/07
	32	Experimental data gathering 1	100%	4 hrs	0 days	Sat 3/3/07	Sat 3/3/07
	35	Analysis of data and results creation	100%	10 hrs	0 days	Tue 3/27/07	Tue 4/3/07
	36	Computer simulation and comparison of results	100%	4 hrs	0 days	Thu 4/5/07	Fri 4/6/07
	39	Meeting minutes submittal	100%	1 hr	0 days	Fri 4/6/07	Fri 4/6/07
	40	Creating Reports and presentation	100%	25 hrs	0 days	Tue 4/10/07	Tue 4/24/07
	44	IPRO day	100%	8 hrs	0 days	Fri 4/27/07	Fri 4/27/07
14		Ionut Parv		87 hrs			
	ID	Task Name	Units	Work	Delay	Start	Finish
	24	Smoke control research(TG5)	100%	30 hrs	0 days	Sat 2/3/07	Tue 2/27/07
	26	Research delivering and presentation	100%	2 hrs	0 days	Thu 3/8/07	Thu 3/8/07
	28	Midterm report creation	100%	4 hrs	0 days	Tue 3/20/07	Thu 3/22/07
	33	Experimental data gathering 1	100%	4 hrs	0 days	Sat 3/24/07	Sat 3/24/07
	35	Analysis of data and results creation	100%	10 hrs	0 days	Tue 3/27/07	Tue 4/3/07
	36	Computer simulation and comparison of results	100%	4 hrs	0 days	Thu 4/5/07	Fri 4/6/07
	40	Creating Reports and presentation	100%	25 hrs	0 days	Tue 4/10/07	Tue 4/24/07
	44	IPRO day	100%	8 hrs	0 days	Fri 4/27/07	Fri 4/27/07
15				0 hrs			

Team members were assigned project roles as follows:

Minute Taker (responsible for recording decisions made during meetings including task assignments or changes under consideration):
Mirela Zalewski

Agenda Maker (responsible for creating agendas for each team meeting):
Ivan Bajkovec

Time Keeper (responsible for making sure meetings go according to agendas):
Elijah Stine

Weekly Timesheet Collector/Summarizer (responsible for collecting weekly timesheets from each member of the team and updating everyone with summary report):
WingYin Lau

Master Schedule Maker (responsible for collecting schedules from all the team members and developing a master schedule which tells the team when members are available and how to contact them):
Thomas Holt

iGROUPS Coordinator (responsible for organizing the teams iGROUPS and ensure that it is used properly):
Galen Hammersburg

Obstacles

The first obstacle in this IPRO was to finalize the research tasks. Many of the team members did the research by talking to professionals in the fields of fire protection and smoke control design. Most of these people were very hard to reach. Also, the meetings were too short for a complete explanation of how a smoke control system works. Because of this, the team spent a lot of time doing the preliminary tasks, so by the time midterm reports were due we had not yet reached the midpoint of the project. The research continued long after the experimentations were done by utilizing a guest speaker and a field trip to McCormick Place.

Comment [KTH9]: Some of these obstacles were mentioned in the research methodology section and should be removed from one of the sections.

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Another obstacle was the technology used for the experimentations. Even though everything needed was available, the apparatus used were not the best ones on the market, so the results were not as accurate as they would have been with newer technology. Also, the software used was not known as much as it could have been known in a longer period of time, so all of the computer calculations or validations were difficult to model and understand.

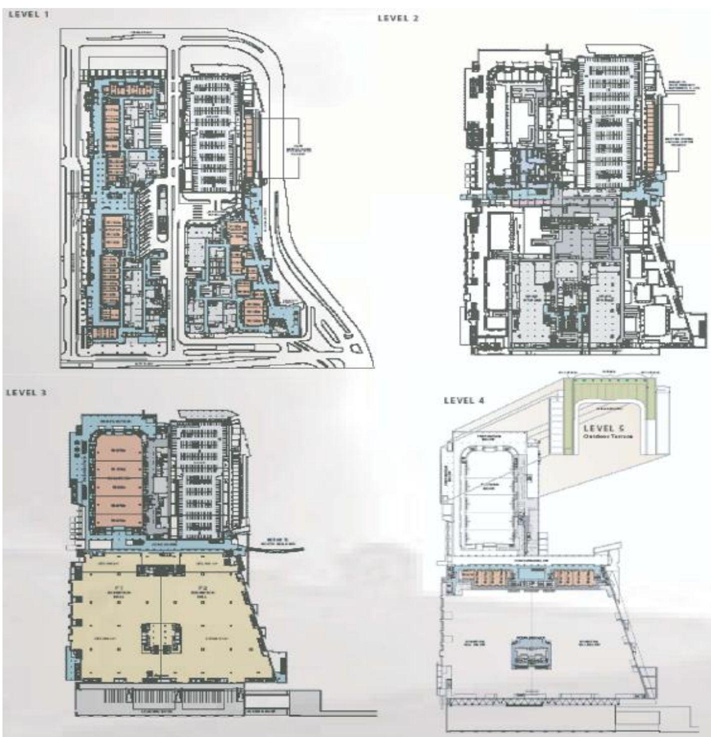
Comment [KTH10]: Some of the apparatus used may have been new, just not as good as other models

