EARLY USE OF ROTAMETER IN ANÆSTHESIA

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THE rotameter has gained widespread use for measuring the flow of gases and liquids in industry. It is also extensively used in anaesthetic practice.

Mr. Karl Küppers of Aachen applied for a German patent on this flowmeter in 1908, which was granted on December 15, 1909 (Küppers, 1909). He had worked out the scientific principles of the apparatus at the Chemical Technical Institute of the Aachen Hochschule (Anonymous, 1910a; Neu, 1910a). Mr. Küppers had obtained patents first for a burner which produced a flame of high temperature. To produce this blue flame for incandescent light or heating purposes it was necessary to bring together two gases in a given volume relationship. It seems quite probable that Mr. Küppers later invented the rotameter as a measuring device to indicate the relationship of the two gases flowing into the burner.

The commercial production of the flowmeter was undertaken in 1909 by the Rotawerke at Aachen under the name Rotamesser. The name of the company was changed to Deutsche Rotawerke on July 1, 1910, when Mr. Felix Meyer took over its management (Handelsregister, 1910). Shortly following the beginning of commercial manufacture two rotameters were sent to the School and Experimental Gas Institute of the German Society for Gas and Water Specialists in Karlsruhe, which was under the
direction of Professor Karl Bunte. Here the flowmeter was studied and tested and a report was made describing the scientific basis for the accurate measurement of gas flows by the instrument and enumerating its possible applications (Bunte, 1910). This report apparently formed the basis of subsequent announcements and articles on the rotameter (Anonymous, 1910b, c, d, 1911a, b, c, d, 1913; Meyers, 1910; Strache, 1913; Bertelsmann, 1911). The flowmeter was also studied at the Chemical Laboratory of the Clay Industry in Berlin and a report was made to the Society of German Manufacturers of Fire-Proof Products on February 16, 1910 (Cramer, 1910).

Dr. Maximilian Neu

Dr. Maximilian Neu of the Heidelberg Women's Clinic adapted the rotameter to provide a known volume percentage relationship of nitrous oxide–oxygen during anaesthesia. Neu attended the February 22, 1910, meeting of the Natural History Medical Society of Heidelberg held in the auditorium of the Pharmacological Institute (Offizielles Protokoll, 1910). At this meeting Professor R. Gottlieb spoke on the advantages of nitrous oxide–oxygen anaesthesia combined with morphine scopolamine premedication; and his associate, W. Madelung, demonstrated the action of nitrous oxide–oxygen anaesthesia on rabbits premedicated with morphine and scopolamine. Evidently Neu was already interested in this type of anaesthesia as he is listed as one of those who took part in the discussion along with Gottlieb and Medelung. At the following meeting of this society held on July 26, 1910, Dr. Neu presented a paper entitled “A Method of Nitrous Oxide–Oxygen Anaesthesia” and demonstrated the use of the rotameter for a patient during an operation (Neu, 1910a, 1910b). Neu first
acknowledges the work of Gottlieb and Madelung with combined nitrous oxide-morphine-scopolamine anaesthesia. He states that "some time ago Mr. Küppers of Aachen was able to construct an apparatus to measure gas which bears the name 'Rotamesser' and which serves to indicate the consumption of gas in a simple way. The scientific principle of the apparatus was worked out at the Chemical Technical Institute of the Aachen Hochschule (Professor Rau)." He then describes the principle of the apparatus. Further he states that "Herr Professor Bunte in Karlsruhe has just recently tested the apparatus in his experimental gas institute and found that the readings of the rotameter are correct. . . . By means of this apparatus, it was now an easy thing to produce an accurate mixture of nitrous oxide and oxygen. In particular, an apparatus must have the ability to produce a mixture according to percentage of volumes, and the Rota-apparatus provides exactly a mixture of gases in fixed volume ratio. A postulate of pharmacology is also realized according to which only an apparatus which conveys the complete dosage mixture directly to the airway gives actual and certain control over the concentration of anaesthetics in the atmosphere of the lungs." An illustration shows the arrangement of the apparatus.

He continues: "If I, for example, place the apparatus so that the float of the oxygen meter is on 1, and that of the nitrous oxide meter stands on 4, then I have a percentage volume relationship of 20:80, that is, I allow the apparatus to measure for a unit of time of one minute; therefore 1 litre of oxygen and 4 litres of nitrous oxide flow through the measuring tube in the minute. By means of the apparatus I am in a position to multiply the consumption relationship, whereas the percentage relationship remains the same. I
can thus, for example, allow 2 litres of oxygen and 8 litres of nitrous oxide per minute to flow through. With that the volume relationship naturally remains unchanged. With the arrangement which I demonstrate to you we were in a position to allow exact dosage mixtures of gas to flow to the patient. We have gradually learned to accomplish N₂O-O₂ anaesthesia with complete depth." Further on he states that he is already occupied in designing a scientific apparatus to analyze the blood circulation during anaesthesia. A footnote states that the Rotawerke at Aachen has undertaken the construction of such an apparatus. The apparatus is not described and a careful search of his subsequent writings does not reveal a record of any further work on this subject. The use of the rotameter to measure blood-flow rates was reported by Gregg et al. in 1942.

