Innovations Optima, LLC
Eco-friendly Engineering Consulting Company

Airflow characteristics of direct-type kitchen hood systems in high-rise apartment buildings

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Introduction

- Today's high-rise apartment buildings exhibit high degree of air-tightness.
- They are also subjected to stack effect and seasonal, unpredictable, wind pressure variations.
- Therefore, it is questionable if the adoption of direct-type systems alone in place of the shared-type would yield the level of capture efficiency close to the hood design specification.


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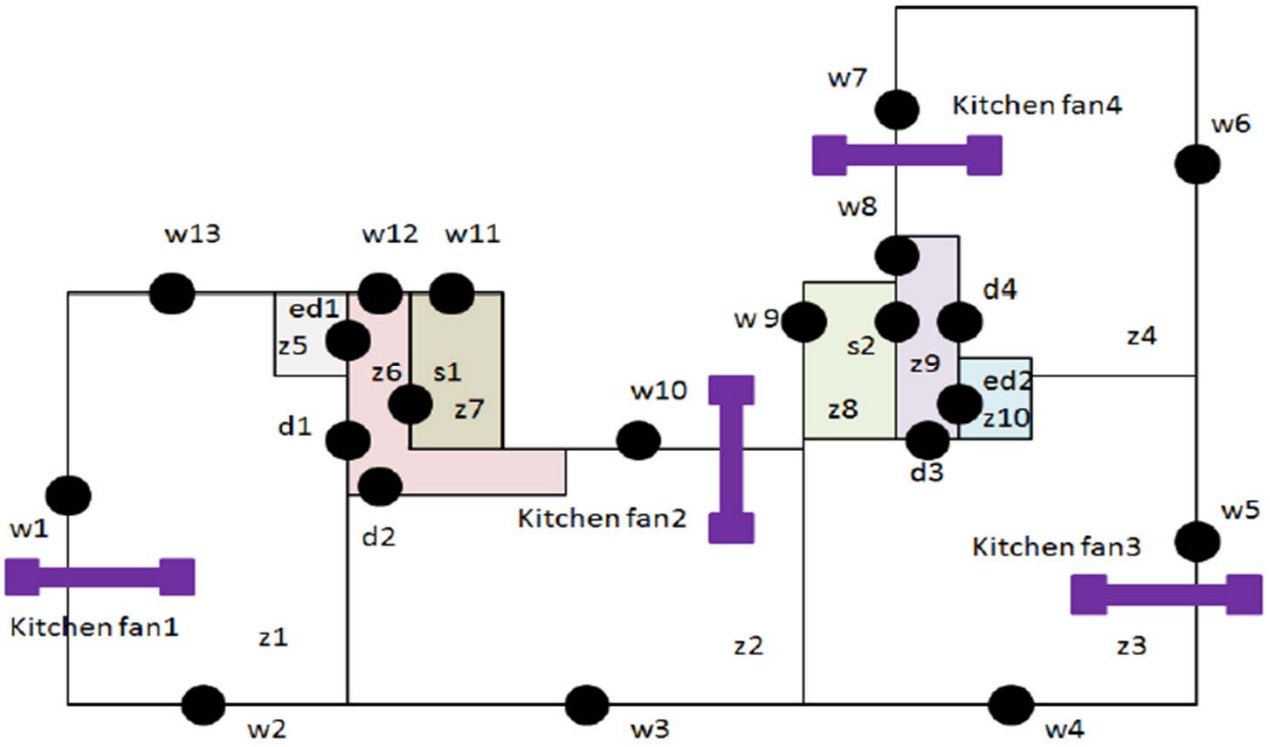
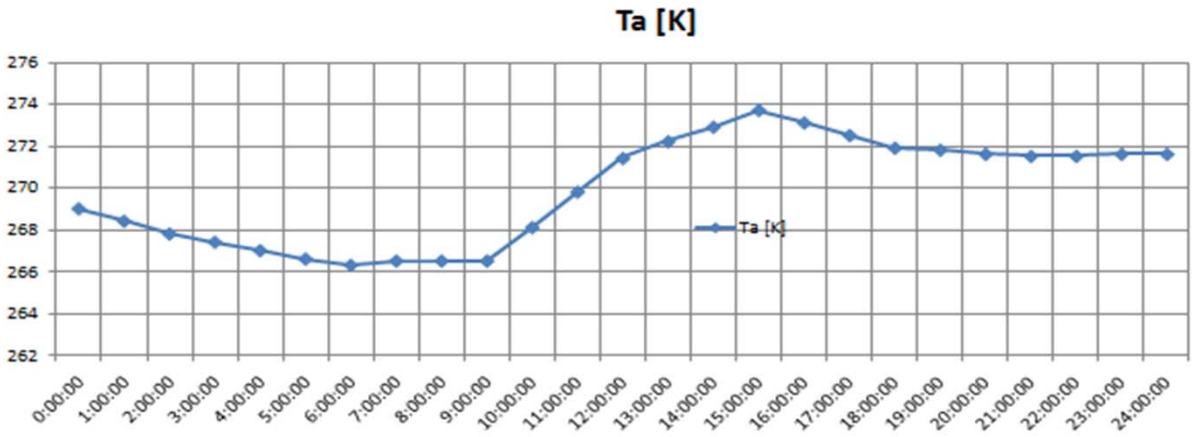
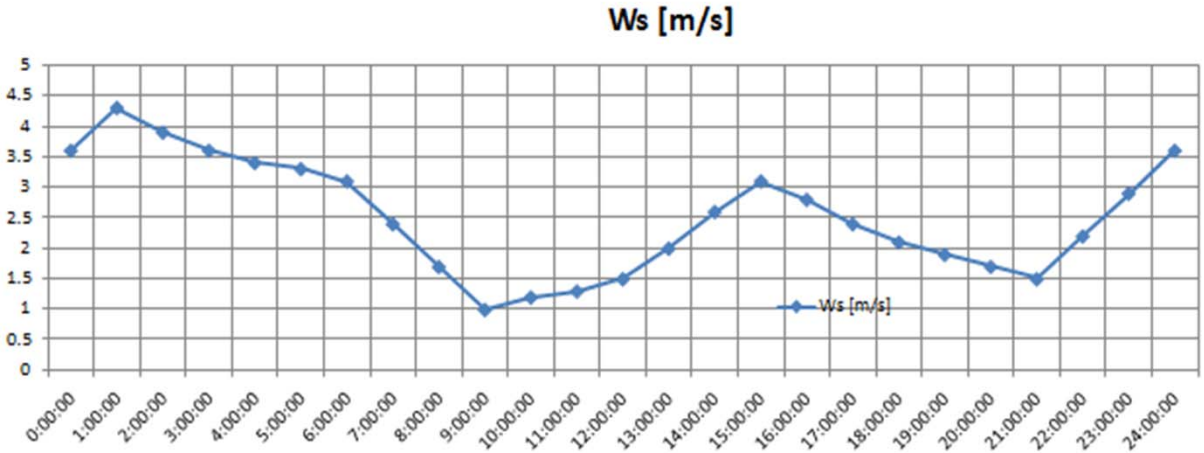