Overall, time was the main obstacle in getting better and more accurate results. In a longer period of time, the experimentations could have been done in a bigger place that requires more measurements and different scenarios. Also, a smoke simulation could have been done (using the cold smoke), which would have been a very important source of understanding how the stack effect works. In the same time, the research could have been vaster, with many other explicit cases of the stack effect creating problems in case of a fire.

Comment [KTH11]: I think that something should be included about the interdisciplinary fields of our team members, some who had no previous knowledge of the stack effect or anything else studied in this Ipro

Results

Case Studies & Interviews



Floor plans of ~~the~~ McCormick Place

Comment [KTH12]: Fix label.

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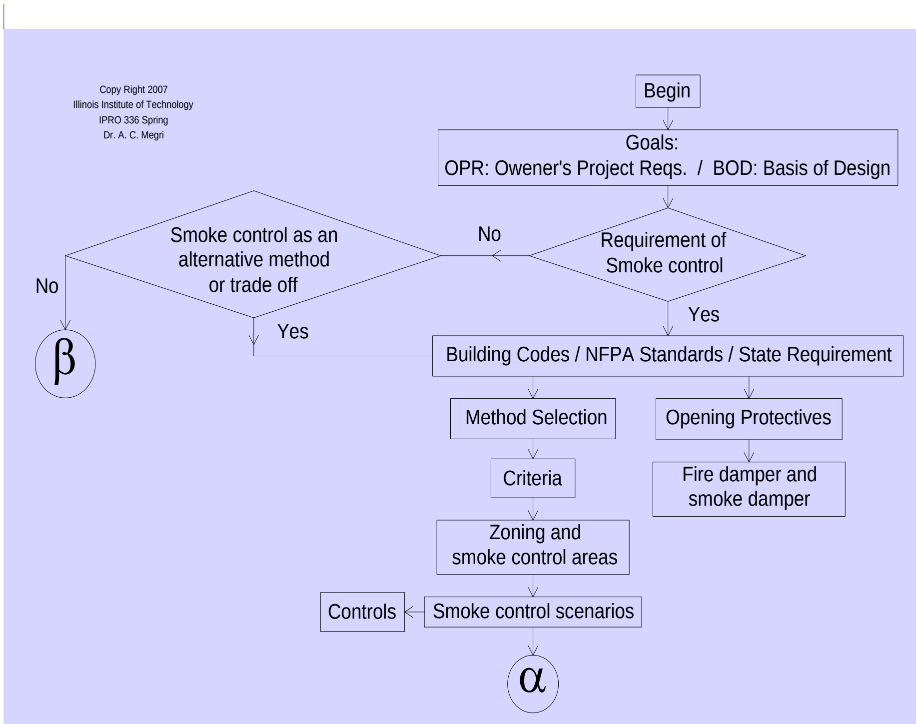
The study of McCormick Place and the many interviews conducted~~given~~ by members of IPRO 336 were used primarily to create a procedure that determined the necessity and design of smoke control systems. Each member, or team of members, collaborated with each other after gathering their data, and created a flow chart that can be used as a guide to the design of smoke control systems. Currently, professionals in the field of smoke control work solely off of their personal experience and general knowledge of the physical and dynamic properties of air and smoke flow. There are no texts, papers, or standards that define or explain smoke control systems. The most any standard will say is that a smoke control system, equipment like sprinklers or air returns, is required. The location, layout, size, and many other parameters of the system are left undefined. The flow chart created by members of IPRO 336 is the first step in defining those parameters. It lays out all of the items and methods needed to be considered in the design of a smoke control system. The flow chart is shown below.



