LETTERS TO THE EDITOR

SIR:

I would like to bring to your attention a very serious and potentially dangerous situation which has arisen on two occasions in the past in the Hospital for Sick Children. It is felt that this information should be made known to anaesthetists and hospital administrations, as a similar situation in all probability exists in other Canadian hospitals.

The situation concerns a sudden increase in pressure within the nitrous oxide (N_2O) pipeline system of our hospital. In this institution, the pressure is maintained at 60 psi, and on both occasions the pressure increased to 80 psi. The N_2O line is connected to the machine and the gas passes to the rotameter without going through a regulator and pressure relief valve, which was by-passed when cylinders on the machines were no longer required. Consequently, any increase in line pressure was reflected in an increased flow through the rotameter and to the patient. Fortunately, these sudden changes were quickly noticed by the anaesthetists on both occasions and there were no untoward effects.

Nitrous oxide was supplied from two banks of cylinders. Gas from all cylinders in each bank passed through a manifold to a pressure regulator and then the lines from each bank were joined to form the main line leading to the operating rooms. These regulators can be manually controlled and are necessarily adjustable when a change is made from one bank to the other. On the first occasion of increased pressure, it was determined that one of these bank regulators was faulty, and on the other occasion human error was involved in resetting the pressure when the banks were changed.

Remedial action was instituted at once, as follows:

1. A closer supervision is in effect by the engineering departmental staff, including an improved and detailed check-off list which is to be carried out during each shift. No criticism of the engineering department is implied, as they have conscientiously maintained a regular surveillance and maintenance of all equipment in the past.
2. Present regulations (CSA Standard Z32-1963, section 4.3) require that regulators function within a 50 per cent leeway, i.e. the over-pressure relief operates at 50 per cent over the regular pressure. Thus a regulator set at 60 psi would allow the pressure to rise to 90 psi and still meet the regulations. Consequently, a new pressure regulating valve is on order from the manufacturer which will be pre-set and will not have an over-pressure relief set at 50 per cent. This will be placed in the main line.
3. In case the new regulator fails, a solenoid switch will be placed beyond this regulator. It will automatically allow a blow-off of N_2O to the atmosphere if the pressure rises in the system.
4. An alarm system has been set up in the engineering department.
5. All pressure indicators in each operating room are being individually checked out and re-set.
6. All anaesthetic machines will require a new yoke to allow the N_2O line to

pass through a regulator and pressure relief valve which are presently being developed.

7. The capacity of each N₂O bank has been increased from five to ten cylinders.

In conclusion, I would like to recommend that the existing code pertaining to the medical gas pipeline system be reviewed.

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SIR:

This year [1968] has seen the fifth anniversary of the tragic death of Dr. Hugh Orr Cameron whose inventions concerning anaesthesia have now been patented, with all potential benefits accruing to this university.

On October 5, 1963, at the age of 29, Dr. Hugh Orr Cameron died in an explosion. The medical profession lost in him a fiercely independent member, and an imaginative inventor. He graduated from the University of Toronto in 1957. Following graduation, he demonstrated for a year in anatomy, and then worked for two years in experimental surgery under Doctor W. Bigelow at the Banting Institute. Thereafter, he decided to become a general practitioner in Northern Ontario. His father owned a plant for the manufacture of nitrous oxide in Toronto. This stimulated his interest in anaesthetic gases. In time, this interest grew so intense that he worked day and night on the achievement of his self-set goals. A few months prior to his death he gave up his practice to pursue his aims in Toronto. During this period he became for a time a frequent guest in the Department of Pharmacology in order to use some measuring devices. There he initiated lively discussion, and, between criticisms, debates, and experiments, his ideas crystallized.

Dr. Cameron's problem

For more than a century volatile anaesthetics were administered in such a way that one could seldom be sure of the precise quantity to which the patient was exposed. During the past decade, and especially after the introduction of halothane, many efforts were made to produce adjustable vaporizers that would permit the physician to choose concentrations of anaesthetic vapours at will; the resulting vaporizers have profoundly affected anaesthesia but are, nevertheless, either expensive or inaccurate. Dr. Cameron was convinced that it should be possible to construct containers from which gases containing fixed concentrations of anaesthetic vapours could be released without the use of complicated vaporizers. For instance, he visualized a tank from which to draw nitrous oxide containing 3 per cent halothane. Such a mixture could easily be diluted according to immediate need, using only the flowmeters of any ordinary anaesthetic machine.