Figure 1: Layout of apartment used to analyze airflow

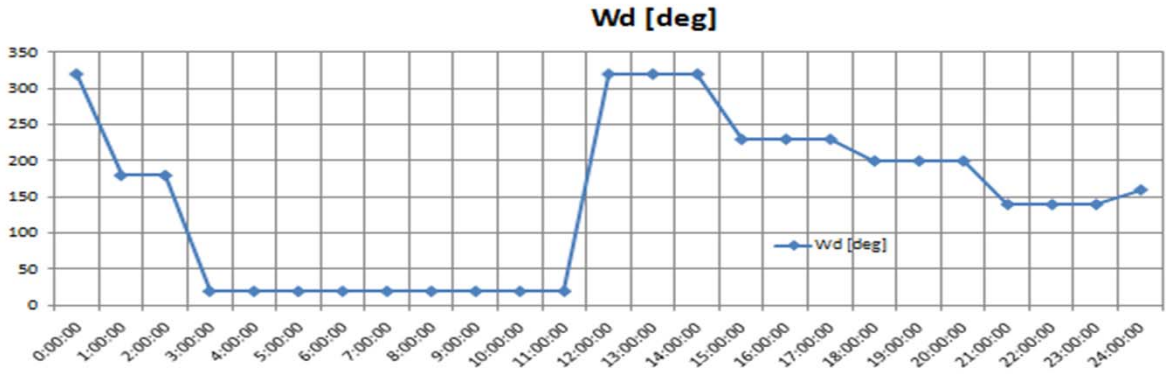


(a) 24-hour temperature distribution for Jan. 1st (from CONTAM input)



(b) 24-hour wind speed distribution for Jan. 1st (CONTAM input)

Figure 2: Example of CONTAM input for the 1st of January



(c) 24-hour wind direction distribution for Jan. 1st (CONTAM input)

Figure 2: Example of CONTAM input for the 1st of January

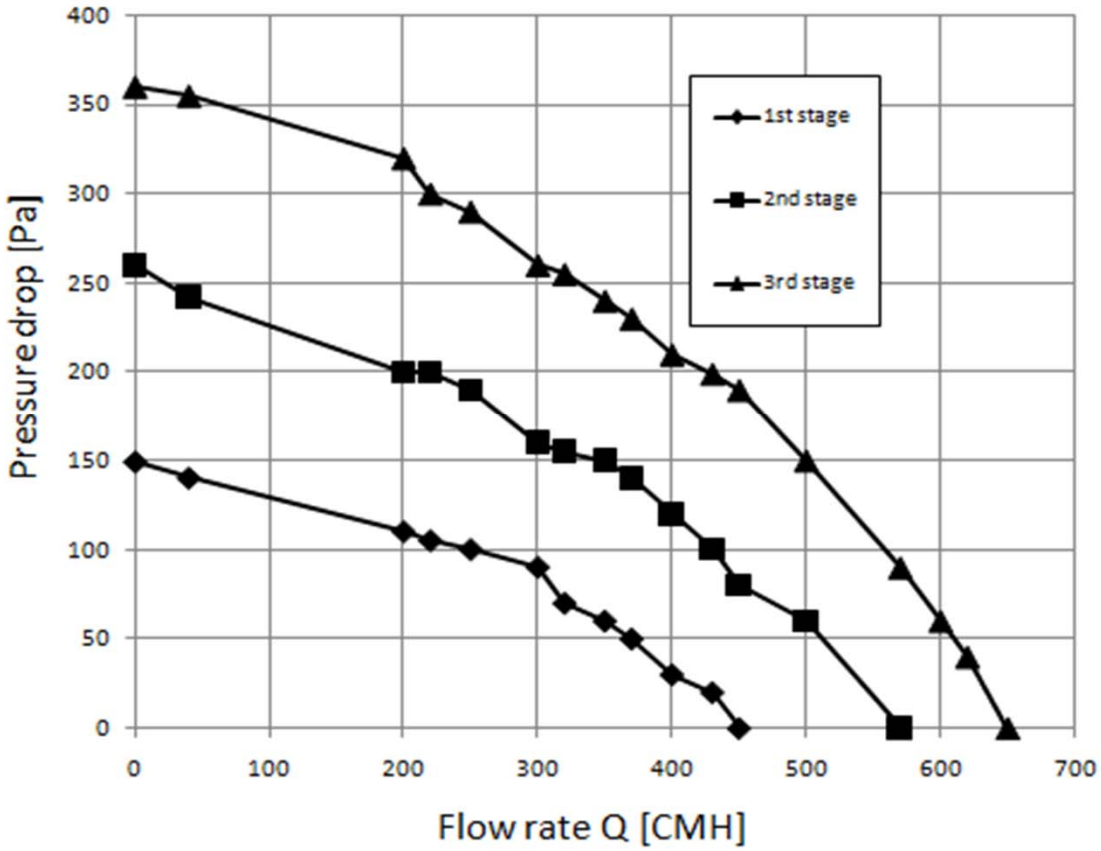
Table 1: Selected Parameters

	Parameters
1	Air Tightness
	(1) alt0: Reference without fan
	(2) alt1: Reference
	(3) alt2: 10% Reference with doors
	(4) alt3: 10% Reference
	(5) alt4: 1% Reference with doors
	(6) alt5: 1% Reference
2	Fan performance
	1st speed, 2nd speed, 3rd speed
3	Building elevation
	30, 60, 110 stories

Table 2: Example of leakage area per square area

alt3	Zone1	Zone1	Zone1	Zone1	Average
cm^2	16.7	27.4	25.2	42	27.825
door	3	3	3	3	3
window1	28	45	42	20	33.75
window2	45	0	0	0	11.25
total cm2	92.7	75.4	70.2	65	75.825
m^2	97	97	97	97	97
cm^2/m^2	0.956	0.777	0.724	0.670	0.782

