VENTILATION SYSTEM PERFORMANCE

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KEYNOTE SPEECH

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VENTILATION AND INDOOR AIR QUALITY - A DESIGN ENGINEER'S POINT OF VIEW

1. Introduction

Mr. Chairman, ladies and gentlemen

I consider it a great honour to have been asked to participate to this meeting as keynote speaker. I am neither an indoor air quality specialist nor a ventilation expert: I am an engineer, responsible for design and commissioning of civil and industrial HVAC systems for TEKNE SpA, a leading consulting engineering firm based in Milan.

I think you will agree with me that designing air-conditioning systems for humans (as opposed to cattle, poultry or industrial products) can be stimulating and challenging at times, but also frustrating and infuriating.
This is because HVAC impinges on human comfort which, as everybody knows, is a highly subjective notion.

An electrical engineer's life is much easier: his systems either work or don't, and if they don't the cause is usually straightforward and fairly easy to find. But the air-conditioning expert isn't so lucky; he is beset with objective technical problems (nothing works as intended, at least in the beginning), and harassed by complaints from the tenants and users who are either too hot, or too cold, or complain of draughts ... and so on, ad infinitum.

But I do not want to bore you with my lamentations: I think I had better mention the points one ought to bear in mind when designing for satisfactory indoor air quality, outline the consequences which can befall when one does not, and finally try and define the information which design engineers need and expect from specialists such as you, in order to avoid the most obvious pitfalls and satisfy the highest possible percentage of clients.

2. Design fundamentals for satisfactory indoor air quality

Textbooks say that, in order to minimize indoor air quality problems, the HVAC design engineer must take at least the following parameters into account:

- indoor air temperature and relative humidity;
- ventilation rates;
- air circulation;
- air filtration.

About the first two parameters a lot has been said and written, and there is very little to add to the comfort range diagram published e.g. in the ASHRAE Handbook of Fundamentals (Fig. 1). It is just worth mentioning that relative humidity, which according to the above mentioned chart can be allowed to swing in a rather broad range (30 -70%), should really be controlled more closely because of its impact on IAQ parameters, and should be limited to the 40 - 60% range (fig. 2).

As for ventilation rates, there is no clear cut rule in Italy; the UNI standards recommend a minimum outdoor air flow rate of 15 m3/h (4.17 L/s), to be increased to 20 - 25 m3/h (5.5 - 6.95 L/s) if smoking is allowed. Local health authorities may enforce higher values, and they usually do for specific applications such as classrooms, theatres or hospitals.

In my professional practice, if no local standard or regulation specifies otherwise, I use the ventilation rates laid out in ASHRAE 62-1989 standard.

Air circulation (intending as such the total air flow rate in a room with its associated terminal velocity) is seldom a problem in Italy, given the widespread popularity of 2 - and 4 - pipe fan-coil systems with or without primary air. I do not have great sympathy for fan-coil units; they are noisy, take up floor space, are useless against indoor air contaminants, and their filters just act as dirt collectors, not to mention the fact that they require maintenance, at least for filter cleaning/changing. It is a fact, however, that they are very popular with tenants because they feel they are in control.

UNI standards recommend that terminal velocities be kept lower than 0.15 m/s. Since all-air systems are not very common outside the industrial environment or special applications (auditoria, theaters etc.), and VAV systems in particular are few and far between, the problems about ventilation effectiveness as outlined in ASHRAE 62 (fig. 3) are no great source of concern.

Outdoor and return air must of course be filtered; the former to reduce the amount of contaminants present in a city environment, the latter to control the indoor pollutants. Except when a higher efficiency is required (such as in hospitals or clean rooms) we specify a filtration system with an efficiency of 95% N.B.S. dust spot methods on all air handling units: and this even though it is known that this is not sufficient to remove typical indoor contaminants such as bacteria, tobacco smoke and fungi. More efficient filtration systems however are too expensive to install and maintain in an office environment; an acceptable compromise can thus be reached by associating a medium efficiency filter with adequate outdoor air dilution as required by ASHRAE 62 - 1989.

I think that it is only natural for the HVAC engineer to expect that there will hardly be any complaints if he designs his system according to these guidelines; but unfortunately it is not always so.

3. Case histories

The parameters influencing human comfort and indoor are quality are many, and the designer must be aware of them all. If he misses out just one, he is bound to have complaints; but if he tries to account for all of them, he may still have problems.

