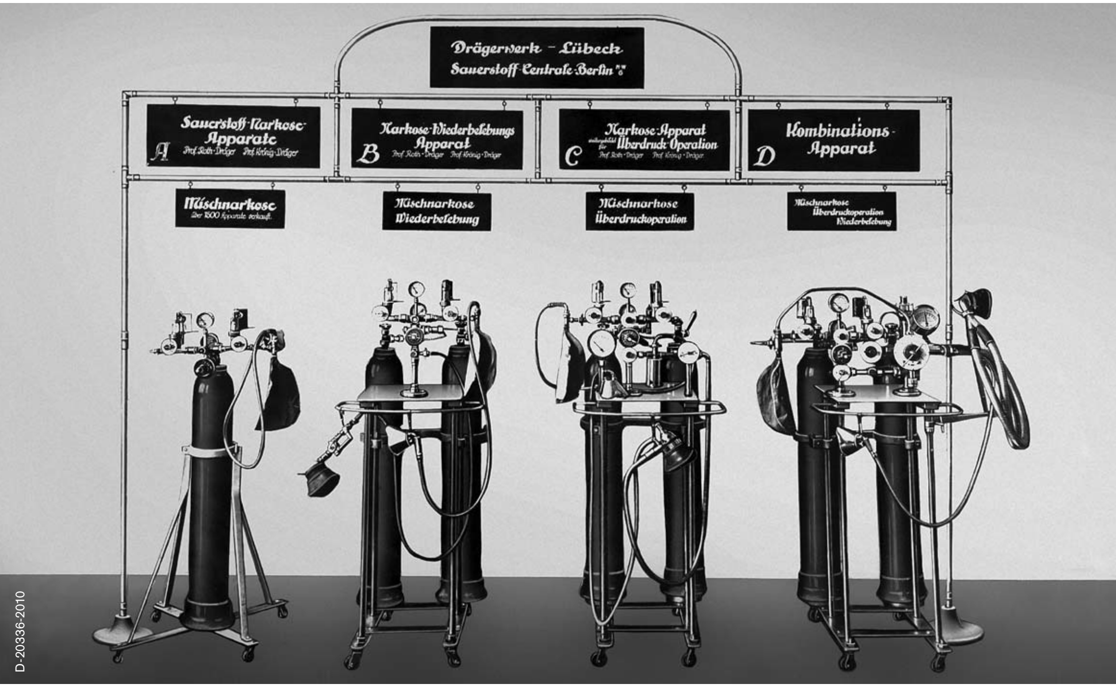
Dräger



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The History of Anaesthesia at Dräger

Volume I

Dräger. Technology for Life®

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Volume I

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Foreword


Dr Christian Dräger

Dear Reader,

It all started 150 years ago: in 1846 it first became possible for patients to have their teeth extracted under anaesthesia. This original „ether intoxication“ was the beginning of anaesthesia technology, a development which has continued to the present day – to our modern anaesthesia workstations.

Dräger's name has been closely linked with advances in this „medical discipline“ for over 100 years. The development of Dräger anaesthetic machines showed the way forward. We are especially indebted to the inventive initiative of company founder, Heinrich Dräger, and his son, and my grandfather, Bernhard, for their pioneering, technical innovations. It was they who laid the foundations for the world-wide reputation our anaesthetic machines enjoy today. We know from information from hospitals in Germany and abroad that, true to our motto, „Technology for Life“, many Dräger machines have been in use for over 30 years. Today, the medical world continues to associate Dräger products with ongoing technological development and innovative solutions to problems for doctor and patient alike. Dräger means reliability and quality. We are proud of that legacy, to which we also commit ourselves for the future.

This book gives a comprehensive account of the history of anaesthesia at Dräger. The first volume takes us from the invention of the cylinder regulator at the end of the last century through to the mid-Sixties, when Halothane was discovered as the new anaesthetic agent. A second volume will cover the years from that time up to our most recent developments.

References are made to events which occurred in parallel with the Dräger developments to illustrate the historical background against which Dräger have written their own small part of history. This account shows what engineering skills could achieve even in the past. The exciting story has been preserved in the Dräger archives, and written up with the benefit of his technical expertise and involvement by our long-serving Chief Engineer, Josef Haupt. His first publication on Dräger anaesthetic machines was published way back in the Seventies. Today we are deeply in his debt for his early pioneering work which provided the detailed groundwork for this current revised edition.

And so, wishing you much enjoyment in your reading of this history,

Yours,

Dr Christian Dräger

Early history

Pars pro toto
The history of many established and internationally famous German companies begins in the late 19th century. So, too, does Dräger's history – and with it the development of anaesthetic machines.

The oxygen cylinder was one of the important inventions of those days which was, and still is, more closely linked to the name of Dräger than anything else. Although the physicist, Linde, had discovered the process of liquefaction to separate air into its components, O_2 and N_2, it was not until the 1880s that engineers succeeded in compressing and storing oxygen and other gases at high pressure and the first seamless, high-pressure containers made from hand-forged steel came onto the market. The steel cylinder shown here contained pure oxygen, produced by the Linde process, and is probably one of the earliest containers of its type. The inspection mark dates the filling to 1885.

The technology was surprisingly advanced as the cylinder can hold over 1500 litres of oxygen at a filling pressure of 150 bar. Nevertheless, materials technology has continued to develop to the present day and so, as the data in the table shows, has succeeded in increasing filling pressures and capacity while at the same time reducing weight. Today, an O_2 cylinder of equivalent size holds a third more oxygen but weighs about twenty kilos less, which means it is easier to handle.

	Cylinder 1885	Cylinder 1970
Capacity	10.4 L	10 L
External diameter	140 mm	140 mm
Length	1235 mm	1020 mm
Weight	36.4 kg	12 kg
Filling pressure	150 bar	200 bar
O_2 content	1560 litres	2000 litres
Weight per litre of stored O_2	23 g/L	6 g/L

The development of materials technology over 85 years.

The possibility of separating gases and storing them in compressed form was, undoubtedly, a fundamental step along the road to using oxygen, but it would be only fair to say that compressed

41 076

Oxygen cylinder of 1885.

The first Nobel prize is presented in 1901, in memory of its founder, Alfred Nobel. Conrad Röntgen (for physics) and Emil Adolph von Behring (for medicine) are among the winners.

gas techology was still in its infancy at that time. It was the pioneering work of Heinrich Dräger (1847 to 1917) which steadily opened up the route.

Using compressed gases
In order to use the compressed gases, early oxygen cylinders were fitted with the pressure-reducing valves then available. However, these were certainly not adequately developed. In fact, there was just not enough viable equipment available for dispensing the oxygen stored under pressure and the users were exposed to considerable danger from the pressurised containers. Heinrich Dräger, the founder of Drägerwerk, became aware of this danger early on while working with pressure-reducing valves from various manufacturers. In the 1890s he and his son, Bernhard (1870 to 1928), searched hard for new, workable solutions to the problem.

„*... At the beginning, we accepted the pressure-reducing valve uncritically as the right and proper thing. We were to be bitterly disappointed. ... My son and I started to think about the problem of the pressure-reducing valve. The result of our thinking was a completely new design. ...*“ Heinrich Dräger wrote this in his memoirs, because his experience of the durability and safety in use of the valves then available had been so unsatisfactory.

The first device produced by this father-and-son initiative was a valve known as the **„beer pressure regulator“** which was used as a gas source to control the pressure of carbon dioxide in beer barrels. Soon after this they made a real breakthrough by modifying the new design to make an **„oxygen regulator“**. The development of this automatic oxygen regulator, together with a new type of cylinder valve, meant that it was possible to use a high-pressure cylinder without risk and to dispense oxygen in a properly controlled fashion. A milestone had been reached, especially for anaesthesia.

The development of the injector
The oxygen regulator with the safe, effective cylinder valve was to stand the test of time. However, Heinrich and Bernhard Dräger had another challenge to overcome. Welding technology needed a way of mixing compressed gases and their success in developing an oxygen-driven injector for this purpose was a third fundamental invention. It was about this time that medical technology started to notice the achievements of the House of Dräger.