Figure 3: Performance curve for kitchen hood fan



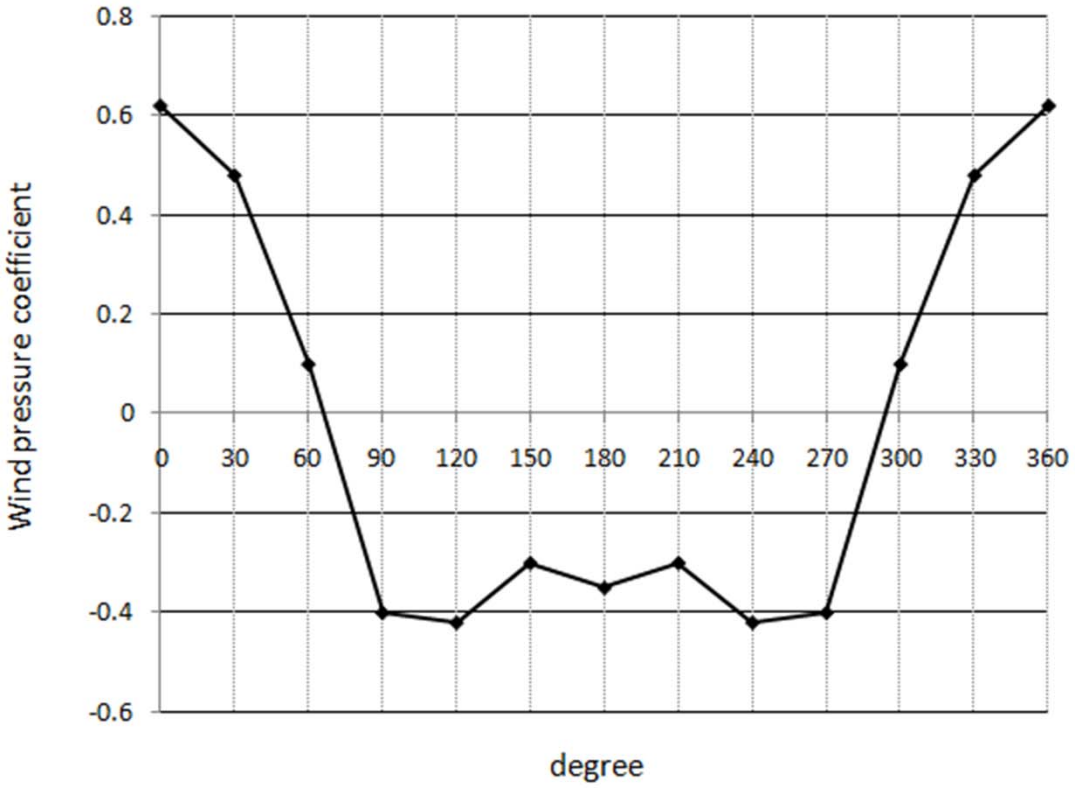
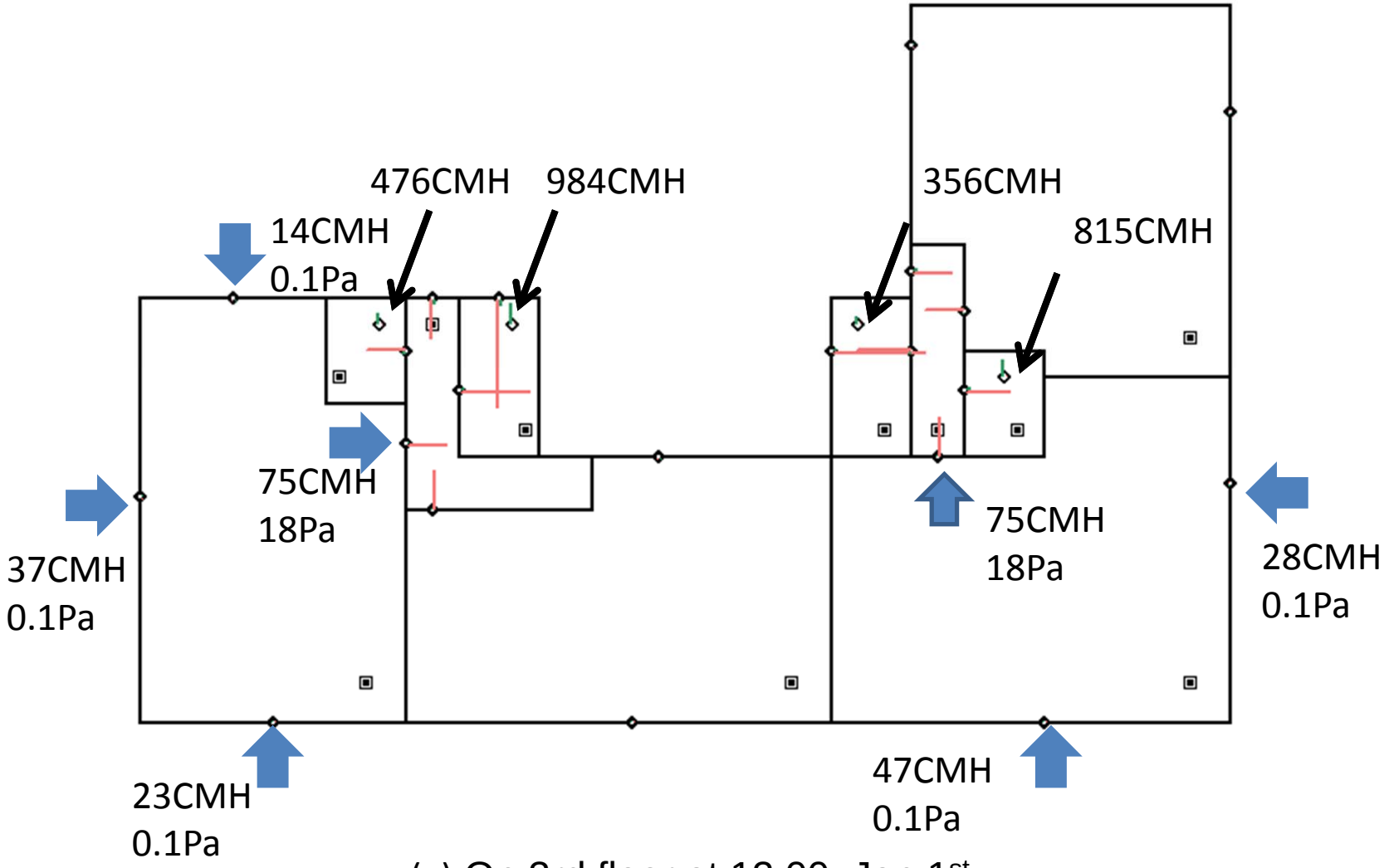


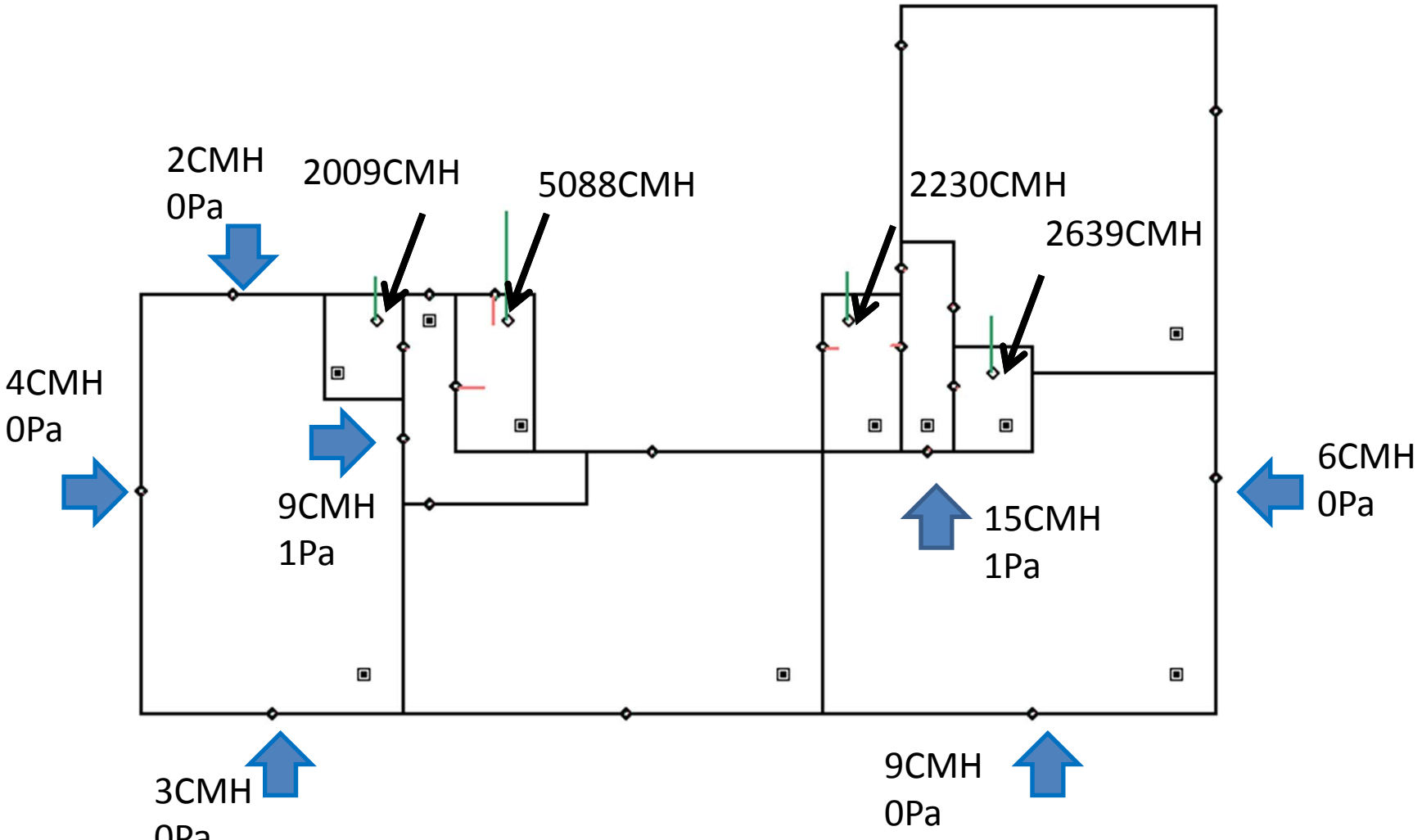
Figure 4: Assumed wind pressure curve surrounding the building by Azimuth