In a revamped office building in Northern Italy the designer had specified an all-air constant volume HVAC system with terminal reheat (provided, as it should always be done, by heat recovery condensers in the air-cooled chillers).

Indoor air conditions specified were within the comfort diagram, and in particular the design relative humidity in winter was 40%. Specifications for outdoor air called for 50 m3/h (13.6 L/s) per person, or 1.5 air changes/h, whichever the greater. Outdoor air was fed to the air-handling units, located one on each floor, via an air handler equipped with a coarse filter having an efficiency of 88% according to ASHRAE 52/76; each floor unit, which handled both outdoor and return air, was provided with a bag filter, efficiency 95% N.B.S.

During commissioning outdoor and total air volumes, as well as ambient temperatures and humidities, were determined; all values conformed to Specifications within the permitted ranges. In theory, then, everything was fine: the tenants, however, did not agree.

The most frequent complaint was of "air draughts", and was interesting enough to notice that they occurred more often in winter and in the intermediate seasons than in summer.
Two types of air outlets had been envisaged for air diffusion: one was a conventional linear grille, and the other a perforated type diffuser, which was integrated in the false ceiling structure.

Because of architectural reasons, the linear grilles were used in some rooms which had a large window area and a shallow depth: the resulting cooling load was so large that 10 - 12 air changes were required to offset it. Even so, the measurements showed terminal velocities at the workplaces below 0.15 m/s; but the billowing of the curtains due to the large amount of supply air was very impressive, and upset and frightened the tenants.

With the perforated diffusers, complaints came mainly from those who sat immediately below the air outlet: in some cases terminal velocities of 0.3 - 0.5 m/s were detected in spot measurements. However, this velocity depended to a very large extent on the temperature of supply air; if the reheat coil was working, and supply air temperature was at 23 - 25°C, there was no problem: but if someone was hot and suddenly decreased the room thermostat set point, he would experience an immediate shower of cold air at 16° C as the valve on the reheat coil closed immediately.

Eventually a solution was worked out by resetting room and supply air temperature upward in those rooms where cooling was required in intermediate seasons: in other cases the solution had to be more drastic, and involved either relocating the diffusers or spreading the air flow over a greater number of supply outlets.

In another building a complaint was registered immediately after system start-up ; many of the tenants complained of itches and skin and nose irritations. A specialized organization was called upon to analyse room air; as well as a total dust content variable from 0.3 and 2.3 mg/m3, chiefly due to site dirt, a concentration of 1 to 7 fibers/liter of fiberglass was found. This insulating material had been specified chiefly for acoustic purposes as duct liner downstream of the VAV boxes; obviously, wherever the installation had been incorrectly applied, it had become loose and detached itself, being carried into the rooms by the air stream.

After a few days, the complaints ceased and did not occur again: obviously all the material which could become loose had done so.

4. Consequences

The above examples show that textbook knowledge and experience sometimes are not sufficient to prevent a building from being defined "sick" (i.e. such that more than 20% of the tenants experience various illnesses which cease upon leaving the building). Design may be done "by the book", and yet the client is dissatisfied. Some obvious down-to-earth consequences which can be drawn are:

- do not use internal duct lining if at all possible;
- even though there is no way to anticipate the actual behaviour of air outlets in a given environment until the system is started, select them with great care. Check terminal velocities for many ranges of room and air temperatures (there are now computer programs which allow the designer to "see" the effect on his video);

- in VAV systems, always use outlets which can vary their area according to their flow rate, so that throw and air movement is not impaired; at the air handling unit, provide controls to maintain constant outdoor air flow rate at part load;
- if a final room layout is not available, build some leeway into the diffusers; use flexible duct connections, and leave some blanked-off duct runouts;
- either do not allow the tenant to fiddle with the room thermostat, or else explain in simple terms how the system works, what it can do and what cannot be expected to do;
- recognize that the best design is no guarantee against faulty installation and sloppy execution, and monitor contractors very closely;
- finally, design for maintenance. Filter cleaning must be easy, or it will never get done. Oppose the architects in their attempts to cut technical room space and height.