Today it is impossible to say whether the idea for the anaesthetic apparatus came from the doctor to the engineer or the other way round. We would probably now say that the research was interdisciplinary. What is certain, though, is that Heinrich and Bernhard Dräger were the first people in Germany to make an anaesthetic apparatus for oxygen and chloroform. To do so they worked with a close friend, Dr Otto Roth, who was the principal surgeon at the Allgemeine Krankenhaus in Lübeck. The year was 1901.

The apparatus which was the result of this co-operation was really only a prototype but it was the forerunner for the Dräger apparatus which followed. It was very like the bubbler devices in common use in England at the time, which are still known today as chloroform or ether „bubblers“.

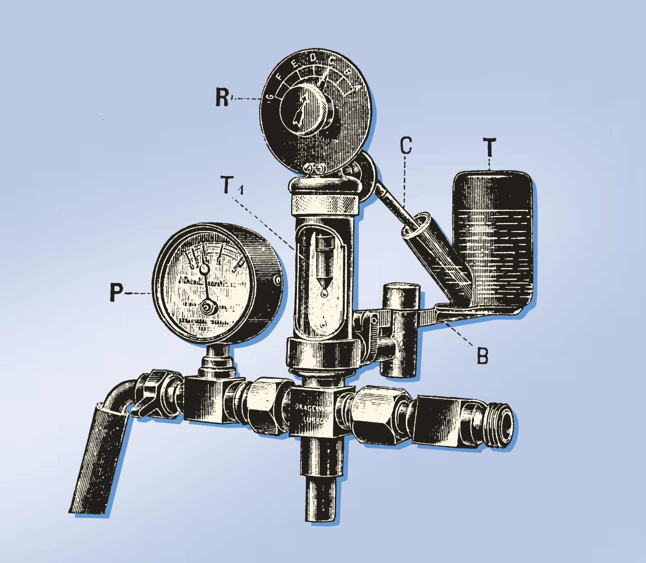
Reich patent no. 154339

Clinical trials carried out by Dr Roth soon confirmed a problem with this type of apparatus that had already been suspected. It was difficult to deliver accurate doses of chloroform because of cooling as a result of evaporation. Here was another challenge to the ingenuity of Heinrich and Bernhard Dräger. In record time they developed a completely new and unique drip-feed device for liquid anaesthetic agents which used the injector they had developed themselves. The oxygen was no longer routed through the anaesthetic agent but instead passed through an injector to generate suction. They registered their **drip-feed device**, and were immediately granted German Reich patent no. 154339 on 26th August, 1902.

On 10 December, 1903, the Nobel committee of the Norwegian parliament presents the Nobel prize for physics to Pierre and Marie Curie.

Naturally, it was Dr Roth who carried out the clinical trials at his hospital, and in November of the same year he published the news of this important development along with the results of his trials. In his article in the ‚Zentralblatt für Chirurgie‘ no. 46, entitled „Oxygen-Chloroform Anaesthesia“, he wrote:

„If this fault was to be eliminated, it was essential to stop passing oxygen through the chloroform. After lengthy trials it has become possible to drip-feed the chloroform in a way that can be seen in a specially-designed vessel using the suction effect of the oxygen



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The drip-feed device of the first anaesthetic apparatus: T is the chloroform vessel which kept the chloroform at a constant level. B is a spring lever which supported vessel T. T_1 is the sightglass which monitored the number of drops. 25 drops equalled exactly 1/2g of chloroform. R is the control scale.

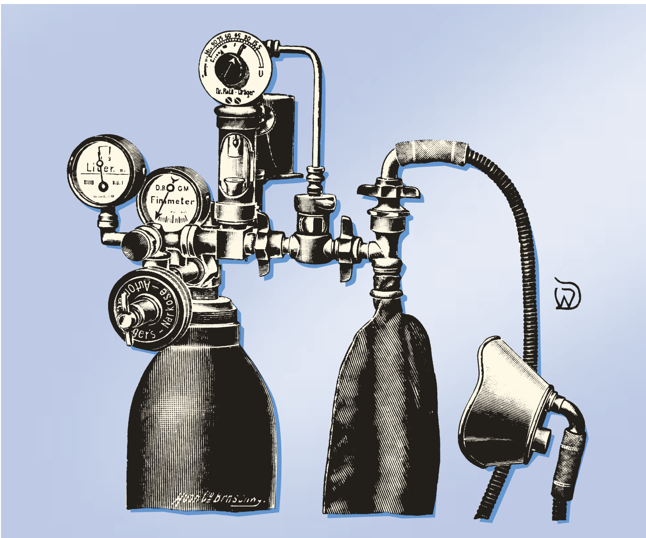
flow; its special design ensures that the droplets are always the same size, so that 50 drops always equal one gramme. An adjustable valve controls the number of drops and so large or small amounts of chloroform can be fed into the oxygen flow of the drip-feed device, as required, at the appropriate rate for evaporation. The indicator shows the number of drops on a scale above the valve – and also, therefore, the amount of chloroform administered in grammes – which are evaporating within a minute. An accurate drip-feed is thus guaranteed which cannot be affected by the impatience of the operator."

Ever since this time, the name of Dräger has been inextricably bound up with developments in anaesthetic technology.

Entering the 20th century

From first steps to maturity
The **Handapparat 145 N** or **Roth-Dräger** of 1902 could be regarded as the prototype of a long line of Dräger anaesthetic apparatus. Its most important components were the pressure-reducer to control the gas flow from the cylinder and the drip-feed device to control the flow of anaesthetic agent precisely. We still have both these components after many decades because they were produced as a journeyman's piece by a fine mechanic in the Dräger factory at that time. These two components were used in the reconstruction shown here.

Operating principle
Oxygen stored at 150 bar in the steel cylinder was reduced in pressure and dispensed by the



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The prototype in a series of Dräger anaesthetic apparatus, 1902: Hand-held apparatus 145 N.

pressure reducer. The gas simultaneously drove an injector which drew chloroform from a storage bottle. The anaesthetic agent could be accurately controlled by the number of drops per minute, and evaporated in the oxygen flow. The patient then inhaled the resulting anaesthetic mixture, which has been pre-set by the anaesthetist, from a breathing bag via an inspiratory valve, hose and mask. Expiration to the atmosphere took place via a separate expiratory valve on the mask. It was, as we would call it today, a semi-open system (non-rebreathing system), accurately controlled by thin, mica plate valves with low resistance.

This first design was developed a stage further soon after it appeared. On the suggestion of Prof Georg Krönig from Jena, and with his co-operation, a second drip-feed device was added. This was designed for a second anaesthetic agent, that is for ether. In 1903 Dräger, therefore, had three models available, all similar in design but with different options for administering anaesthetic agents:

- oxygen/chloroform
- oxygen/ether
- oxygen/chloroform/ether

A year later Dräger exhibited an anaesthetic apparatus at the World Exhibition in St Louis, USA. This apparatus aroused great interest and was regarded as a pioneering „first“. Dräger received a silver medal for its Oxygen-Chloroform Apparatus.

Years of trials lead to a first great success for the Wright brothers in 1903: Orville Wright’s motorized aeroplane is able to stay in the air for 12 seconds, and fly a distance of 70 metres.

This diploma was presented to Heinrich Dräger at the St Louis Exhibition in the USA in 1904, together with a silver medal for the outstanding „Dräger Oxygen-Chloroform Apparatus“.

28 026

From prototype to batch production
Success and world-wide recognition assured Heinrich and Bernhard Dräger that they were on the right path, and led to more new designs and modifications. They had two objectives: on the one hand, they aimed for cost-effective batch production; on the other, experience in daily clinical use had shown that the drip-feed device could still be improved.

The outcome of their work, the **Roth-Dräger Mixed Anaesthetic Apparatus** was launched in 1910. The way in which it worked remained basically the same as that of its predecessors, but the two objectives set had been reached.