Neu gave his second demonstration of the new apparatus and a paper at the 82nd Meeting of the German Society of Scientists and Physicians held at Konigsberg on September 20, 1910 (Neu, 1911a, 1911b). He first refers to the advantages of combined morphine-scopolamine-nitrous oxide-oxygen anaesthesia based upon the research of Gottlieb and Madelung. He then goes on to state: "The hypothesis for a rational application to man was to find a method able to produce an exact dosage and a variable gas mixture. This postulate the author was able to fulfill. The author availed himself of Mr. Küppers of Aachen for the construction of the anaesthetic apparatus along with the gas measuring apparatus which bears the name Rotameter and therefore serves, in a simple manner, to indicate the gas flow. With the help of this apparatus an exact dosage mixture of nitrous oxide-oxygen in the desired percentage of volume could be produced. Apparatus for pure nitrous oxide, nitrous oxide-air, and nitrous oxide-oxygen anaesthesia
has existed in quantity in America, the land of laughing gas anaesthesia, for quite some time, but none of this apparatus renders possible the measurement of the gas and the variation of the mixture of the gas. The essential importance and newness of the apparatus lies in the carry-over of measurement of gas into the technique of nitrous oxide anaesthesia and in the development of the principle to vary momentarily the percentage mixture of gas. By means of the combined method of morphine-scopolamine, nitrous oxide-oxygen anaesthesia and of the new apparatus 41 anaesthetics were given."

The paper was discussed by Gottlieb of the Pharmacological Institute of Heidelberg who reported his work with Madelung on the increased effectiveness of nitrous oxide-oxygen anaesthesia on animals following premedication with morphine and scopolamine. He recommended the apparatus of Neu since it would provide exact dosages in the application of this research to man.

Neu again demonstrated his apparatus at the Natural History Medical Society of Heidelberg on February 7, 1911 (Neu, 1911c). "Mr. Neu demonstrated his useful apparatus for nitrous oxide anaesthesia. He gave first of all a technical communication on the apparatus. The apparatus stands on a nickel-plated and movable table to which the nitrous oxide and oxygen tanks can be attached. On the tank is a reducing valve through which at the same time the gas capacity in the tank is controlled. The gas passes through the rotameter to a mixing bag, which can be closed by a stopcock. The apparatus is so built that it can be readily combined with the Tiegel-Henschen positive pressure attachment for intrathoracic surgery. . . . The Deutsche Rotawerke in Aachen which undertakes the manufacture and distribution of this useful anaesthesia apparatus,
guarantees the exact calibration of the rotameter tube.” He then mentions the high price of nitrous oxide which up to then had only been made in England and America, and expects that the German chemical industry will soon undertake the manufacture of nitrous oxide and thus reduce the price.

Dr. Neu demonstrated his apparatus and delivered an extensive paper on nitrous oxide-oxygen anaesthesia at the 40th Congress of the German Society of Surgery on April 22, 1911, at Berlin (Neu, 1911d, 1911e) in which he repeated previous observations and stressed the following advantages of the machine: “The action of the rotameter is stabilized by the rotation of the specially built float. Suitably engraved white spiral lines on the float make its movement perceptible to the eye. The graduation in litres flow rate per minute is fixed empirically during calibration of the tubes. The adjustment is reached quickly and easily. Thus a momentary and certain variation of the dosage is guaranteed. The Deutsche Rotawerke in Aachen build the apparatus and guarantee the exact performance of the metering tube.”

Maximilian Neu was born in 1877. At the time of his writing he was a lecturer at the University of Heidelberg and an assistant at the Women’s Clinic. At some of the medical meetings where he demonstrated his apparatus, he also delivered papers on obstetrics and gynaecology. He wrote many papers in these two fields, the last of which is listed for the year 1929. He was a member of the German Society for Surgery and is listed as a member up to 1935. He died on October 22, 1940, in Heidelberg. It has not been possible to find an obituary notice in the medical literature.
Lack of Widespread Use

Following Neu's demonstrations, others employed the Rotameter anaesthesia apparatus manufactured by the Deutsche Rotawerke and reported on its use (Schlimpert, 1912; Zweifel, 1913). Some writers said that nitrous oxide-oxygen anaesthesia could not produce adequate relaxation for abdominal operations. Neu insisted this was not the fault of the apparatus but that the nitrous oxide-oxygen anaesthesia combined with morphine and scopolamine could produce sufficient abdominal wall relaxation if skilfully administered (Neu, 1912). However, since the Rota apparatus did not provide for the giving of ether, this was considered a disadvantage. The apparatus was expensive, being almost twice the price of other types. Nitrous oxide gas at that time was only beginning to be made in Germany; and most of it being imported was expensive. Apparatus for giving ether was cheaper and therefore preferred. Since nitrous oxide was not used extensively in Germany, widespread interest in Neu's rotameter apparatus for the accurate measurement of gas flows did not develop.

Subsequent Adaptations of Rotameter to Anaesthesia

Following encouraging research on animals, Gauss and Wieland introduced acetylene into clinical practice in 1922 (Gauss and Wieland, 1923a). For the first 163 acetylene anaesthetics a Neu-Rota nitrous oxide apparatus was recalibrated by Wieland for use with acetylene. The first apparatus specially built for acetylene anaesthesia was made by Dragerwerk, Lubeck. This apparatus incorporated a rotameter for the measurement of the flow rate of the acetylene-oxygen mixture. Several illustrations of the apparatus exist in the reports of acetylene anaesthesia.
Until 1939 the rotameters used on anaesthetic apparatus in England were obtained by Trost Brothers Ltd. from the Deutsche Rotawerke in Aachen for whom they acted as sales agents. This Deutsche Rotawerke was the same company which had built the rotameter anaesthesia apparatus for Dr. Maximilian Neu in 1910.

REFERENCES
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