5. What the engineer needs from ventilation and IAQ specialists

Basically, what is needed is not a collection of papers full of graphs and formulae, but some design guidelines. For instance:

a) More data about he best pattern for air distribution. I have read that at the latest ASHRAE meeting it was maintained that the maximum ventilation effectiveness (as defined by ASHRAE 62-1989) is achieved by introducing air at floor level and returning and exhausting it from the ceiling. If so, which floor outlets should be used and how should they be spaced? What is the minimum supply air temperature and the maximum outlet air velocity available? Is this solution applicable with VAV systems? What happens in the heating season?

b) ASHRAE 62 states that there is an Indoor Air Quality procedure which can be used to achieve acceptable IAQ in lieu of the Ventilation Rate procedure. How does one apply it in practice? Which instrumentation should the HVAC consultant acquire?

c) How does one calculate or determine the stratification factor S defined in Appendix F of ASHRAE 62?

These are just a few questions, and the list can probably be much longer. I am convinced that the answers to these questions can be easily supplied by many in the audience, and I apologize to those for my ignorance. What I have tried to convey in these few minutes is the concern, which is probably shared by many colleagues of the design community, for the IAQ problem, and the desire to find help and advise. Like Socrates of old, I "know that I do not know", and this, hopefully, is the basis of real knowledge.