Comment [KTH13]: The flow chart used in this document (and also the powerpoint presentation) does not match spelling corrections that were made in the flow chart for the poster. "Owener's" should be "Owner's" ….. "coNridors" should be "corridors"

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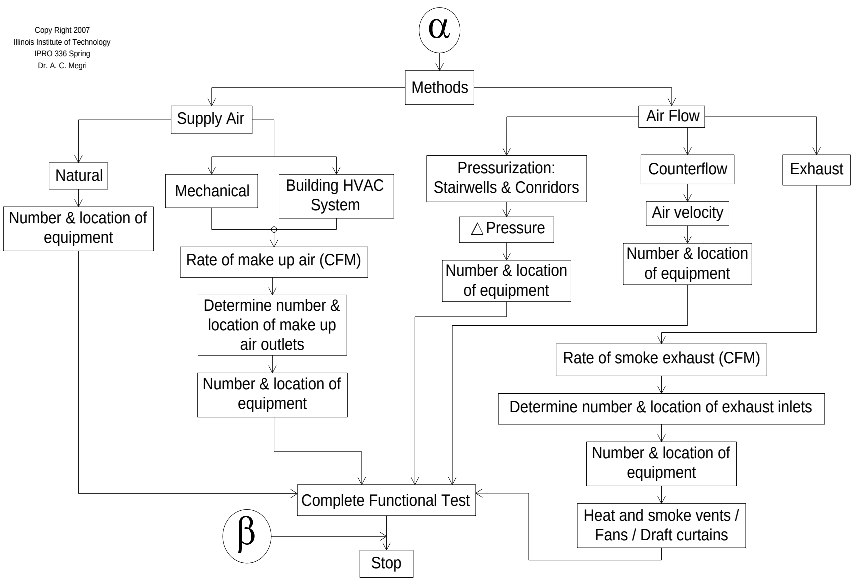

The very beginning of the flow chart is dependent on the layout and general use of the building. These two characteristics are very important as they determine if a smoke control system is even necessary. Deciding this is the only area of the flowchart where national or state standards and codes contribute. Once the necessity is determined~~,~~ the process can continue~~is in the air~~. The flow chart divides~~continues~~ into the different methods of smoke control. Here the main procedure and pieces to the different methods are displayed and the pros and cons of each can be weighed. All methods end with a complete functional test to determine the effectiveness of the system. The flow chart's absence of the influence of stack effect on smoke control is encouraged the experimentation done by IPRO 336.

Experiments 1 & 2

The purpose of the two experiments performed was to evaluate the effects of pressure variation on the airflow from mechanical systems. This is an important issue in high-rise design due to stack effect. The biggest difference between the first experiment and the second experiment was that in the second experiment all visible cracks in Alumni Hall Room 228 were sealed off. This made a very big difference in the data as not nearly as much air was able to escape Room 228 as did in the first experiment.

Comment [KTH14]: This was mentioned earlier in the procedure section.

Comment [KTH15]: Room 228 is mentioned here, but the specific rooms tested aren't mentioned earlier

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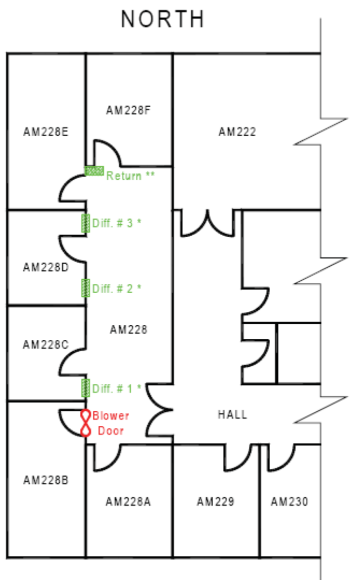

AM Floorplan

The results from the first experiment displayed quite a few trends. Regardless of the conditions of the diffuser, the airflow increases as the pressure difference between the two zones on both sides of the blower door increases. Because of the depressurization created by the blower door, the airflow leaving the experimental room through the blower door causes more air to be pulled from the diffusers. When all three diffusers were open the airflow through each was not the same. Apparently the HVAC system is not perfectly balanced. This could be the case in many buildings and could affect flow paths through corridors and large areas. This would cause problems in predicting the flow of smoke in case of a fire.

Comment [KTH16]: Explain what is in each picture???

Photos from the experiment

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Photos from the experiment

The second experiment verified many of the trends that were noticed in the first experiment. Additional analysis was made due to the new experiments done with the air conditioning and return vent. When the blower door was on, data showed that the difference between the sum of the airflow through the diffusers and that through the return decreased with an increase in pressure. This is logical because as the pressure increased more air was taken through the blower door; therefore the return was responsible for taking less air. A large difference was also found between the total airflow through the diffusers and the return when the blower door was off. Most of the difference was due to the fact that the fan, though off, was not sealed. In future experiments the fan should definitely be sealed when it is off or the airflow through the fan opening should be measured so that the data can be verified through the continuity of airflow.

