A General Primer Pressure Gradients Against Disease, Weather, Smoke

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Summary

This paper attempts to provide a general basis for implementing the principles of pressure differentials to aid in providing more user friendly air quality in buildings. This is a new technology application to be added to the commonly used air changes and filtering for cleaner air. The success story of smoke control can now be used as a major strategy against pollution and disease control in buildings. Stale bacteria-infiltrated air can also be contained to its spaces of origin and exhausted from its sources in the building. Unless carried in a box, smoke won't move from a low pressure space to a higher pressure. This paper attempts to stimulate a more precise and more complete use of pressurization concept as used in smoke control. Slight, purposeful air flows for pressurization arrangements can be important contributions. It is just too easy and inexpensive to leave undone.

Used Air In Buildings

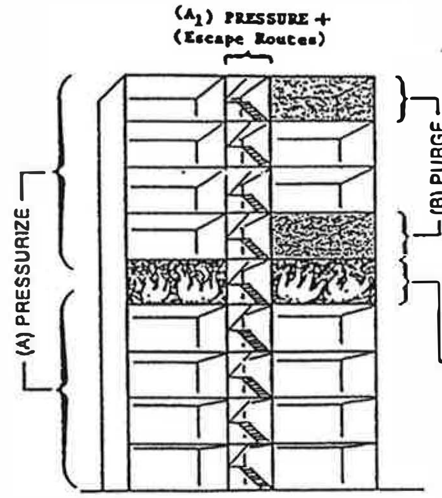
Many of the first molecules trapped within original construction are still there – 25-50-100 years later. They are joined by good clean molecules and bad dirty ones; and, in time with systems that mostly recirculate high percentages of used air there will probably be more bad air than good...so why not change that. How? By improving already existing air changes and filtration methods but with the addition of a selected pressures technology. Is it difficult and expensive? No! So this paper is written to help establish the basic schemes for instituting I.A.Q. pressure gradients capability as an energy reducing add-on system to air changes and filtration. Intra-building pressure gradients is a spin-off pressurization control technology that was developed for smoke management in fire-involved buildings.

Fire Involved Buildings

At first the invisible toxic gases from fires seemed an insurmountable technical obstacle, but as smoke control slowly arose in the early seventies it was soon realized that rather minute pressure differentials at a physical barrier (walls and ceilings) could do the job. It is now well known that few situations exist where extraordinary flow pressures are needed to contain and control smoke from its tendency to spread lethal (sometimes invisible) combustion gases.

These pressurization objectives are outlined in Figure I and Chart 1.

The success story of smoke control can now be used as a major strategy against pollution and disease control in buildings; while reducing air changes and filtration systems loads.



SMOKE SYSTEMS FUNDAMENTALS
SITUATIONS / OBJECTIVES

FIGURE I

3 BUILDING SITUATIONS:

(A) NON-FIRE ZONE—NO SMOKE
(B) NON-FIRE ZONE—SMOKE,
(C) FIRE-ZONE—SMOKE & FIRE

3 PHASES OF FIRE ZONE FUNCTION CONTROL OBJECTIVES

(C1) SMOKE CONTROL—NORMAL AMBIENT—350°F NEGATIVE (or NEUTRAL) PRESSURE
(C2) CONTAINMENT—450°F-2000°F STILLED AIR
(C3) SMOKE CONTROL—UNDER 150°F PURGE (AIR CHANGES)

SMOKE SYSTEM PRESSURE OPERATIONS
CHART I

	BUILDING SITUATION	BUILDING AIR/SMOKE/FIRE ZONES: PRESSURIZE	EXHAUST	PURGE	(A1) ESCAPE ROUTES: PRESSURE	FIRE CONTROL (REFUGE) SPACES: PURGE AS NEEDED
NORMAL	CONTINUOUS	HVAC	HVAC	HVAC	+.01	HVAC/.01
	PEAK USE	HVAC	HVAC	HVAC	+.03	+.03
	OFF HOURS	Selected .03	HVAC Econ.	HVAC Econ.	+.01	HVAC/.01
FIRE/SMOKE ZONES	"A" CLEAR	+.06/.16*	—	—		
	"B" SMOKE	—	—	+.01	+.08/.18*	+.08/.18*
	C-1 (0°-350°F	—	-.02	-.02		
	C-2 (350°-2000°F)	FIRE PRESSURES OR .02" NEGATIVE AS POSSIBLE				
	C-3 (Below 150°F)	—	—	-.01		

*Sprinklered Building +.06/.08 / Non-Sprinklered Building +.16/.18

NOTE: It is preferable that (A1) escape routes (and fire control spaces) have slightly higher pressure objectives over the normal occupancy zones. Interior stairwells may be best pressurized with multiple injections on every 2-4 floors, with intermediately placed pressure set relief barometric dampers (also other pressure setting methods such as pressure sensing damper or fan flow control could be considered) — seek the full pressure range from the maximum door force limit of .4" to the smoke containment minimum of .04" from the accepting authority. (See NFPA 92A Table 2-2 for door size pressure charting.)