Mr. Chairman, ladies and gentlemen, thank you very much for your attention

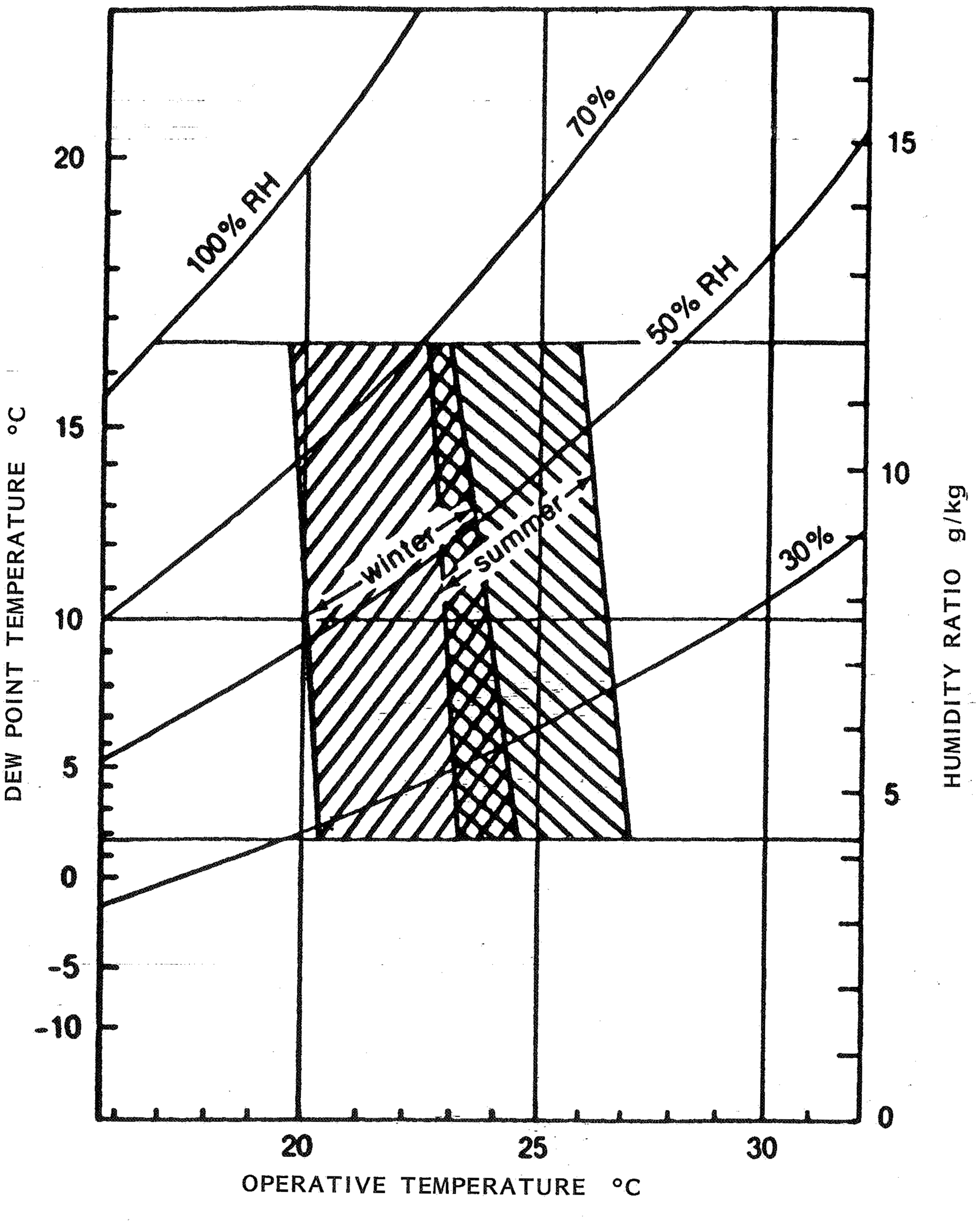
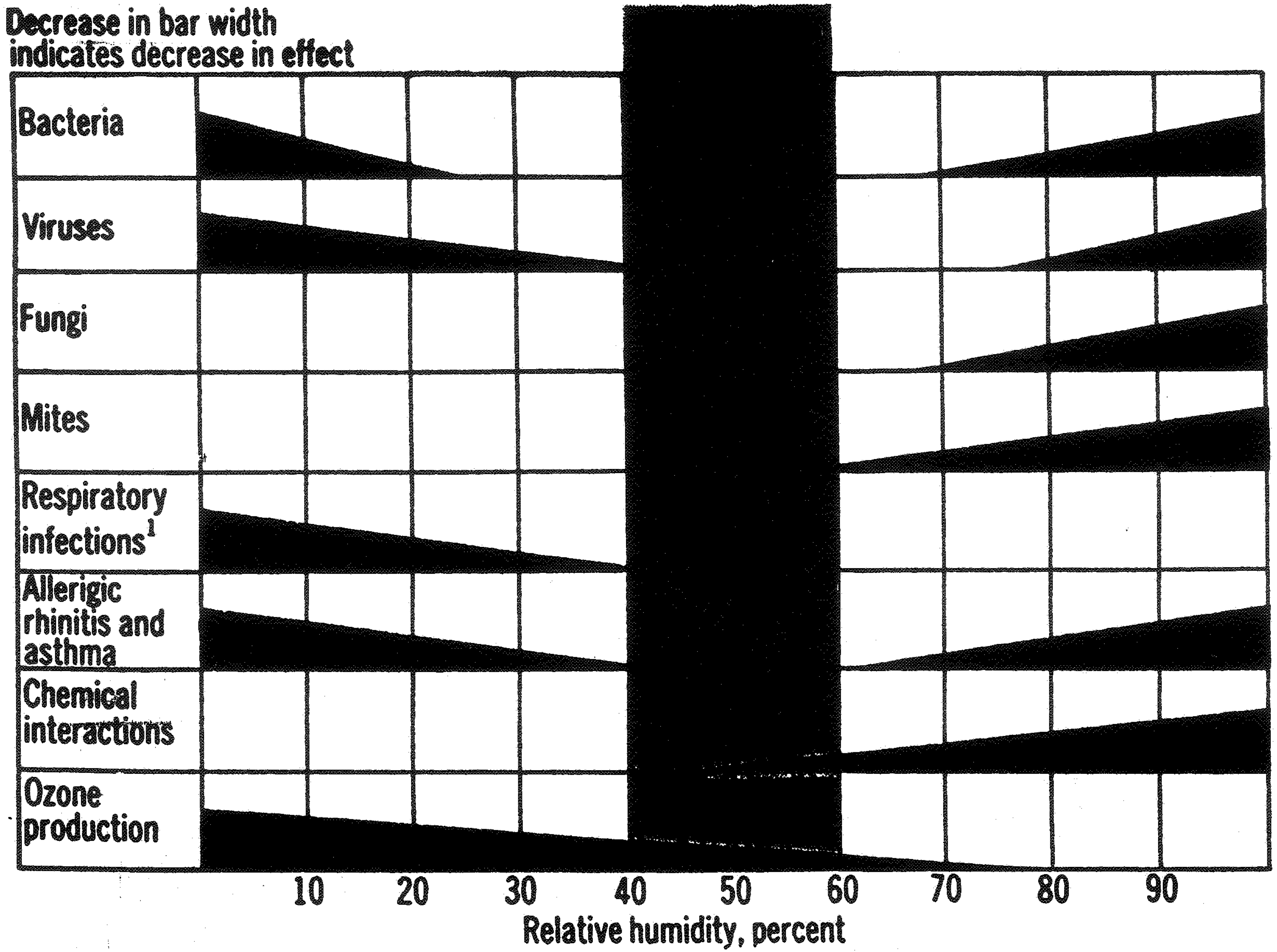