The solution of the problem

Under a pressure of 750 psi, nitrous oxide is a liquid, and commonly used cylinders contain nitrous oxide in liquid form. Liquid nitrous oxide behaves in many ways like an organic solvent and is miscible with volatile anaesthetics, for instance halothane. It is therefore possible to fill a cylinder with a mixture of liquid nitrous oxide and halothane.

For many mixtures of two liquids, there exists a particular proportion at which the two components evaporate at the same rate, that is an azeotropic mixture. One may recall that a mixture of 96 per cent alcohol and 4 per cent water is of such a nature and thus cannot be separated by distillation. Dr. Cameron attempted to find such mixtures of anaesthetics and nitrous oxide but without useful result. For instance, if there is an azeotropic mixture between halothane and nitrous oxide, the halothane concentrations are so low as to be useless. If one places a high concentration (say 5 per cent) of liquid halothane with liquid nitrous oxide into an ordinary cylinder and then taps the vapour, the two gases are drawn off in proportions determined by their respective vapour pressures. In practice, the proportions are variable.

There is a way to overcome this difficulty. Let us assume again that there is a liquid of 5 per cent halothane in nitrous oxide contained in a cylinder. If one leads the liquid to the release valve, either by inverting the cylinder or by using a siphon tube, the desired proportion must be in the release valve, and the drop of liquid vaporized at this spot must contain the predetermined proportion of halothane. This works for a short time, but then fluctuations of halothane concentrations occur. The vaporization consumes energy to strongly cool the valve. The halothane tends to condense, since it has a very much higher boiling point than does the liquid nitrous oxide.

Dr. Cameron built a device which had its point of vaporization at the end of a thin copper pipe. It was then possible to heat the pipe in the hope that the copper would conduct sufficient heat to the orifice to prevent halothane condensation. Dr. Cameron noticed that this procedure greatly reduced the fluctuations of halothane concentration. This experiment pointed the way to the full understanding of the principal problem involved, namely, *How could one have enough heat at the point of vaporization to keep it at a temperature which would prevent condensation of the less volatile component?* The uni-directional heat transfer through a copper pipe was insufficient to overcome the cooling effect of vaporization. Air has a low heat capacity and is therefore not a good vehicle to transfer heat to a point of vaporization. However, liquids such as water have high heat capacities. The volatile mixture of halothane and nitrous oxide was therefore evaporated from an orifice under water. A gas of the desired composition bubbled from this orifice since the water prevented condensation. No droplets of condensed halothane fell to the bottom of the water container, proving complete evaporation and mixing of the molecules of halothane and nitrous oxide.

Water has a very much greater heat capacity than either air or metal, and the heat content of the water is therefore sufficient to maintain smooth vaporization for some time. With continued vaporization, however, the heat in the water would be used up. It could only be replenished from the heat of the room air.

The rate of heat transfer from air to water would therefore become a critical factor in determining the duration of smooth vaporization. On prolonged vaporization and insufficient heat transfer from air, the water might freeze and block all vapour formation.

At this stage, Dr. Cameron came up with another idea. He added liquid CO_2 to his mixture of liquid nitrous oxide and halothane, and he added sodium hydroxide to the water. On evaporation, CO_2 enters the sodium hydroxide solution simultaneously with nitrous oxide and halothane. The latter agents bubble through but the CO_2 immediately reacts with the sodium hydroxide in the water and thereby liberates heat. In this way the anaesthetic mixture was made to carry its own heat-generating material so that smooth vaporization was assured.

A few days before his death Dr. Cameron contemplated replacing the sodium hydroxide in the water with sodium or potassium peroxide. This also reacts with carbon dioxide to yield heat, but in addition this reaction releases oxygen. It would thus be possible to have a device ready to deliver a predetermined mixture of oxygen, nitrous oxide, and a volatile anaesthetic.

Dr. Cameron was too restless to let himself be hindered or held back by success or to pause to publish. In addition, many of his notes perished with him. This necessitated some delay in the reconstruction of his work. But it is never too late to honour the ingenuity and generosity of a man who achieved with his work an enduring memory for himself.

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