Table 3: Apartment units selected for kitchen hood operation between 11:00-12:00

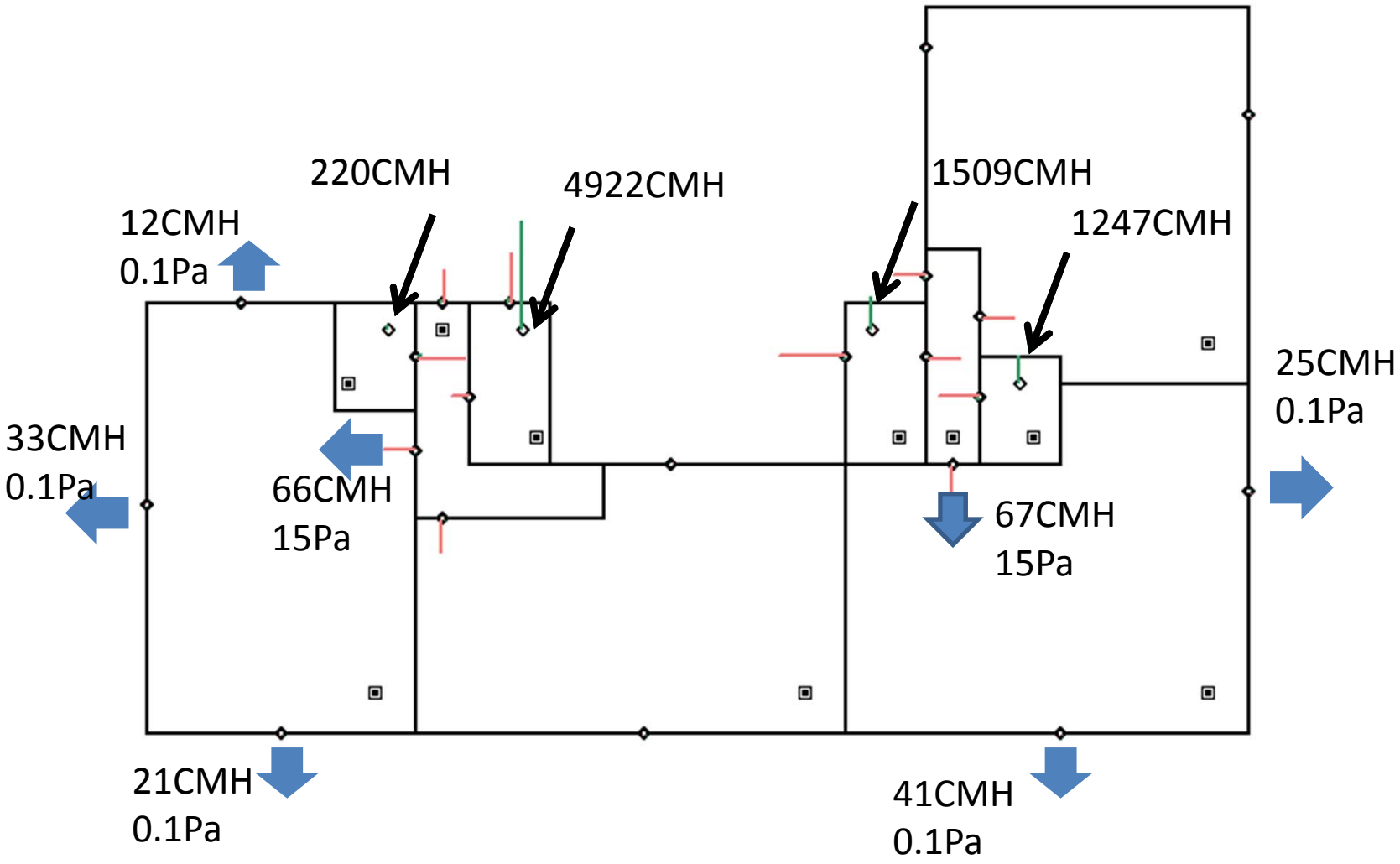
	zone1	zone2	zone3	zone4		zone1	zone2	zone3	zone4
3	■				19			■	
4					20		■		■
5			■		21				■
6		■	■		22				
7					23	■	■		
8				■	24				■
9	■				25				
10			■		26	■		■	
11					27	■	■	■	■
12		■			28		■		
13			■		29				■
14					30	■	■		
15	■			■	31	■	■		
16			■		32	■	■		■
17			■		33	■	■		
18					34	■	■		■