The smoke control processes evolved from containment by physical barriers, to smoke containment by pressure-assisted barriers. This paper attempts to stimulate a more precise and more extensive usage of this smoke control by pressurization concept.

The Health Situation

The news carries more and more stories of lost worker time and flu epidemics. In our town there are consultants at work on why people are 'always' sick in some high rise buildings.

There really isn't a need for drastically expensive measures – the solution is not beyond HVAC technology. Indoor Air Quality can be enhanced by selected pressure gradients; e.g., smokers within a lower pressure space would not bother those occupying spaces at the higher end of the pressure gradient. When the bad air is concentrated in less space, the energy for changing and filtering is lessened.

Fresh Air Intake (By Legislation?)

With the energy crunch, economics caused landlords to block fresh air intakes – even in airplanes. This is a very large part of the problem. Surprisingly we do little about air quality even when we have the option. During your early morning walk around the hotel you just slept in, count the number of open windows – 5% at best. Do we need to pass a law on fresh air requirements? Is this one of many inadequate behavior patterns that lead us into more government, e.g., trash collection, sewage disposal, etc. We do take it for granted but isn't breathing even more basic than these? Sometimes we compete with kerosene stoves to see who goes out first. Congress did legislate air intake for car air systems. Well, we can at least ask for a higher percentage of fresh air taken into the heating, ventilating and air conditioning (HVAC) system.

Air Filtering & Cleaning

In a space station filters, cleaning and regeneration are the order of things. They won't be permitted to lost air into outer space. Its not quite that drastic here (yet) so the best of their technologies are more and more needed in our great indoors.

Energy

The very slow pressure gradient induced air motion from inside to outside through all the building outside surfaces prevents the direct flows intrusion or outside temperature extremes. This principle appears to provide energy economies (-- in conjunction with heat exchange from hot outgoing air to cold incoming (and vice-versa for cooling) is quite a viable technology).

Pressure Gradients

One real battlefront for successful pressure designs will come basically from inside pressure zone levels – and there can be several working and shifting. Once the leaks and circulation harmonies are established, the system of gradients can begin. There would be one major gradient down from the actively occupied spaces to the most contaminating space (see Chart III). The neutral pressure plane inside to outside might be considered a base datum point, but without inside to outside openings it may not be very relevant to normal HVAC operating pressures. The real datum position for the mechanical system would be the atmospheric pressure located at ground level.

A smokey fire in a damaged building will have smoke circulation's that would be highly reactive to inside vs. outside pressure/density differences. The natural gradients are the base design criteria. There can be several gradients that vary by the amount of temperature/density consistency along with circulation. The range would be from unheated or cooled stairshafts through elevator vestibules to the highest pressured occupied spaces. The (theoretical) neutral points would vary by the gas laws as the temperatures and gravity relative air densities vary. Density changes with temperature. The temperature changes with pressure in the atmosphere at the .2°-.5° per 100 ft. dry-wet lapse rates. The pressure lapse rate occurs all on its own from gravity with 1.3" W.G. pressure loss per 100 ft.

The relative density of outside to inside air is a basic influence and season changes cause a complete force (flow) reversal. Hotter air inside has an upward and outward bias while cooler inside air wants down and out. But, mechanically induced motion relativity's are the real subject as opposed to inside vs. outside interfacing.

Atmospheric Conditions

A building is a container that sits in the atmospheric pressure gradient. It is leaky but more pertinent is that it has air pumps that basically attempt to circulate HVAC air (hopefully, breathable). This circulation also is a pressure equalizing phenomenon. By distribution of equal temperature HVAC air, along with nearly equivalent zone volumes, the battle against gravity is almost won, but not quite. Without purposeful significant leakage both in and out, the result approaches some mid-point between the outside lapse rate and the inside equalization possibilities. The marriage of these depends on relative density. It is possible that no neutral level exists in the building that equals the outside pressure and all the air is cooler and more dense, and would flow out only from the bottom portion of the building; or heated, warmer, lighter air would only flow upwards and out if there were pathways to the outside. These seasonal or climatic-caused extremes are not normal in the more populous temperate zones of our planet where the building HVAC air is partially lighter and partially heavier than the outside – so a neutral plane does normally exist as a natural base reference.