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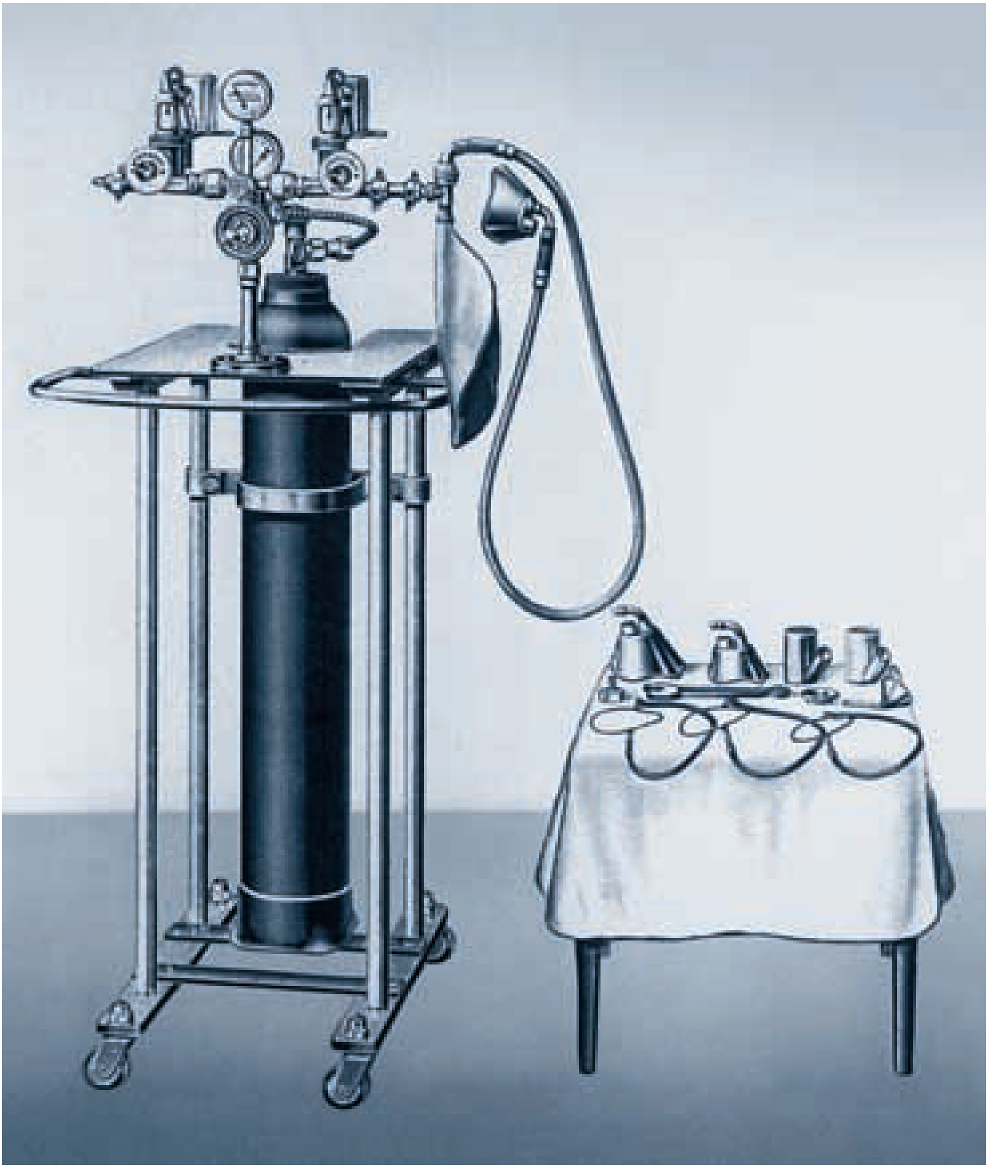
Number Two:
The 240 N double apparatus, 1903.



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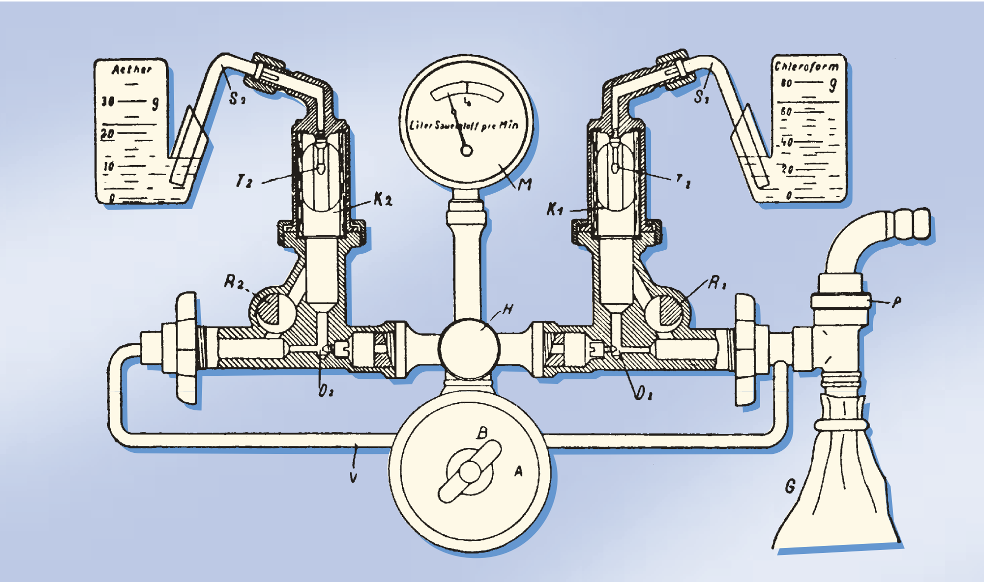
In 1910, the Roth-Dräger Mixed Anaesthetic Apparatus was developed in co-operation with surgeon friend, Dr Otto Roth.



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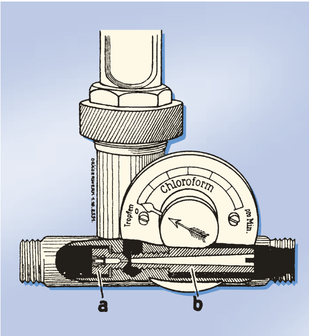
Technical drawing of the Roth-Dräger Mixed Anaesthetic Apparatus for ether and chloroform.

A contemporary illustration shows how the apparatus worked: *„The illustration is a cross-section drawing of the two drip-feed components. When valve H is opened, the low pressure set with adjusting screw B on reducing valve A according to pressure gauge M flows to injectors D1 and D2. A vacuum is produced in sightglasses K1 and K2, and the anaesthetic agent is sucked up the risers S1 and S2 and drips visibly and audibly from drip-feed cones V1 and V2 into the oxygen flow from the injectors. The number of drops per minute is controlled by changing the vacuum in the sightglasses with valves R1 and R2. Opening the valves wider increases the flow of the circulating gas and so the vacuum is lowered and vice versa. Chloroform-oxygen vapour and the ether-oxygen vapour are mixed in a breathing bag or reservoir bag G and are routed through the inspiratory non-return valve P into the metal hose leading to the mask.*



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An important development: the Dräger injector, an accurately controlled drip-feed device.

The illustration „... shows how the injector in the apparatus, which has been described, is actually made. The pressure jet (a) and the venturi (b) can be removed with a screwdriver so that cleaning is easy ...“

All of this apparatus was a great success for Drägerwerk. By 1912, that is in the first ten years of Dräger anaesthetic technology, over 1500 machines had been sold throughout the world.

Greater safety in anaesthesia

Medical developments and the demands of anaesthetists and surgeons very soon led to further changes to the original Dräger anaesthetic apparatus which Heinrich and Bernhard had made in 1902 in co-operation with their friend, Dr Otto Roth. Just a few years later an Anaesthetic Artificial Respiration Apparatus was produced. This was intended for artificial pneumatic ventilation and was named the **Roth-Dräger-Krönig** after the collaborators. This apparatus had a second oxygen-driven injector which was independent of the anaesthetic components. With this injector and a hand-operated switching valve, positive and negative pressure could be produced in a tight-fitting ventilation mask. The anaesthetist could now discontinue anaesthesia, if breathing stopped or some other incident occurred, and reflate or deflate the lung with oxygen-enriched air in breathing rhythm.