Comment [KTH17]: Dr. Megri: please check for accuracy of content.

In these experiments, there were many sources of imprecision. They were conducted within an existing office building, not a laboratory where the conditions could have been controlled more accurately. The airflow through the fan fluctuated constantly. The digital readings on the manometer fluctuated constantly which made it hard to get a correct reading. Also, the manometer used has a margin of error of approximately 3.0 percent. The temperature and humidity of the room and surrounding environment were not static, which could have possibly affected the results of the experiment.

Not only do these experiments display how stack effect in high-rise buildings influences airflow, but they can also be used to encourage energy saving techniques that would save money in smaller buildings and residences. Heating a home during the winter costs a great amount of money. Data showed that sealing up the experimentation room significantly decreased the amount of air that was allowed to travel through the room. While doorways in residential buildings can't be sealed up like they were in the experiment, many cracks around windows and doorframes can be. If there are many cracks around the house, heated air escapes and the new air that replaces it needs to be heated. A decrease in airflow through the house results in a more efficient building and lowers heating costs.

Comment [KTH18]: This paragraph doesn't fit with the rest of the report as we didn't test a house and air leakage isn't necessarily the biggest cause of energy loss.

Validation with~~of~~ CONTAMW

Two different CONTAMW files were created for the two experiments. This was because the room in which the experimentation was done had very different properties due to the fact that in one experiment all visible cracks were sealed, while nothing was sealed in the other experiment. The sealing of the cracks allowed much

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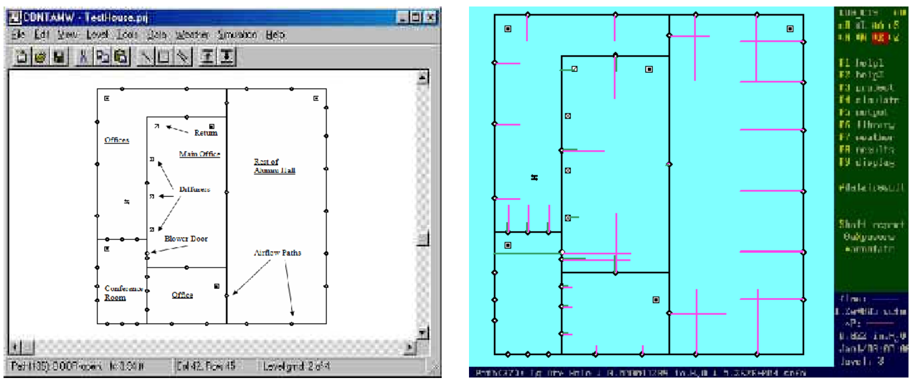
less air to flow through the room which resulted in smaller airflow coefficients for the walls surrounding the room. CONTAMW was effectively validated for both experiments. Results from the experiment and from the CONTAM program could not be identical due to the imprecise equipment and experimentation practices mentioned earlier. However, a comparison between the results usually yielded differences of less than 15%. The data points tend to become more different as more variables are produced. For example, the comparison between the experiment and CONTAM would be much closer for a scenario in which only one diffuser was open than for a scenario in which all diffusers and the return were open. Data was also harder to verify as the pressure difference between the two rooms increased.

Comment [KTH19]: Or were the experiments validated by CONTAMW?



Screenshots of ~~the~~ CONTAMW

Recommendations

The results and conclusions of IPRO 336 can be expanded upon through more research, experimentations, and computer programming. Many smoke control professionals were contacted and interviewed to gather information for this IPRO and~~but only~~ one building, McCormick Place, was used as a case study. We have learned that the design of smoke control systems depends on the size, layout, and use of the building. For this reason, many other different types of buildings could be studied. From high-rises to large public buildings, such as hospitals or convention centers, many different strategies and designs for smoke control are sure to be found.

Different buildings could also be utilized for experimental studies. Instead of using a blower door to simulate pressure differences between rooms, airflow experimentation could be done on many levels of a high-rise building. The difference between the airflow through diffusers and returns could~~an~~ be collected and compared for a range of heights. More accurate equipment would certainly help obtain quicker and more reliable results. Instead of using an erratic analog manometer to change the airflow through the fan, a digital one with a constant airflow could be purchased and utilized. Equipment that automatically stores the data would produce many more data points and would allow for much quicker and easier data analysis. The airflow paths through buildings could be determined using smoke tests. Zones in buildings with smoke control systems can be isolated with a harmless contaminant released inside. The effectiveness of the system would be measured by how quickly the contaminant leaves and the flow paths could be recorded. Models could also be used to determine

Comment [KTH20]: Already mentioned in other sections.

different strategies for smoke control. For example, a model atrium could be built with multiple flow paths through the building and fans to simulate mechanical airflow systems. Smoke would be released into the atrium and the effectiveness of the mechanical systems and different control strategies could be measured.

