Anaesthetic Gas Pollution in Operating Theatres: New Prospects in HVAC System Design

Mazzacane S
Department of Architecture, University of Ferrara, Ferrara, Italy

Introduction

In this paper, the problem of anaesthetic gas pollution in operating rooms is discussed. 2000 experimental investigations were carried out in different operating theatres in North-Italy for a period of 3 years, from 1995 to 1997. Spatial and time concentrations of nitrogen oxide (N_2O) were monitored for different functional conditions of HVAC systems (working from 12 vol./hour to 20 vol./hour of external air flow rates), for different operations (Neurosurgery, childrensurgery, plasticsurgery, othorinolaryngology surgery and so on) and not only in operating rooms but also in adjacent rooms in the same surgery department. Contextually it was monitored the biological concentration of N_2O in personnel urine, that is a good indicator of real inhaled gas quantities. The results show that usual HVAC plants, with constant flow rates, are not able to guarantee the right gas concentrations suggested from international laws, in terms of TLV or TWA. In fact, the concentration range can vary very much (until 1000 % in comparison with the minimum values) depending on aleatory parameters among which: the efficiency level of anaesthesia device, the kind of anaesthesia technique and urgency of operation, the patient characteristics (his metabolism, average, weight, circulatory efficiency), the possibility to intubate or not the patient, the occupied position of surgery team respect to the patient mouth, the operations number in the same day session (more following operations give more transient states and more pollution). The results show the common ventilation art to be inadequate to maintain acceptable IAQ conditions, with serious damages from personnel health point of view (1, 2). Therefore, the common approach to design problem must be reversed: instantaneous gas concentration, being an aleatory and not predictable variable, can pilot the HVAC system air flow rate, so that ventilation (dependent variable) will be proportional to pollutant presence. In consequence of this approach, other laboratory investigations, carried out in a test room representing an operating theatre for 3 years, demonstrated the possibility: to reduce contamination with VAV plant driven by an ambient gas detector; to reduce, in this way, on average, the external air flow rates, with smaller energy consumption (electrical, thermal and refrigerating); to improve IAQ and comfort conditions not only for a smaller gas concentration, but also for smaller air turbulence.

HVAC Control Algorithm

The dynamic operation of the HVAC system (3) is driven by an automatic procedure which has been developed in order to achieve the goals described in the sequel:

- real-time control of the air quality, with fast reaction to unexpected generation of volatile pollutants;
- optimization of the energy costs, by tracking the environmental conditions and setting the HVAC parameters properly;
- improvement of the comfort conditions by adjusting the air flows and, when possible, minimizing the average air velocity;
- simplification of the maintenance procedure.

These functionalities are implemented on a electronic control, whose structure is schematically depicted in Figure 1. In practice, a feedback loop is introduced in this scheme, in order to optimize the system. In detail, trough suitable sensors placed in the considered room, the environmental parameters are sampled and sent to the control unit, by means of the data acquisition system. In this way that system continuously provides traditional thermo-hygrometric measurements, but also environmental data, such as gas or particle concentrations.

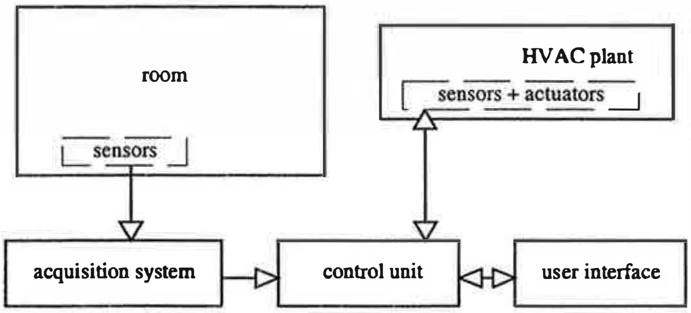

Figure 1. Architecture of the control system.

The control unit, comparing the sampled data with the target values, previously set by means of the user interface, is able to detect any improper drift from the requested environmental conditions. Consequently, it drives the actuators of the HVAC system accordingly, so that those conditions are forced to stay in a defined safety range. In essence, this result can be obtained in different ways: increase of the air changes levels; modification of the air flows; adjustment of the overpressure conditions (with respect to the adjacent rooms).

The simplified flow diagram of the algorithm that supports the control procedure is reported in Figure 2. Once having defined the target parameters (maximum concentration for dispersed gases and/or particles, range of the differential pressure between adjacent rooms, etc.), the system enables its data acquisition device, devoted to provide information about the environmental conditions. Such data are compared with the thresholds that represent the concentration upper bounds for every pollutant. After that, in a normal situation, similar tests are done on: thermo-hygrometric variables, status of the air filters, differential pressure.

The algorithm continuously loops along the basic logic path, in a user-transparent way, until all the operative parameters stay within an acceptable range. On the contrary, when a given limit is trespassed, suitable routines start. For the sake of brevity, we can summarize their actions as shown in Table 1, where in the first column are listed the possible causes of system alarm, in the second one are indicated the subroutine devoted to solve the relative problems and, finally, in the last column are reported the variables on which such subroutines operate.

