Defining the purpose and determining the basic parameters of an anesthesia machine are essential when we consider the job the anesthetist has using the machine. As far as he is concerned, an anesthesia machine is mainly a mechanism for executing his commands. It is he who determines and sets the concentration of the anesthetic and the artificial pulmonary ventilation (APV) regimen, but it is up to the anesthesia machine, jointly with the APV machine, to ensure maintenance of the prescribed parameters.

In accordance with the purpose it serves, an anesthesia machine has to satisfy a number of demands concerning the dosage of volatile anesthetics and compressed gas, the respiratory circuit and the administration of APV, the checking and measuring equipment, etc. Each of these elements plays a definite role, each making a substantial contribution to the functional and operational efficacy of the machine. However, primary consideration must be given to the basic function of the anesthesia machine, i.e., metering the dosage of inhaled anesthetic, since this very method of anesthesia administration determines the most important factor, the concentration of the anesthetic in the inhaled mixture. Hence the main problem in the design of an anesthesia machine concerns the dosage of vaporized anesthetics, and the vaporizer, being the means for controlling the dosage, is thus the crucial element of the anesthesia machine.

There is as yet no known ideal anesthetic that has sufficient anesthetizing power, allows rapid induction and recovery of the patient, and exerts minimal negative side effects on the patient. That is why the anesthetist must be able to choose, from a number of anesthetic agents that cover the entire range of conceivable situations, the one most suitable for the patient and the operation. One solution would be to equip the anesthesia machine with several vaporizers; another way is to use a universal vaporizer. The latter is preferable because of simplicity of design and construction, size, and cost. However, the requirement that several anesthetic agents be administered by means of a single vaporizer puts considerably higher demand on the efficiency of the vaporizing chamber and on the precision of dosage, since anesthetics differ substantially in their physical properties, molecular weight, saturated vapor pressure (particularly at boiling point), viscosity, molecular diffusion coefficient, etc.

A substantial factor in inhalation anesthesia is the breathing pattern of the patient. Two different forms of inhalation exist with regard to the pattern of gas movement through the vaporizer: intermittent (nonstationary) flow, with spontaneous breathing and air APV, and constant (stationary) flow, when the energy of compressed gas is utilized. The difference between the two breathing regimens (concerning gas flow rate, curve of rate change), changes in ambient temperature, and the pressure pulsation in the patient’s circuit during the administration of APV all pose serious difficulties on the maintenance of constant anesthesia dosage.

Accuracy of dosage is one of the most substantial properties of the machine because it allows the anesthetist to establish a definite and, in many typical situations, unequivocal link between the depth of narcotization and the concentration reading on the vaporizer scale. The higher the dosage precision, the more precisely does the vaporizer scale indicate the possible depth of narcosis.

We have mentioned that anesthesia is administered to the patient while he is breathing spontaneously,
as well as while he is under APV. In the former case, the vaporizer must not disturb the patient's breathing. The type of vaporizer that does not do so is a low-resistance (drawover) vaporizer, as opposed to a high-resistance (plenum) vaporizer, from which flow can be obtained only with the assistance of a secondary source of energy, e.g., compressed gas.

In a vaporizer with division of flow, precise dosage is accomplished by steady division of flow and by balanced saturation of the carrier gas with the anesthetic vapors. The first problem is solved by designing a distributing mechanism in which the bypass lines and the vaporizing chamber have similar hydro-mechanical parameters. The resistance of the distributing system itself should exceed that of the chamber and connecting channels by one or two orders of magnitude.

When selecting the parameters for the distributing system it is advisable to concentrate on the extreme regimens of gas movement, i.e., laminar and turbulent. It should be noted that the resistance of a turbulent distributing system falls rapidly with decrease in gas flow rate and becomes comparable to that of the turboducts and the chamber. Hence the upper resistance limit (at maximum flow rate) has to be sufficiently high so as not to fall into the range of small pressure drops (at minimum flow rate), which do not ensure steady division of flow. In plenum vaporizers it is possible to concentrate either on the turbulent or laminar mode, but for drawover vaporizers the laminar mode is the more natural choice, because its advantages become apparent at relatively small linear velocities of gas. If the permissible resistance to breathing is limited, as in the case of a drawover vaporizer, a rather small range of pressure drops — up to 10 mm H₂O — is available. In that case the laminar mode permits a more economical utilization of target resistance range than does the turbulent regime and widens the permissible range of flow rate in which the outlet concentration remains steady.

It is not always possible to obtain a purely turbulent or purely laminar regime. In principle, we should speak of either predominantly turbulent or predominantly laminar mode, and the effect of harmful resistances that interfere with the gas flow pattern in one line, e.g., the chamber line, should be compensated for by a similar resistance in the other line — in this case, the bypass.

Applying known relations between hydraulic resistance, flow speed, and physical parameters of gas mixture, we can, given a chamber with balanced saturation, establish the analytical relation between anesthetic concentration (C) at the vaporizer outlet and the construction parameters of the distribution system, the physical properties of the anesthetic agent, and the carrier gas, temperature, and pressure. Thus, for a turbulent regime [1]

\[
c = \frac{P_{an}}{\rho} \left[ \frac{1}{1 + \frac{P_{an}}{P_c} \sqrt{1 + \frac{P_{an}(P_{an} - 1)}{P - 1}}} \right]^{\frac{1}{P_{an}}}
\]