Figure 1. Acceptable ranges of operative temperature and humidity for persons clothed in typical summer and winter clothing, at light, mainly sedentary, activity (≤1.2 met)



[1]Insufficient data above 50% RH

Figure 2. Optimum relative humidity ranges for health

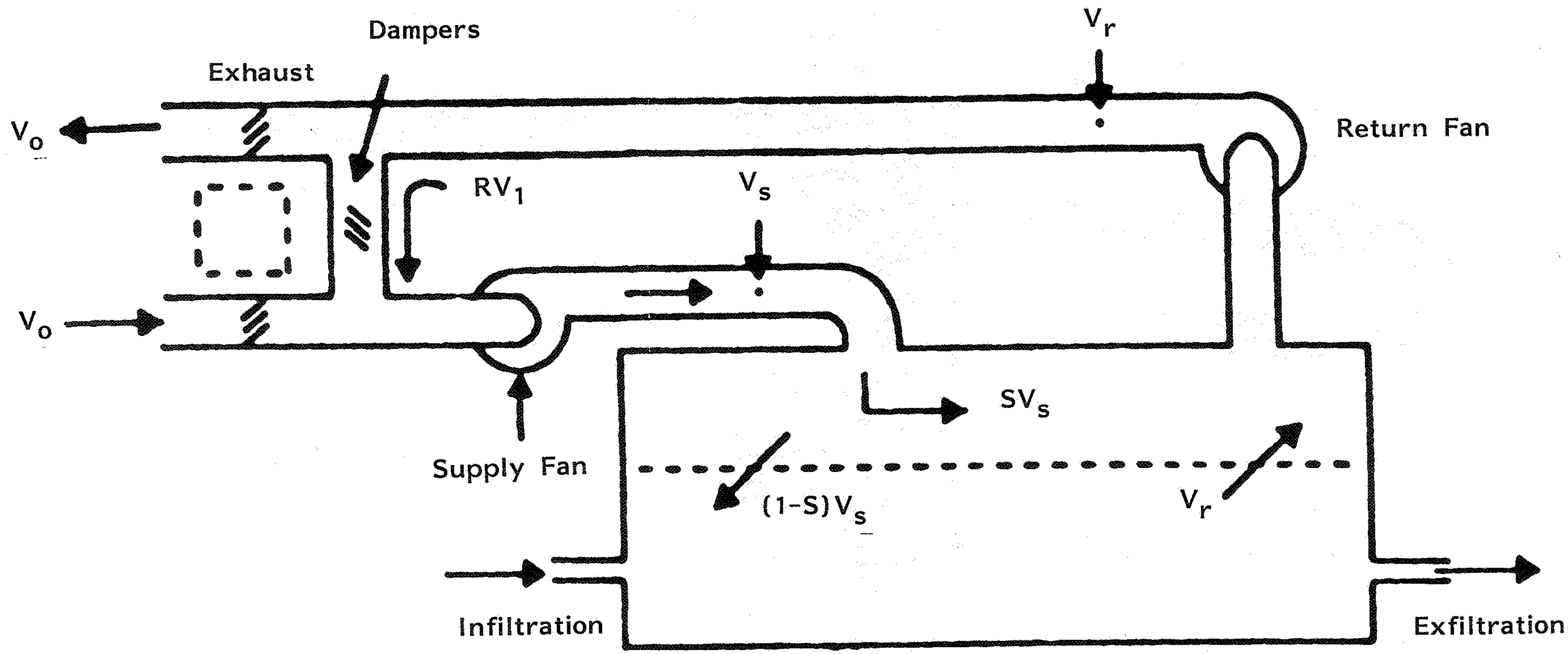


Figure 3. Typical air distribution system

Discussion

Keynote Speech

M J Holmes (Arup R & D, UK)

You have requested that good design guidance is required not calculation methods. Your example of a linear diffiner with 12 air changes and room velocities of 0.1 m/s resulting in discomfort is in conflict with a UK design guide. Could you elaborate and explain why conventional guidance was not satisfactory?

A Sandelewski (Techne, Italy)

The result is not in conflict with the guide you mention. Terminal air velocity measurements at the workplace were consistently lower than 0.1 m/s. However, the shallowness of the room made the air flow very evident at the window. Curtains billowed alarmingly, and this was worrying for the room tenant. Moreover, in the room there was an objective operating problem because of the large window area. However, purely from air diffusion standpoint everything was ok.