(a) On 3rd floor at 12:00, Jan 1st

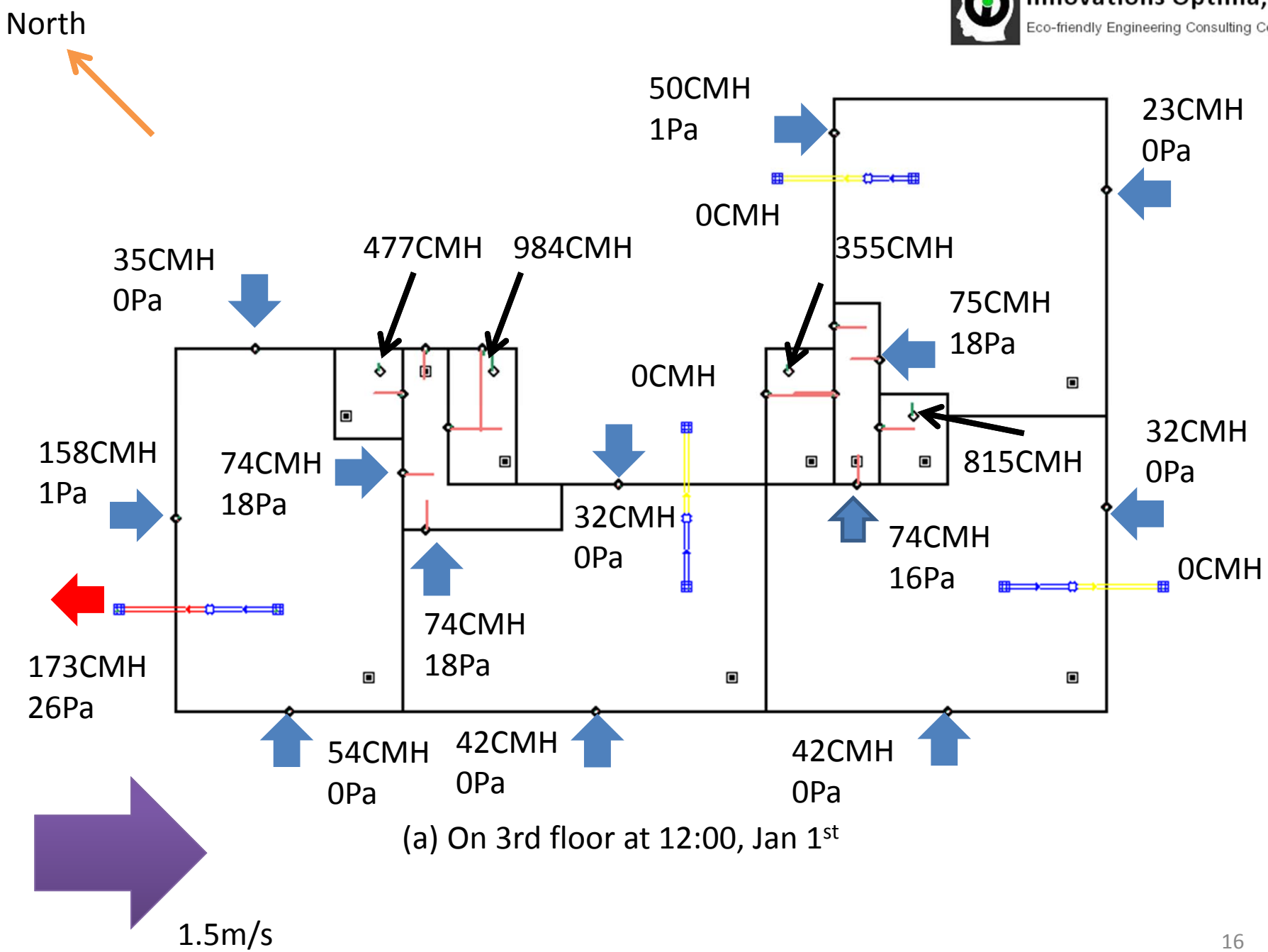


(b) On 16th floor at 12:00, Jan 1st

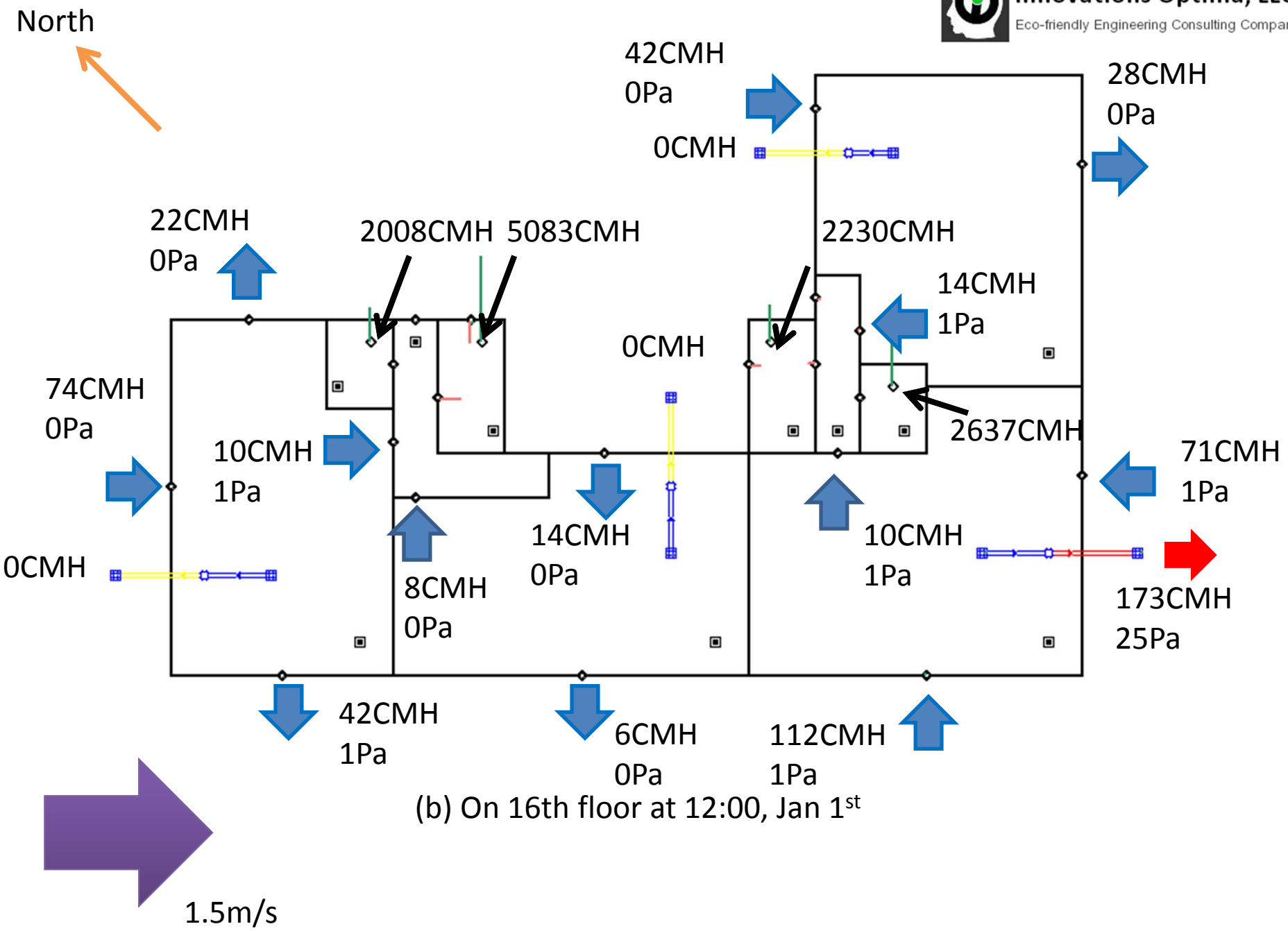


(c) On 29th floor at 12:00, Jan 1st

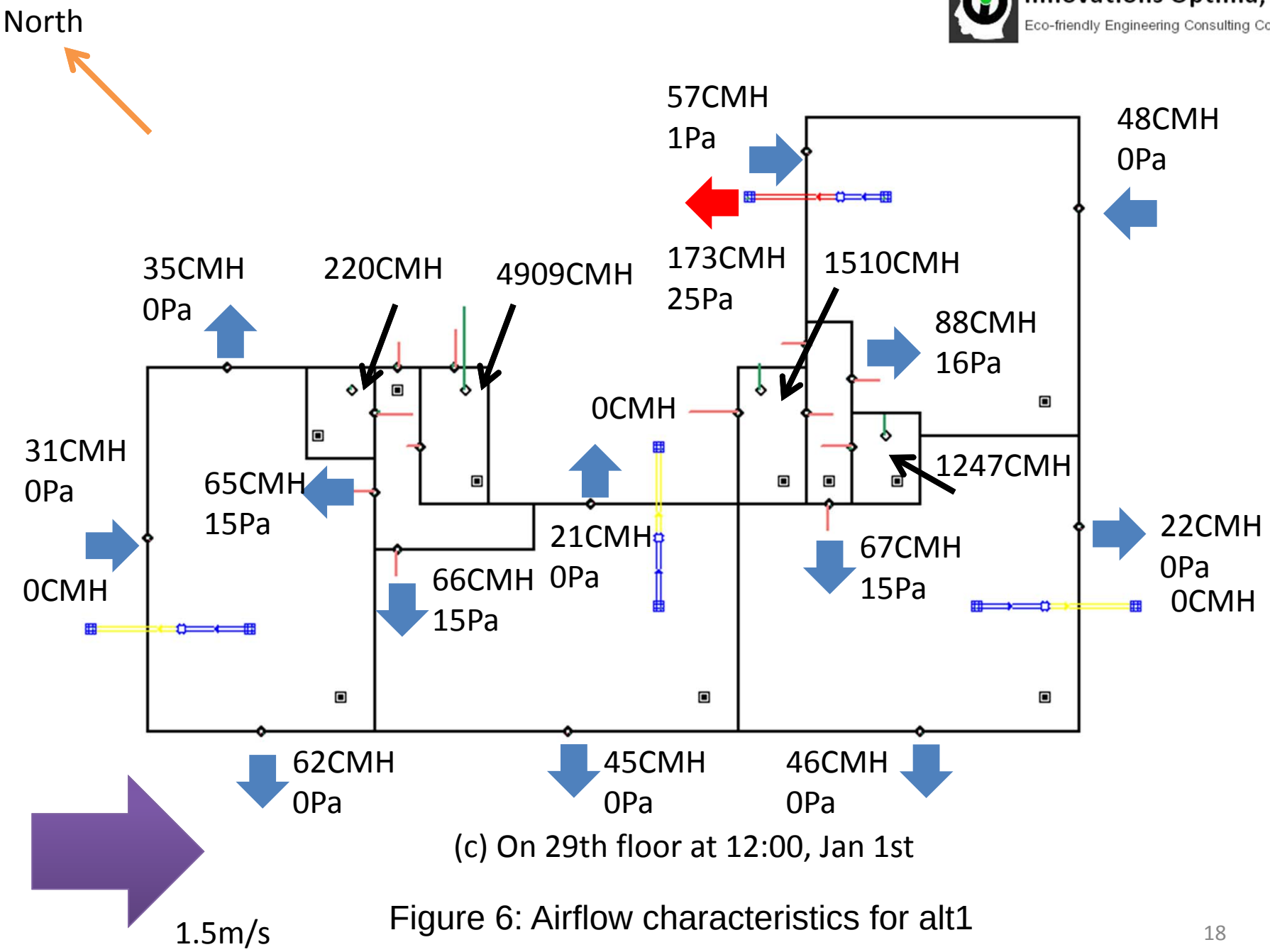
Figure 5: Airflow characteristics for alt0