In & Out Flows

With machine power we mostly ignore the susceptibility of naturally induced air flows. There is a case for placement of intakes and exhausts – unfortunately, these energy saving concepts can be thwarted by such things as automobiles exhausting into low intakes. Nevertheless, our pressurization objects must be take these natural gravity pressure source conditions into account.

Which brings us to wind – expect for the smoke control safety aspects let's forget about wind – unless we get back to windows (aptly nomenclated). Wind may have its structural and some temperature considerations but as far as HVAC pressures dynamics goes we have sealed ourselves from most of wind's forces. Our container may be leaky but unlikely to the point that windward and leeward will cause much pressure gradient control difficulties for a standard HVAC mechanical system.

One important wind related parameter to be developed would be pressure sensing probe placements so that outside air movement pressure changes would be properly averaged into the datum reference.

Solar power can raise internal building temperatures significantly; but few buildings are built like nuclear power plant control rooms that can 'spike' at 0.5" W.G. when fully involved in fire conditions. The gases do expand but they are quickly diffused or relieved by mechanical circulation.

The Pressure Differentials

Actual pressure gradients needed to prevent air migrations from one space to another are low. For small wall and floor openings, a pressure differential of .01"-.03" W.G. will generally suffice. Air or a thin film of water generally will not flow against those potentials. With large openings such as doorways we can see some vagaries -— even two directional flows. So pressures with velocities must be considered. 200–300 FPM will generally insure against unwanted back flows through open doorways; but then there are door closers.

When all is told and accounted for our conclusion is that despite multiple flow adversities, selected space pressure control is rather easily within normal mechanical possibilities - - it is left in the areas of interspacial directional flow design, i.e., the gradients are produced by more air in than out for higher, and less supply than return for continuous lower space pressure. Even variable flows can keep the necessary gradients in effect with damper operation control.