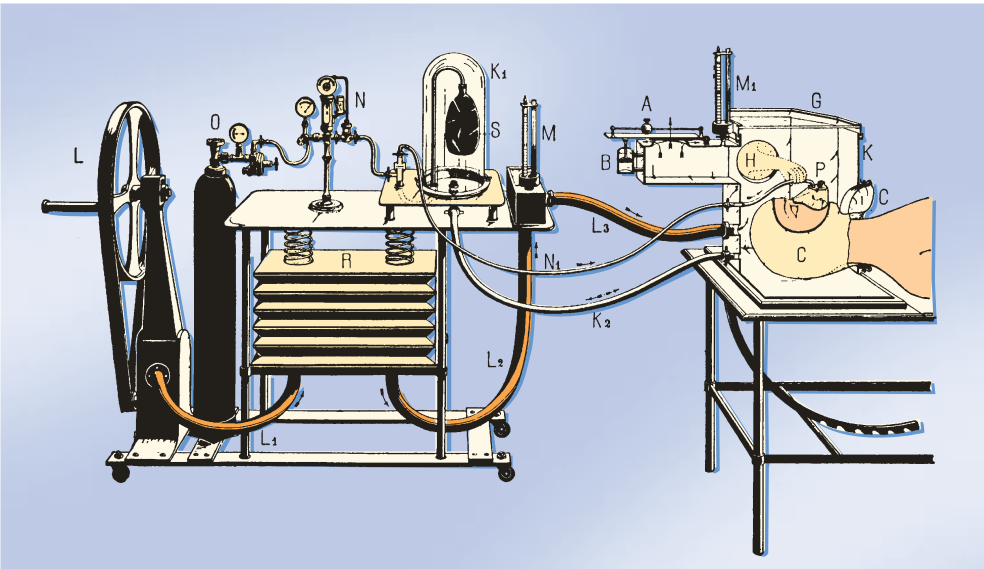
40 756

Dating from 1911: the Roth-Dräger-Krönig Positive Pressure Mixed Anaesthetic Apparatus, with Prof Bruhns' positive pressure device.

Open thorax surgery

Attempts by surgeons to carry out open thorax operations were the trigger for Drägerwerk to further develop the Roth-Dräger. Attempts to respond to the demands of surgery first began in 1905. The problem that open thorax operations pose to the engineer is that when the thorax is open the lung has to be kept inflated with positive pressure during inspiration and expiration to prevent its collapse. The chamber which was invented and used by Prof Sauerbruch was not satisfactory because it was too expensive and awkward to use. Drägerwerk's designers made several attempts to solve the problem. One example was the Brauer-Dräger Positive Pressure

Still expensive and difficult to handle, the Brauer-Dräger Positive Pressure machine for use during surgery on the open thorax, 1906.

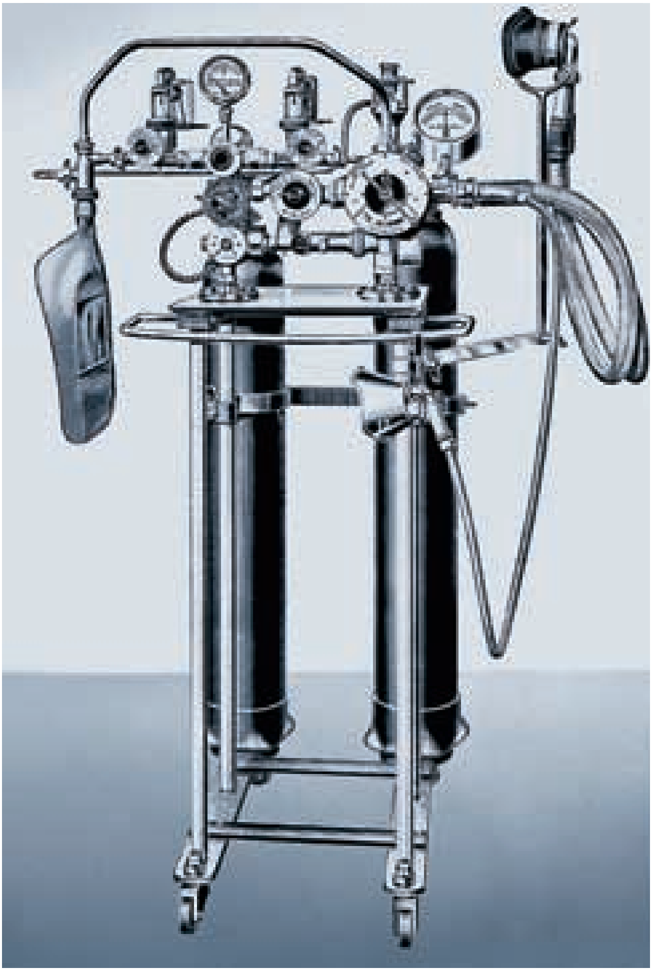


Machine. A contemporary sketch gives some insight into its design.

A whole series of different designs of apparatus were tested clinically until finally, in 1911, the Roth-Dräger-Krönig Positive Pressure Mixed Anaesthetic Apparatus was ready for marketing. Again it was the injector, a component which was now standard for Dräger, which solved the positive pressure problem. This was driven by oxygen, independently of the anaesthetic component, via a separate shut-off valve and pressure reducer. The injector entrained a relatively large, but regulated, volume of fresh air, which was delivered to the lung via its own hose and a tight-fitting mask. The degree of positive pressure could be controlled with a spring-loaded expiratory valve on the mask. When using this first, practical solution to the problem, the flow of anaesthetic gas had to be stopped during the positive pressure phase. This was certainly a handicap, as was obvious to Dräger, and a problem that their ingenuity could not leave unsolved. Further work was to bring success.

In 1912, Drägerwerk was able to present a combined apparatus for mixed anaesthesia, positive pressure anaesthesia and artificial respiration. This apparatus was seen as a significant improvement and a useful combination of the three preceeding Roth-Dräger models. It became world famous as the **Dräger-Kombi** and maintained its high reputation for over 30 years.

On the tenth day before Christmas, the Norwegian, Roald Amundsen, and his team of four explorers are the first to reach the South Pole. His competitor, Robert Scott, loses the „race“ to the Pole and arrives there second on 12th January, 1912.



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Dräger's combined anaesthetic apparatus of 1912, known by doctors as the „Dräger-Kombi", enjoyed world-wide success for over 30 years.

A contemporary summary written by its designer, Hans Schröder, explained how it worked extremely well.

The illustration „... shows the Roth-Dräger combined apparatus for routine anaesthesia, for positive pressure anaesthesia and for artificial respiration. It also includes an injector which sucks in fresh air when the large selector valve is set at positive pressure. Anaesthetic gas is routed to the

40 690

The selector or switching valve on the same apparatus.

selector valve from the well-known drip-feed apparatus, and the anaesthetic mixture flows at positive pressure through the hose to the mask. A second hose routes the expiratory gases through the positive-pressure control valve to the atmosphere. The pressure gauge displays the positive pressure in cm of water. The light-weight aluminium hoses are 25 mm in diameter. A head band with straps ensures that the mask is airtight. It should be noted that the head band has two side arms which prevent the straps from exerting any pressure on the carotid arteries.