(a) On 3rd floor at 12:00, Jan 1st



(b) On 16th floor at 12:00, Jan 1st



(c) On 29th floor at 12:00, Jan 1st

Figure 6: Airflow characteristics for alt1

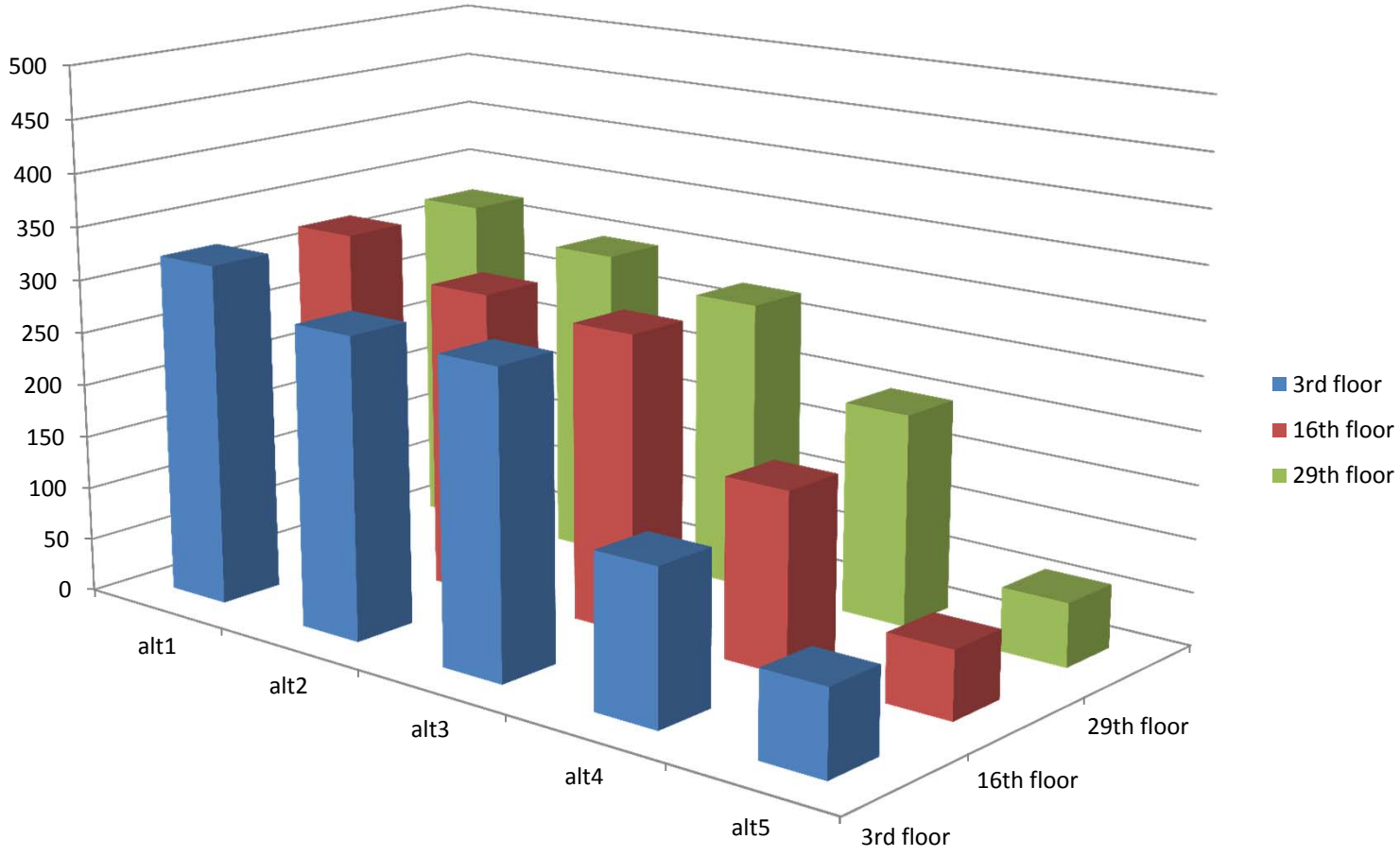


Figure 7: Flow rate distribution with fan operating at speed 1 on the 30th floor [CMH]