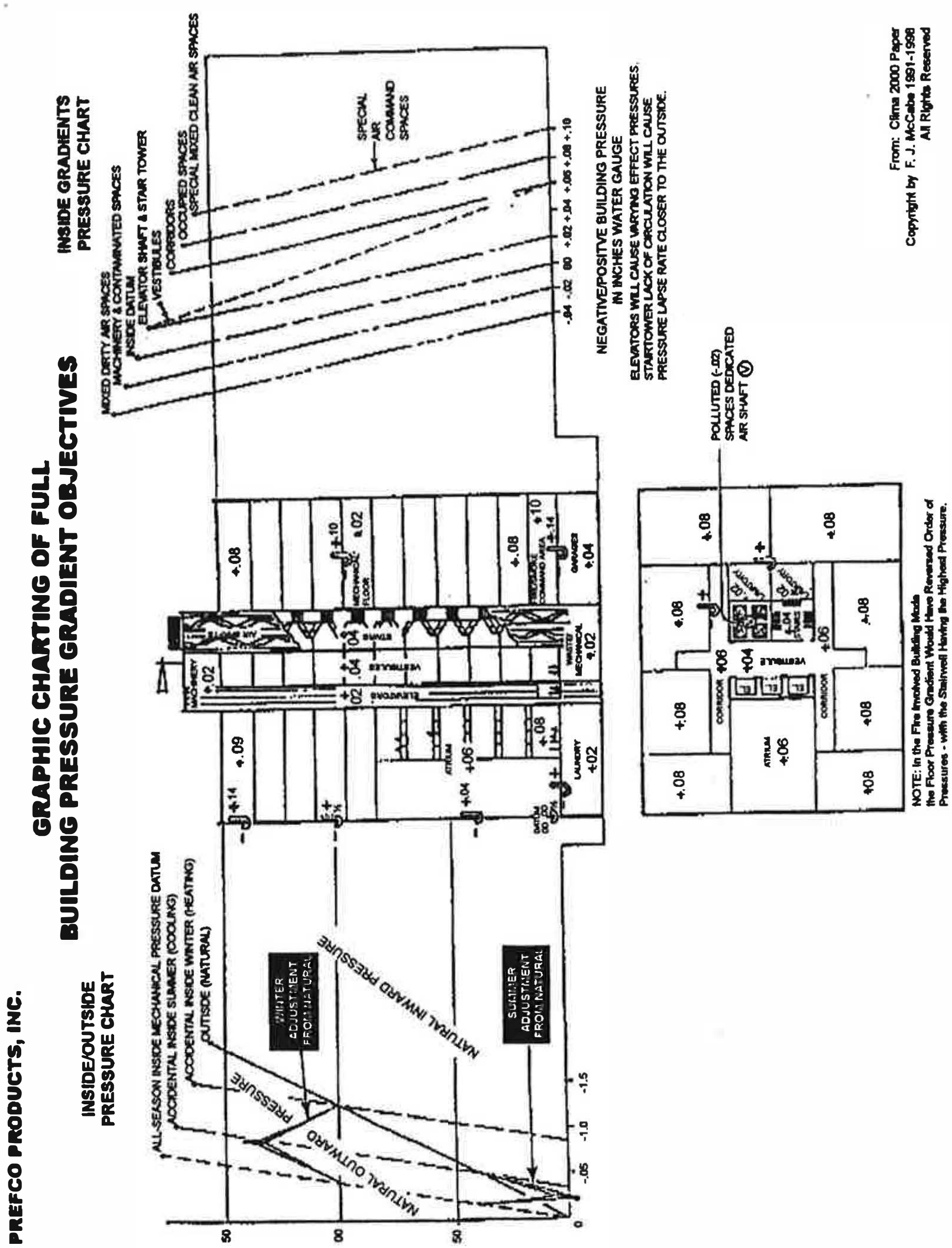
Systems Compatibility's

Central vs. zoned HVAC could be discussed in construction relative detail – but it would seem that central systems with well controlled zone dampering would have the cost effective edge but zoned pressure independent variable air volume would also have ready controllability. Both zoned and central systems would have the required combination smoke/fire dampers that could be fitted with zone pressure setting controls.

Temperature and pressure flows then are done in most simple and sympathetic terms. The basic flows for noise, temperature and the target for breathable air pressures are in the same range as toxic gas control. This also encompasses the smoke control pressure range. So as all the pressures purposes compatibility's become known, that in itself would very likely be a primary impetus for the practicable development and implementation of the complete building pressure control science. (See Chart II.)

The Prescriptions

Simply put, the contamination areas would be continuously held at negative pressure – more air out than in; while the primary occupied spaces would have greater supply than return, to cause relatively higher pressure than lavatories, laundries, machine rooms, kitchens, etc. These would all be the low side of the pressures gradients. Each construc-



tion/usage would have a gradient survey done as part of the original HVAC planning. In hotels the rooms would have the high side. The lobbies and restaurants might be at intermediate pressure.

A chemical laboratory would have the lab at the lowest pressure while offices and other spaces would be higher. Rather than mixing lab return air, separate dedicated HVAC vents would be used to obtain the pressure differentials...and for other more severe human safety mode pressure arrangements.

The basic formula is reversed for smoke control where pressure increases towards the safest dedicated space. The escape route example would be relatively lowest pressure in the corridors, medium in the vestibules and highest in the stairwells. As we have seen, smoke safety can be the deciding factor for pressure gradient design parameters but that would not always be the case. The smoke safety mode would for the most part be left to a control-switched function upon initial smoke/fire detection. This allows normally favoring the pressure gradient air quality condition. In a heavy auto traffic area the buildings would see a total positive pressure always in excess of the lower floors outside the air pressure.

This pressure gradient can also be a real boon to temperature control. Slight downward pressurization from roof and ceiling plenums against warm air rising will significantly decrease temperature losses – vice versa for cooling.

How

The basic approach is sizing the flows which is done partly by sizing the ducts, but mostly by dampering control.

The cheapest systems economies are allowed by combining the air-smoke and fire zones into common spaces. Then it is possible for one set of combination dampers (supply and return) to basically control all the functions. There are several hardware approaches to sense zone of duct pressure and signal the combination damper to modulate to the desired pressure.

Conclusion

More of us will spend more time in the "leaky containers" and this presentation is meant to suggest the possibilities for a cleaner, safer and energy efficient environment. Slight, purposeful air flows for pressurization arrangements can be important contributions. It is just too available and inexpensive to leave undone.

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