A great follow-up to the flow chart would be a computer expert system. A computer expert system is a program that responds with choices or directions to a user's question or data. The program would first prompt the user for information about a building- how big is it, what is it used for, etc. It would then start out with the first steps in determining a proper smoke control design. National and state standards and codes would be loaded into the program and they would be used to help with the process. By the end of the program the result would be a complete smoke control system. Details like the number of sprinklers or exhaust fans would be summed up in a final report created by the program.

References

Internet Sites

- Colt International Limited
  www.coltgroup.com

Interviews

- Ervin Cui, Ph.D., P.E.
  Mechanical Engineer
  Schirmer Engineering

- Michael Cusack, P.E.
  HVAC Project Manager, Mechanical Engineer
  Lehman Design Consultants, Inc.

- Thomas Gray
  Consulting Director, Property Risk Control
  CNA Insurance

- Jeffrey Harper, P.E.
  Vice President, Fire Protection Engineer
  Rolf Jensen & Associates, Inc.

- James Hurst, P.E.
  Mechanical Engineer
  Schirmer Engineering

- Susan Van Klompenburg
  Mechanical Engineer
  McCormick Place Design Team

- Jim Milke, Ph.D., P.E.
  Associate Professor and Associate Chair
  Department of Fire Protection Engineering
  University of Maryland

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- Dan Murphy, P.E., CFPS, LEEP AP
  Senior Vice President, Mechanical Engineer
  Environmental Systems Design, Inc.

- Gerald Schultz, P.E., CSP
  President, Fire Protection Engineer
  Fire Protection International Consortium, Inc.

- Adam Tappen, P.E.
  General Manager, Mechanical Engineer
  Siemens Building Technologies, Inc.

Software

- AutoCAD 2006
  Autodesk, Inc.
  Version 2006

- CONTAMW
  National Institute of Standards and Technology
  Version 2.0

- I-Quest 2006 International Building Code CDROM
  International Code Council, Inc.
  Version 1.0

- Mathcad 13
  Mathsoft Apps, Inc.
  Version 13

Acknowledgments

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- Ervin Cui, Ph.D., P.E.
  Mechanical Engineer
  Schirmer Engineering

  Case study of McCormick Place tour guide and supplied explanations regarding the design of McCormick Places Fire Protection systems. He also helped to develop a methodological smoke control design flow chart.

- Michael Cusack, P.E.
  HVAC Project Manager, Mechanical Engineer
  Lehman Design Consultants, Inc.

  Expertise was used in explanations of AHU systems pertaining to the HVAC system coordination with a smoke control system.

- Thomas Gray
  Consulting Director, Property Risk Control
  CNA Insurance

  Acquired contact information for various professional experts in the field of Fire Protection with emphasis on smoke control.

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- Jeffrey Harper, P.E.
  Vice President, Fire Protection Engineer
  Rolf Jensen & Associates, Inc.

  Expertise was used in a class general discussion for answering questions and clarifications of smoke control regarding techniques and processes of design.

- James Hurst, P.E.
  Mechanical Engineer
  Schirmer Engineering

  Case study of McCormick Place tour guide and supplied explanations regarding the design of McCormick Places Fire Protection systems.

- Susan Van Klompenburg
  Mechanical Engineer
  McCormick Place Design Team

  Case study of McCormick Place tour guide and supplied explanations regarding the design of McCormick Places Fire Protection systems.

- Jim Milke, Ph.D., P.E.
  Associate Professor and Associate Chair
  Department of Fire Protection Engineering
  University of Maryland

  Expertise was used in establishing a methodological smoke control design flow chart.

- Dan Murphy, P.E., CFPS, LEEP AP
  Senior Vice President, Mechanical Engineer
  Environmental Systems Design, Inc.

  Expertise was used in establishing a methodological smoke control design flow chart. As well as clarifications for smoke control design methods and considerations, relating to code criteria.

- Gerald Schultz, P.E., CSP
  President, Fire Protection Engineer
  Fire Protection International Consortium, Inc.

  Expertise was used in the answering questions and clarifications for smoke control, relating to natural and mechanical ventilation methods.

- Adam Tappen, P.E.
  General Manager, Fire Protection Engineer
  Siemens Building Technologies, Inc.

  Expertise was used in the answering questions and clarifications for smoke control design methods and considerations, involving smoke control equipment systems.