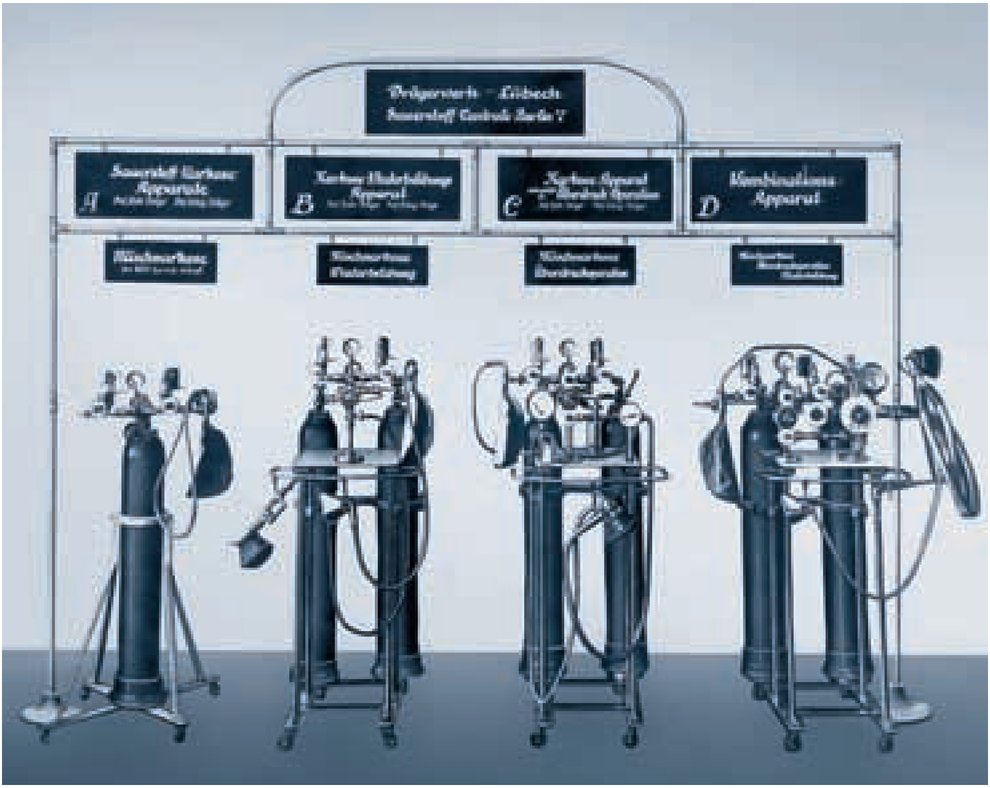
If artificial respiration becomes necessary for any reason the drip-feed apparatus has, of course, to

6709

The Dräger-Combi's air-tight anaesthetic mask with head band and neck straps.

be switched off and the selector valve set to „Pulmotor artificial respiration“. The indicator on the selector valve is then moved from the inspiration stop to the expiration stop and back again in the rhythm of natural breathing, i.e. 15 to 16 times per minute. The suction and the pressure effects of the injector then operate alternately. During inspiration, the lung is inflated with oxygen-enriched fresh air at an end pressure of about 20 cm of water, and during expiration the lung is deflated by the same force. That is to say, the machine performs a task which cannot be done manually.

For routine anaesthesia a narrower metal hose is used with a standard mask and the selector valve



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is set to „mixed anaesthesia“. The gases are routed through different holes in the selector valve, depending on the indicator setting, as the situation requires. It is not appropriate to describe the design in more detail at this point, except to mention that these selector valves, which allow the method of operation to be changed in one movement, are very popular with those who practise anaesthesia.“

Dräger’s well thought-out range of batch-produced anaesthetic apparatus which was available all over the world in 1913.

Dependability and acceptance throughout the world

Before the First World War, Drägerwerk offered a comprehensive and well thought-out range with its four models of anaesthetic apparatus, shown in the photograph of the Dräger stand at the Surgery Congress at the Berlin Charité in 1913 (see page 27). These four models marked the end of the first phase in the development of Dräger's anaesthesia technology. They were sophisticated by the technical standards of the time, and many gave good service in operating theatres all over the world right into the 1940s. „Without doubt this was due to their unusual reliability and consistency in use," said Prof Jürgen Waversik, in 1980.

The Dräger-Kombi Universal Anaesthetic Apparatus sold throughout the world. A few years ago, the Dräger agent in Japan mentioned a Dräger Combi delivered in 1912, which was still in Kyushu Imperial University Hospital as a valued museum piece.

First radio news broadcast on 20th August 1920, transmitted by station 8 MK in Detroit.

1925

1924

History is made with a world „first“

1920

1922

From chloroform to nitrous oxide
From the beginning of the Twenties, and especially in Britain and America, doctors began to make increased use of a new anaesthetic agent, laughing gas (nitrous oxide or N_2O). Nitrous oxide was much more effective than chloroform, which had been used until then, but it was a relatively expensive anaesthetic agent because of the manufacturing process. Once nitrous oxide became known in Germany, doctors and medical engineers began to search for the best method of using it, and, especially, how to minimise gas consumption.

The expertise which Drägerwerk had gained in the early years of the century could now be used afresh. As early as 1903 Dräger had developed a device which operated as a „closed breathing circuit“ and which allowed rebreathing to take place. In the intervening years, Dräger breathing protection equipment had become known all over the world. American miners, who particularly used these masks, were even nicknamed ‚draegermen‘. The masks were important in arduous underground working conditions because exhaled oxygen could be re-used – by the rebreathing principle – and so vital gas could be saved.

Drägerwerk's early attempts to use a „closed breathing circuit“, as it was then known (now we talk of a circle system), for anaesthetic machines, were doomed to failure. This was not because the idea was wrong but because the chloroform then used as the anaesthetic agent reacted with the soda lime when a CO_2 absorber was inserted in the circle system, so that it was impossible to use this method for anaesthetic purposes. Nevertheless, this circle system had gained some acceptance as early as 1906 and had been described in an article by Professor Franz Kuhn in the journal ‚Deutsche Zeitschrift für Chirurgie'.

The first circle system in the world
Almost 20 years later, in 1924, engineers at Drägerwerk recalled previous knowledge and rediscovered the circle system for a „modern" anaesthetic agent, narcylene. In the Twenties this highly purified acetylene had a definite role as a first-class, fast and gentle anaesthetic gas. In 1925, the Dräger Narcylene Anaesthetic Machine, came into being through co-operation with doctors at the University Clinic of Würzburg. It was based on concepts developed by Gauss and Wieland.

In developing the narcylene anaesthetic machine Drägerwerk engineers responded to the needs of the time. The machine already worked like Model A and had the same circle system. However, narcylene was soon abandoned, although it was an outstanding anaesthetic agent in some ways, since it was highly flammable and also explosive. For these reasons, it could only have a limited role in medicine and could not be widely used for anaesthesia. It was only when nitrous oxide became available two years later that a major breakthrough was made. Working with Dr Paul Sudeck and Dr Helmut Schmidt of the University Clinic of Hamburg-Eppendorf, a

5077

Model „A“, the first circle system anaesthetic machine in the world, 1926.

completely new machine (Model A) was developed for oxygen, nitrous oxide and ether which was based on the rebreathing principle. The ether was used mainly to deepen the relatively shallow anaesthesia of nitrous oxide.

The new circle system soon became an integral part of anaesthesia technology. All previous nitrous oxide machines, particularly outside Germany, still operated on the semi-open system. Rebreathing