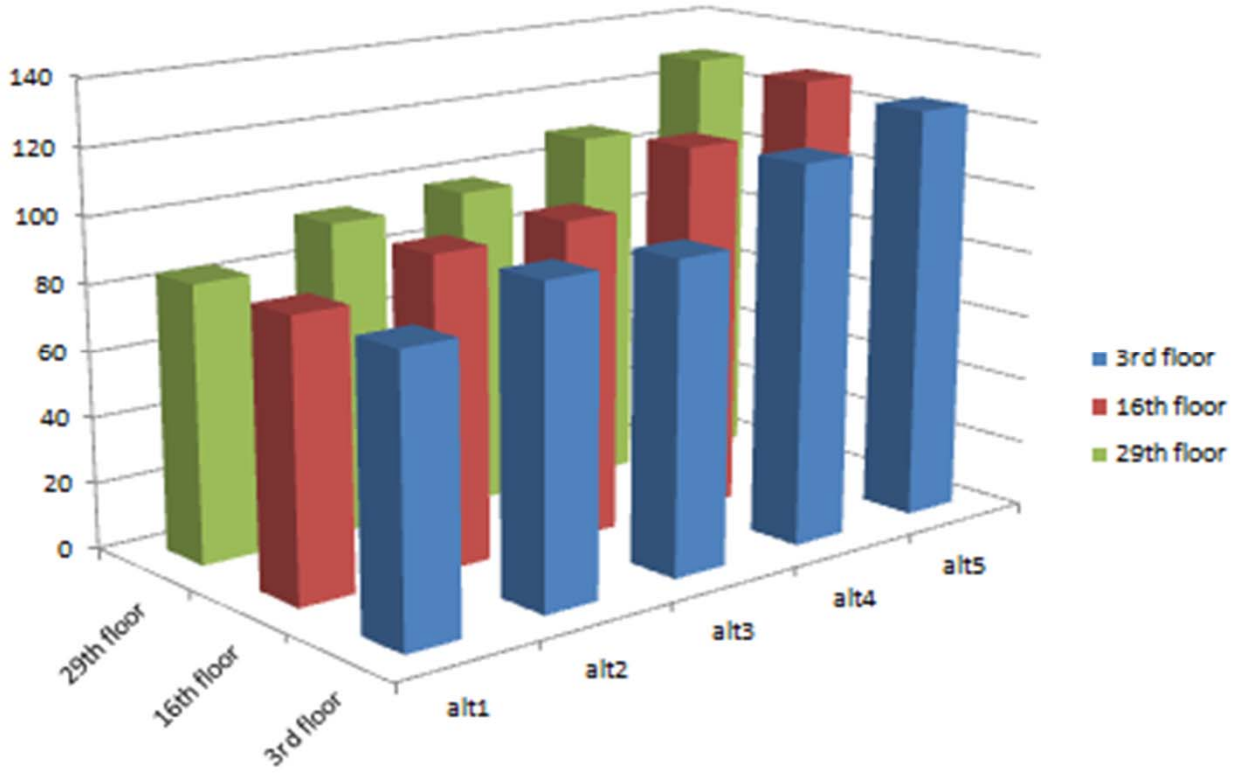


Figure 8: Pressure distribution with fan operating at speed 1 on the 30th floor [Pa]

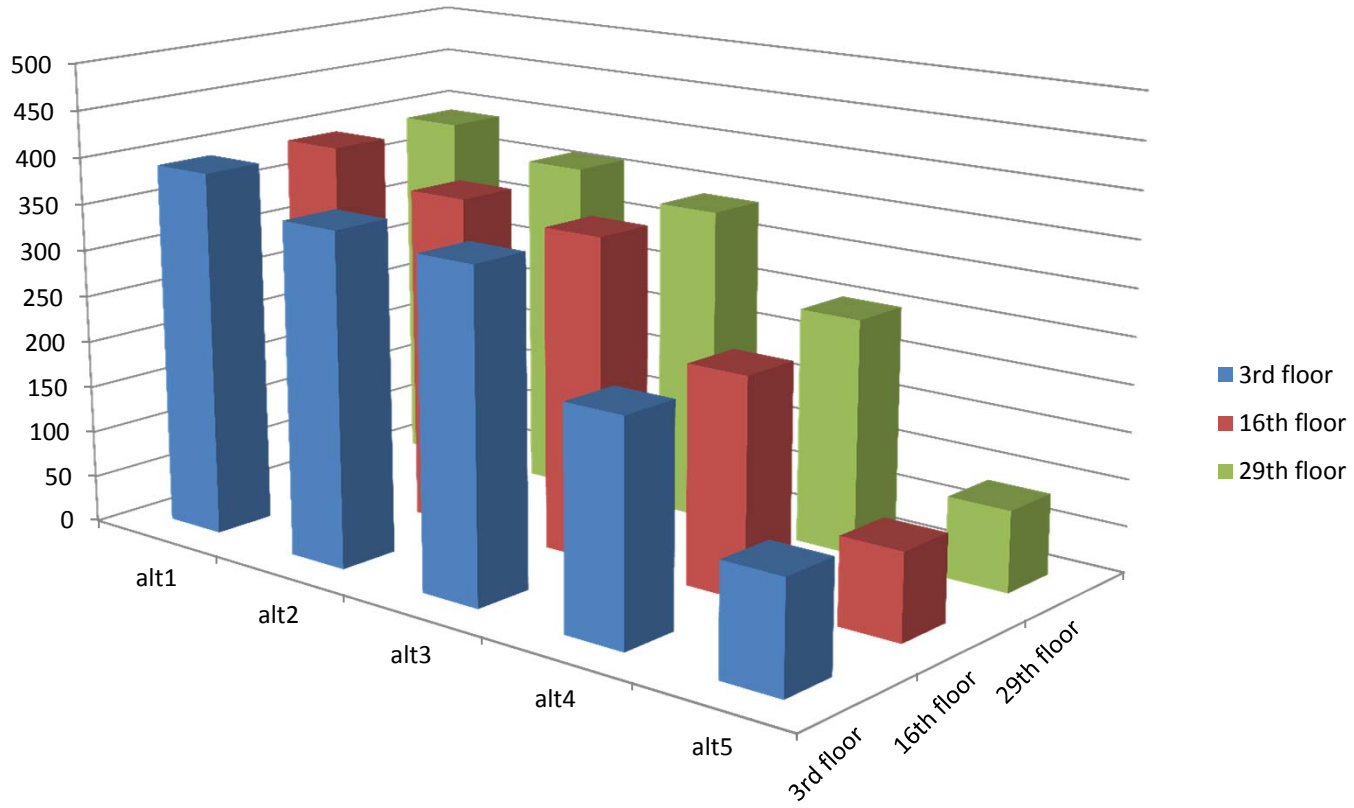


Figure 9: Flow rate distribution with fan operating at speed 2 on the 30th floor [CMH]