Table 1. Control algorithm.

alarm	*control subroutine*	*controlled parameter*
gas/particle concentration	pollution reduction	air changes (air flows levels at the inlets)
differential pressure	room overpressure	air flows levels at the outlets
air filter status	dirty filters	-

Time out 1 and 2, indicated in Figure 2, respectively relate to the alarm considered in the first two rows of Table 1. They are the time limits tolerated for extra-range system status permanence. In other words, each of the above mentioned alarms, previously processed internally to the control procedure, become evident to the user, through suitable signaling tools, only after the expiration of a given time period (different for every alarm type). In normal condition, the latter is needed to allow the system to solve the detected problems. In fact, we can accept a non-ideal operation status if it is temporary and, therefore, quickly modified by the control. The case of the alarm indicated in the third row of Table 1 is rather different. In fact, when the system communicates that the air filters need to be changed or cleaned, the maintenance service is activated, once again through a specific remotized alarm. Finally, time out 3 (see Figure 2) is optional. Signaling a long opening period of the room doors, it makes evident an improper behavior of the operating staff, together with a possible undesired and uncontrolled air exchange among clean and dirty areas.

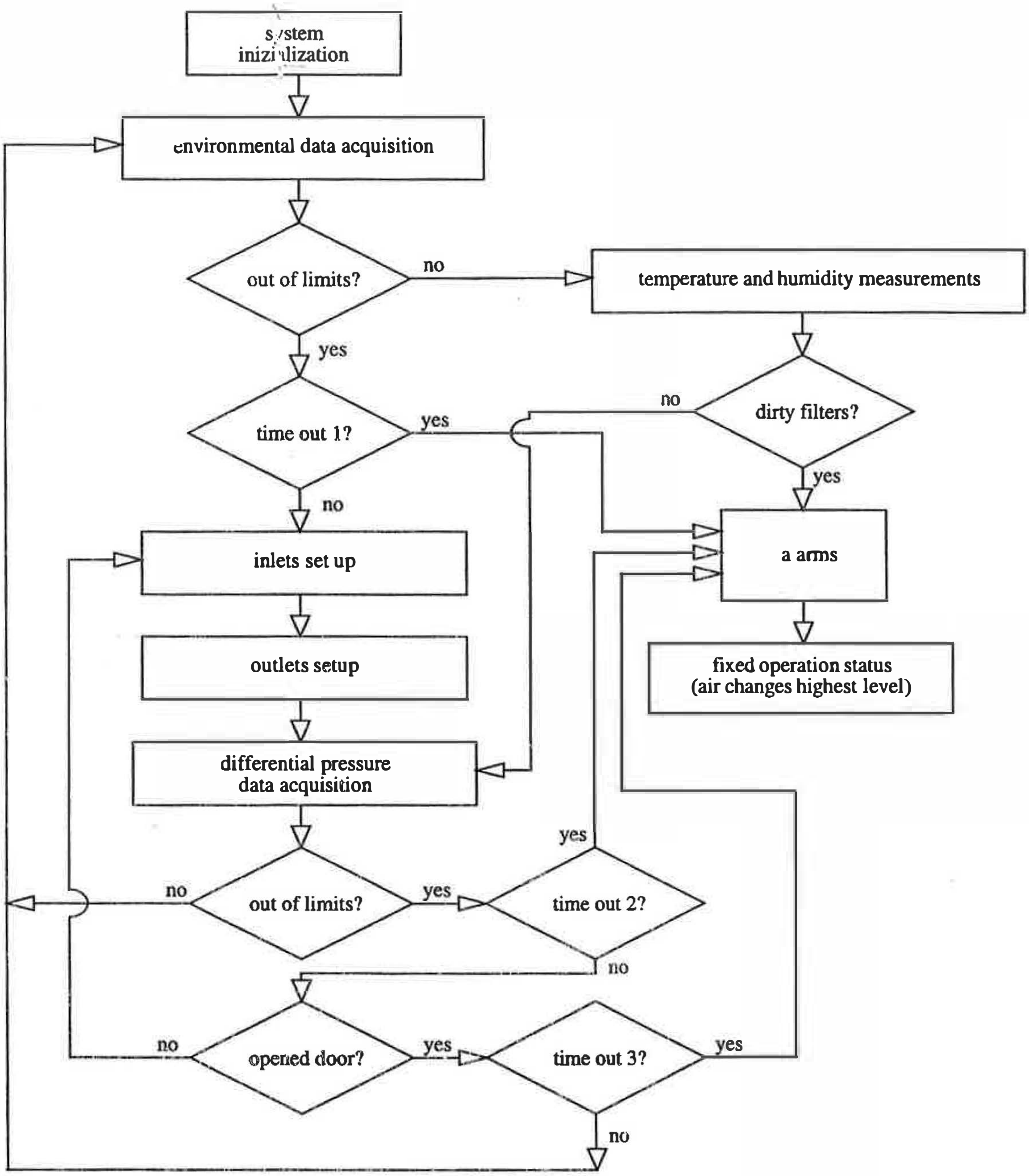

Figure 2. Control algorithm.

References

1. K.Horeauf, M.Lierz, G.Wiesner, K.Schroegendorfer, P.Lierz, A.Spacek, L.Brunnberg, M. Nusse - *Genetic damage in operating room personnel exposed to isoflurane and nitrus oxide* - Occupational and Environmental Medicine - 1999 - pagg. 433–437
2. R.Ruzica Rozgai, Viiena Kasuba, Mladen Peric - *Chromosone Aberrations in operating room personnel* - Am. J. of Industrial Medicine - 1999 - 35, pagg. 642–646
3. A.Borella, A.Dumas, S.Mazzacane-*Energy saving and dynamic control of HVAC systems in operating theatre: an experimenatal approach*- Int.Con. ROOMVENT'98-Stockolm 98-V.1-pag. 213,218-Editors E.Mundt