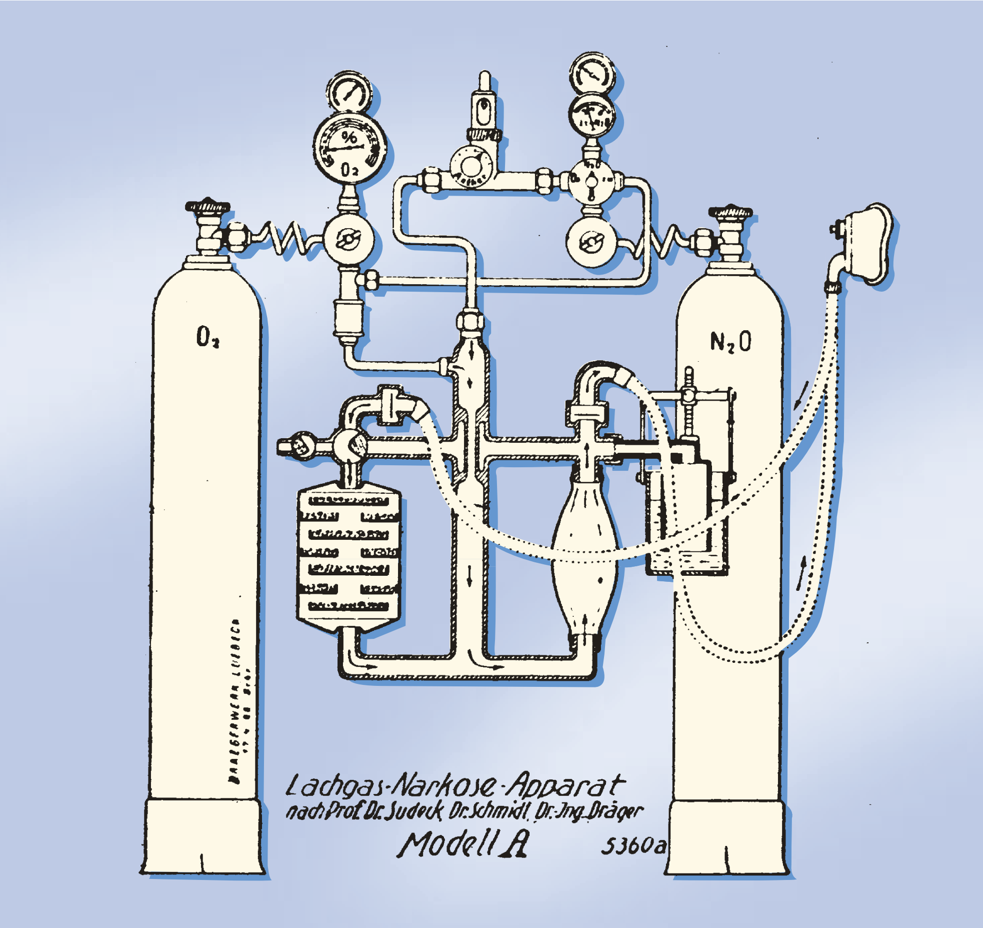
In 1924, the ten-millionth Ford, the „tin lizzy" rolls off the assembly line: at the time it cost just under 300 dollars.

systems with carbon dioxide absorbers for use in anaesthesia were also being developed in English-speaking countries. In 1924 Ralph M. Waters introduced a „to-and-fro" system and in 1930 Brian C. Sword and R.V. Foregger designed a circle system.

A comparison of the two systems shows how they worked (page 51, first and third drawings).

Model A
Dräger made the first batch-produced anaesthetic machine with a circle system in the world, **Model A**, to take advantage of the benefits of nitrous oxide and the outstanding features of the new circle system. A contemporary operating diagram shows why this circle system should be regarded as the pioneer for all later developments. It has all the features which have remained the fundamentals of anaesthetic machines right up to the present day. These were:

- Separate hoses for inspiration and expiration.
- Large area, springless, thin mica plate valves of low resistance.
- The carbon dioxide absorber, which could be switched off partially or completely, was a disposable cartridge even at this stage.
- Breathing bag to give the option of manual ventilation.
- Vent valves or pressure-limiting valves were available on request.



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A simplified illustration of the design of Model „A“.

The old dynamic pressure principle was a proven way of regulating the flow of nitrous oxide and oxygen. This method allowed the anaesthetist to set the desired or required volume of nitrous oxide accurately in litres per minute in relation to the percentage of oxygen. Ether was added, as in the well-known Roth-Dräger mixed anaesthetic apparatus of 1910, by the proven vacuum drip-feed process.

Futuristic appearance of the Dräger Narcylene Anaesthetic machine designed according to Gauss and Wieland's concepts, 1925.

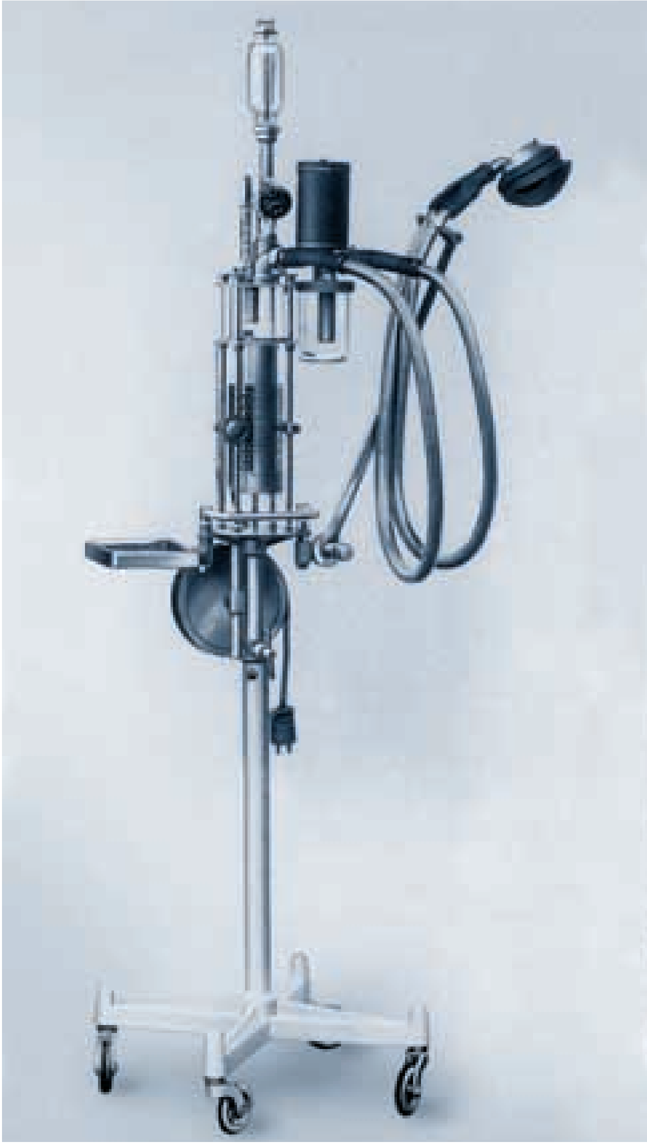
5541

It says a great deal for its high technical standards and its longevity that a specimen of Model A was still in daily use in the University Clinic in Rostock in 1947, that is 22 years after it was installed.

Inhalation anaesthesia in the Thirties

Superheated ether anaesthesia
An accepted worldwide standard for the technology of anaesthetic machines was set by the development of Model A and no revision was called for throughout the Thirties. Nevertheless, it was – and still is – Drägerwerk's claim that new challenges are always met. Hence, besides carrying out trials of narcylene as an anaesthetic agent, Dräger was involved in developing another newcomer to its range of anaesthetic machines. This machine was the brainchild of Dr Max Tiegel, surgeon at St Petrus Hospital in Trier. Instead of administering ether in liquid form via the injector – as in the Roth-Dräger Combined Anaesthetic Apparatus – he wished to use ether as a vaporised gas. The end result, the **Dr Tiegel-Dräger Anaesthetic Apparatus** for superheated ether vapour, was launched in 1934.

In that year, the development engineer described this new apparatus as follows: *„Dr Tiegel of Trier has carried out extensive clinical trials with ether vapour, produced at high temperatures and immediately mixed with air so that the extremely fine molecular distribution of the nascent state is preserved. He has established that the best anaesthetic effects are achieved when the ether drops are vaporized at 60°C. In this situation, side effects are minimised – in particular no post-anaesthetic vomiting.“* Dr Tiegel's apparatus worked by dripping ether onto an electrically-heated silver plate in controlled amounts. A thermostat kept the silver plate at a constant 60°C. The resultant ether vapour combined with the ambient air breathed in by the patient, just as it does in a



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The Dr Tiegel-Dräger Anaesthetic machine of 1934 for superheated ether vapour.

draw-over system. Expiration was through a separate second hose. The inspiration and expiration rhythms of the patient were separated in a simple way with a water non-return valve. Another detail of the design was truly pioneering: for the first time an activated carbon filter was installed in the expiration hose to absorb any remaining ether contained in the expiratory air. This was a significant step in reducing the health risks for surgeons, anaesthetists and assistant staff. Even in the Thirties, Dräger had thought and acted with concern for the environment in the field of anaesthesia.

The first comic was sold from news-stands in USA in May 1934 – the beginning of an era.

In spite of its distinct advantages, the Dr Tiegel-Dräger anaesthetic apparatus for superheated ether vapour remained an outsider in anaesthesia and never made any real breakthrough.