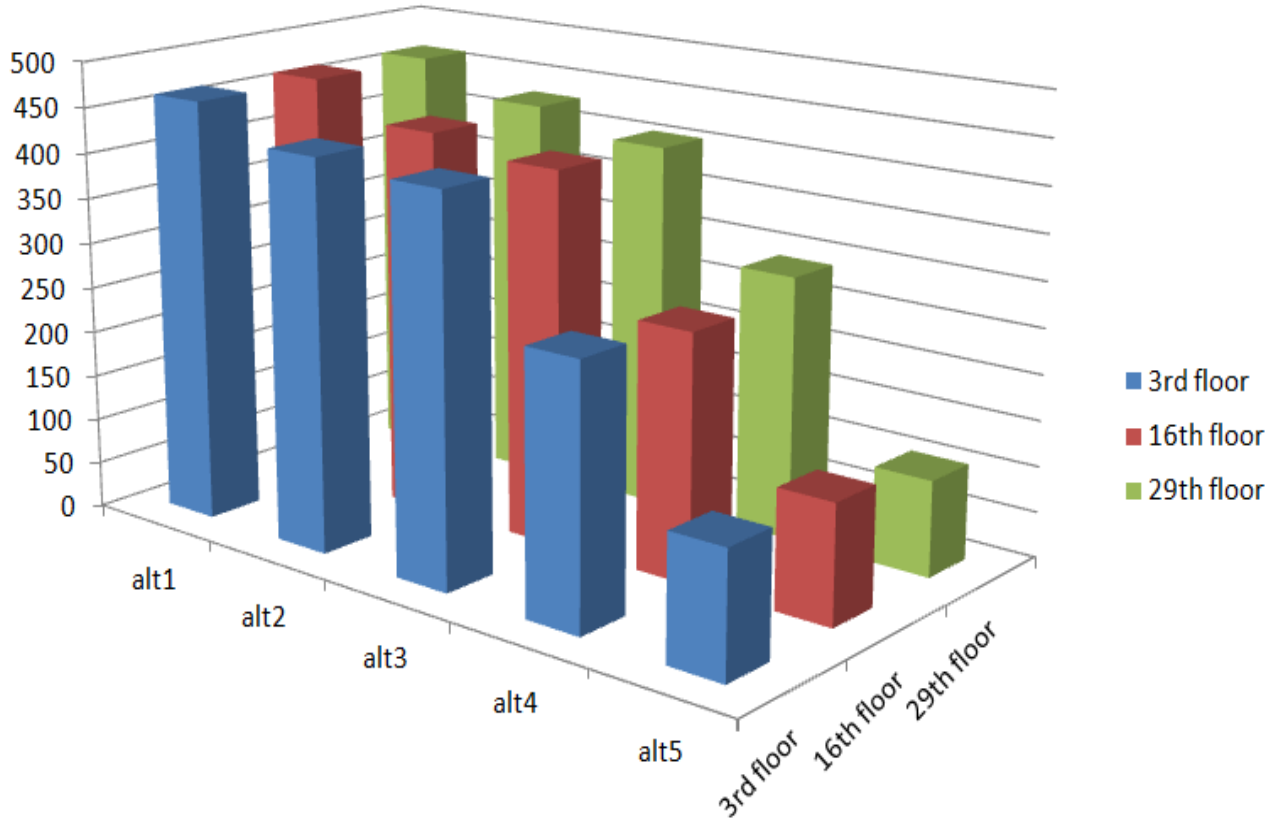


Figure 10: Flow rate distribution with fan operating at speed 3 on the 30th floor [CMH]

Table 4: Comparisons of exhaust air flow rates

Fan	30 story	alt1	alt2	alt3	alt4	alt5
1	3rd floor	322	284	285	144	80
	16th floor	322	290	280	169	64
	29th floor	322	297	275	200	60
2	3rd floor	391	357	350	234	118
	16th floor	391	359	345	233	93
	29th floor	391	363	340	253	87
3	3rd floor	464	428	420	281	135
	16th floor	464	426	410	269	130
	29th floor	464	429	405	290	105
Fan	**60 story**	**alt1**	**alt2**	**alt3**	**alt4**	**alt5**
1	3rd floor	322	272	288	51	77
	29th floor	321	286	272	145	59
	56th floor	322	304	275	215	59
2	3rd floor	391	346	357	187	116
	29th floor	391	355	340	211	86
	56th floor	392	369	343	261	87
3	3rd floor	464	416	424	238	135
	29th floor	463	422	403	245	100
	56th floor	464	435	406	294	101

Fan	110 story	alt1	alt2	alt3	alt4	alt5
1	3rd floor	320	255	286	0	78
	56th floor	321	285	272	58	59
	110th floor	323	315	277	59	60
2	3rd floor	391	335	356	79	115
	56th floor	390	355	340	201	86
	110th floor	391	379	345	292	88
3	3rd floor	463	403	423	166	137
	56th floor	462	421	404	244	103
	110th floor	463	448	408	332	104

Conclusions

(1) In the case of the reference model, when the exhaust hood is not in operation, both infiltration and leakage airflow are observed due to wind pressure and stack effect. When the exhaust hood system is in operation, the exhaust airflow rate remains constant at 322 CMH regardless of the level of building elevation. Therefore, we conclude that the operation of direct-type kitchen exhaust systems is highly effective in minimizing the influence of stack effect and wind pressure in the apartment units based on the reference model.

(2) The level of stack effect increases as the building air-tightness or/and the door leakage area increase. The increased level of stack effect can develop negative pressure zones which work against exhaust airflow. The higher the level of building elevation is, the greater the degree of building air-tightness is, the use of a make-up air system should be considered in order to maintain the effective distribution of indoor air pressure.

Acknowledgments

The authors would like to acknowledge that this study was made possible by a consulting grant from Samsung C&T in South Korea.

Validity verification

Example 18.9

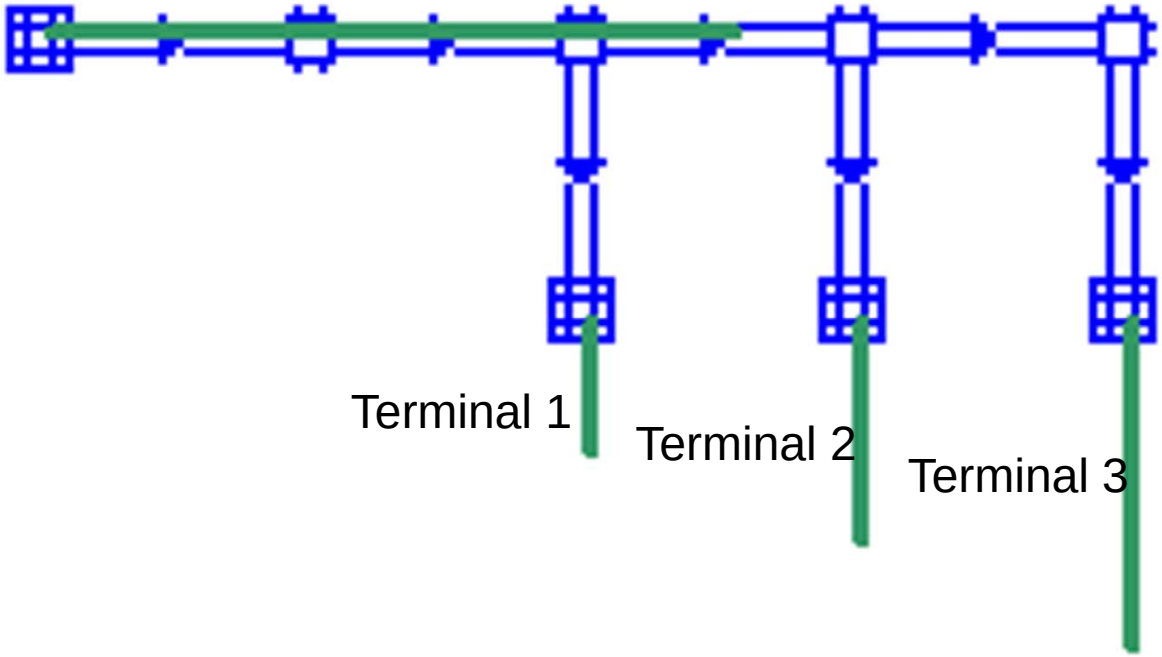


Fig. 2.5 Figure representing example problem by Thomas

Thermal environmental Engineering, 3rd edition, Thomas H. Kuelhn

Table 5 : Results of Thomas's and CONTAM

	Thomas's result	CONTAM	difference %
terminal 1	200 CMH	201CMH	0.5
terminal 2	300CMH	335CMH	11.67
terminal 3	500CMH	493CMH	-1.4

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Thank you.