Optimisation of the proven standard
Twenty-four years after it was first made, the Roth-Dräger-Krönig Mixed Anaesthetic Apparatus (page 21) was updated in 1935. Basically it was improved by adding a new positive pressure feature, injector-driven as might have been expected. It had a spring-loaded breathing bag and was designed in such a way that the anaesthetic gas could be delivered at positive pressure, if required. This meant that, during open thorax surgery, the anaesthetist no longer had to switch off the anaesthetic gas flow. Another advantage of the new **type MÜ** positive pressure mixed anaesthetic apparatus was that, with this new design, the pressure fluctuations between inspiratory and expiratory phases were much smaller than before.

Technical development at a standstill
With the growth in totalitarian fascism in Germany and the outbreak of the Second World War in 1939,

10 044

The „MÜ type" positive pressure mixed anaesthetic apparatus, from the house of Dräger, 1935.

Drägerwerk was not able to continue its development of inhalation anaesthesia. From a technical development point of view, this period has to be regarded as a long enforced break in which medical engineering had to be subordinated to the interests of national socialism.

The updated Roth-Dräger anaesthetic apparatus remained standard equipment until the end of the Second World War. Progressive hospitals used nitrous oxide in Model A, though some non-conformists preferred the Tiegel.

The inventor and engineer, Carl von Linde, dies in Munich at the age of 92. He had discovered a process for the manufacture of liquid air in 1895, and of liquid oxygen in 1902.

1948

A fresh start

1952

1945

1946

One year after the end of the war: Model „D" in use in the operating theatre of the Municipal Hospital Ost in Lübeck, under the guiding hand of Professor Lezius.

Return to the world class

After the end of the Second World War, research and development in inhalation anaesthesia started afresh in Germany. In contrast with earlier years, nitrous oxide was now available in much greater quantities and it was also, therefore, cheaper. Since Hoechst had introduced an improved process for manufacturing nitrous oxide for aero-engines during the War, supplies were adequate in what was otherwise a difficult period of recon-

40 691

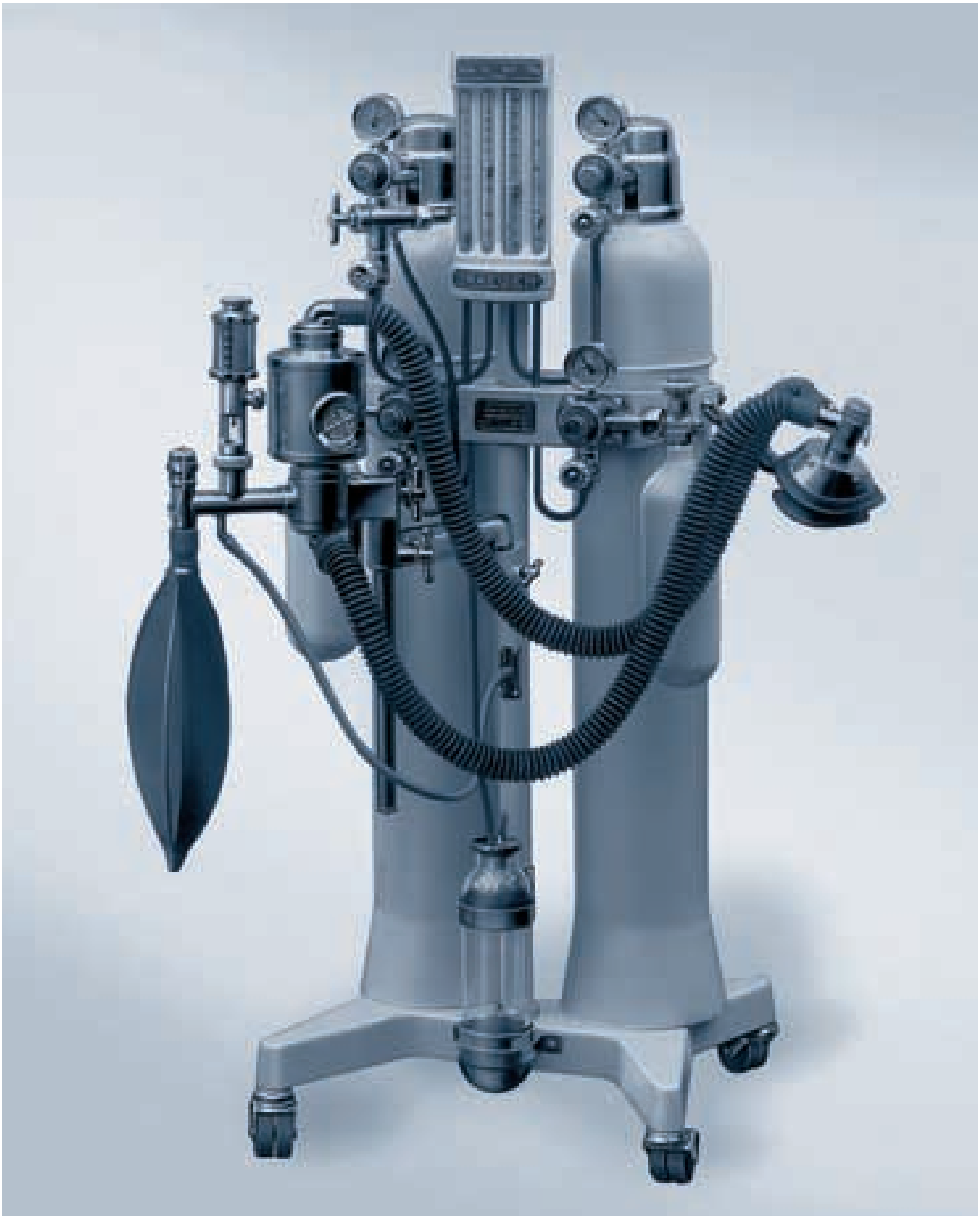
struction. Nitrous oxide had become the standard anaesthetic gas for British and American anaesthetists and it was clear that significant technical advances in anaesthetic machines had also taken place in these countries in parallel with this development. Catching up had to be Drägerwerk's top priority.

In 1946, Japan grants women the vote for the first time in its history.

The **Model D** oxygen/nitrous oxide anaesthetic machine was developed in 1946, only one year after the end of the War. As was appropriate for a time of shortages, model D was intended to be a simple machine with a partial rebreathing system. What was new, though, was that most of the functional instruments were housed in a console with a control panel, the forerunner of the enclosed instrument system with a cabinet.

It was soon apparent that this simple design of oxygen/nitrous oxide anaesthetic machine was exactly what was needed. It came on stream at just the right time to meet the pent-up demand for general surgery in Germany which had been caused by the War.

Circle system anaesthesia
By the late Forties, surgeons were beginning to find Model D inadequate as this type of machine had only limited use in thorax surgery, a field which was growing in importance. Building on their proven Model A, Drägerwerk developed a circle system anaesthetic machine in 1948, **Model F**, which used oxygen, nitrous oxide and ether.



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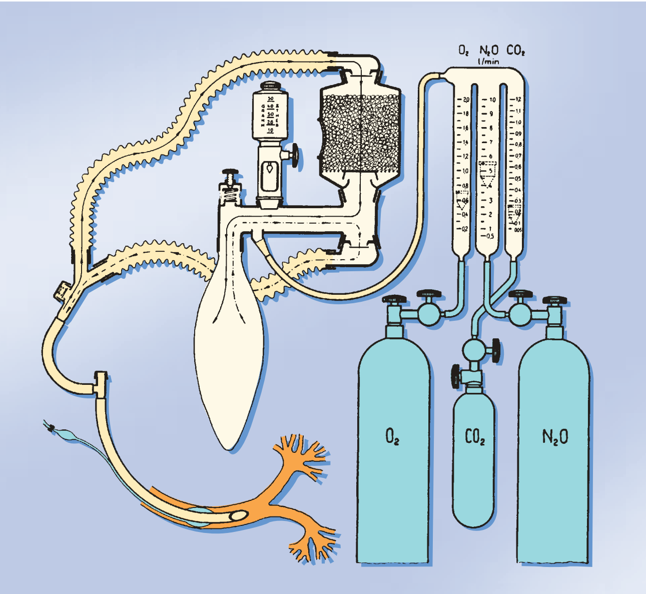
The Dräger Model F circle anaesthetic machine, 1948.



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Operating diagram for Model F with circle system – a world first – with bronchial suction independent of motor or electric power.

Model F was the first Dräger machine in which the gas flow was controlled directly by flowmeters, the so-called rotameters, and not indirectly by static pressure measurement. Model F also boasted several other ingenious improvements, such as the option of connecting cyclopropane and carbon dioxide as additional gases. The circle system, still known at that time as a re-circulating system, could be stripped down completely for cleaning purposes and for steam sterilization, without using any tools.

The CO_2 absorber had been designed by the Dräger engineers to be refillable. When the soda

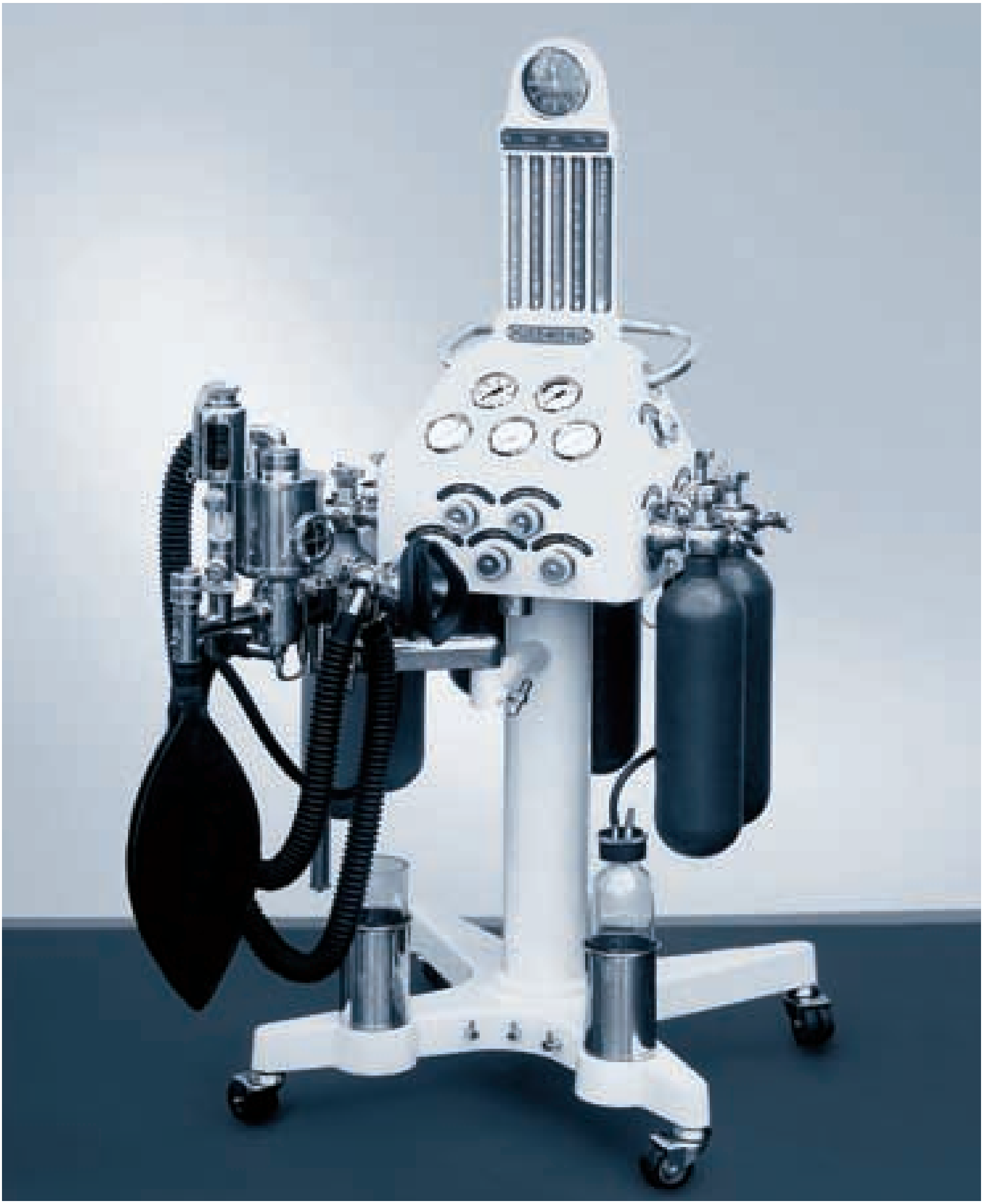
Einstein develops a mathematical explanation for how the planets and the universe function. Scientists greet his theory of gravity with universal astonishment at the end of December 1949.

lime needed to be replaced, the container could be changed in seconds – even while anaesthesia was in progress. To save soda lime, there were two absorbers and it was possible to switch from one to the other. The anaesthetist could also remove the absorber from the system – again in seconds – during anaesthesia so that expiratory carbon dioxide could be used to stimulate breathing.

Model F was also the first anaesthetic machine in the world to provide bronchial suction which did not depend on a motor or electrical power. As might have been expected with Dräger, this worked in the same way as the old, oxygen-driven injector, but the principle was now used for an ejector, which achieved suction of up to -6 metres water gauge in the suction catheter. Subsequently, the negative pressure was further improved, up to -9 metres water gauge. As a result, Model F produced a suction unrivalled by any of the traditional motor-driven OP suction devices of the time.

Model F was, as was appropriate for the time, completely tailored to the needs of the German market. In other countries, particularly markets supplied by the USA, anaesthetic machines with more gases were in demand. To make the machines easier to handle, these gases were stored in small cylinders.

Response to the international market
In order to catch up with the competition in foreign markets as much as anything, Dräger responded to the trend for more gases and smaller, lighter cylinders. **Model G** was designed as the



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„Modern Times“ Dräger Model G Circle System Anaesthetic machine, 1950.

While black and white television is still being developed in Germany, the first TV programmes in colour are transmitted in the U.S.A. from 1951.

Drägerwerk answer to international demand.

This compact machine came on stream in 1950 and had the option of connecting from two to five gases: two cylinders each of oxygen and nitrous oxide were standard, with cyclopropane, helium and carbon dioxide as additional options. The one and two-litre steel cylinders used were fixed to the machine with yoke connectors which conformed to American Standards. Connectors of this type were not approved in Germany because they looked alike and there was, therefore, a risk that mistakes would occur. In fact, mistakes did happen quite frequently until a „pin-index" system was developed to prevent them in the late Fifties.

The variety of gases available meant that more pipework was required and that non-return valves had to be included. All the measuring and operating instruments were built into a streamlined, desk-style housing, and a clock was installed on the rotameter block to assist the anaesthetist with time checks. The circle system from the earlier Model F was also incorporated. Although the machine was received with some scepticism abroad to begin with, because of its unusual design, its sturdiness and practicality soon won the critics over. In fact, Drägerwerk stayed with this basic concept right into the Eighties.

Introducing more convenience into the range
The factors which had led to the introduction of an instrument panel in Model D and a machine

housing in Model G began to gain steadily in importance for everyday use. Dräger was already well-known for the efficiency, reliability and longevity of its anaesthetic equipment but it was now becoming essential to consider ergonomics and ease-of-use as well, when designing anaesthetic equipment. The demand for more convenience in anaesthetic equipment led to the introduction of **Romulus**, a re-circulating anaesthetic machine, in 1952.

It was no different from its predecessor, Model G, in the way it worked but it was different in how it was organised. A cabinet was built in below the machine housing which incorporated several drawers, a writing surface and an instrument tray for the anaesthetist. Gas was supplied from a two- and a ten-litre oxygen cylinder and a two-litre nitrous oxide cylinder. Small cylinders of C_3H_6 and CO_2 could also be connected. The clock on the flowmeter block, designed by Dr Weyland, with special scales and a stop hand for measuring pulse and breathing frequency, became the Dräger Anaesthetic Clock.

The blood pressure gauge was next to the rotameter block, which was to become its usual place, and a filled replacement absorber was on the left, ready for use. In short, on the outside, Romulus was a practical and highly efficient newcomer on the anaesthesia market.

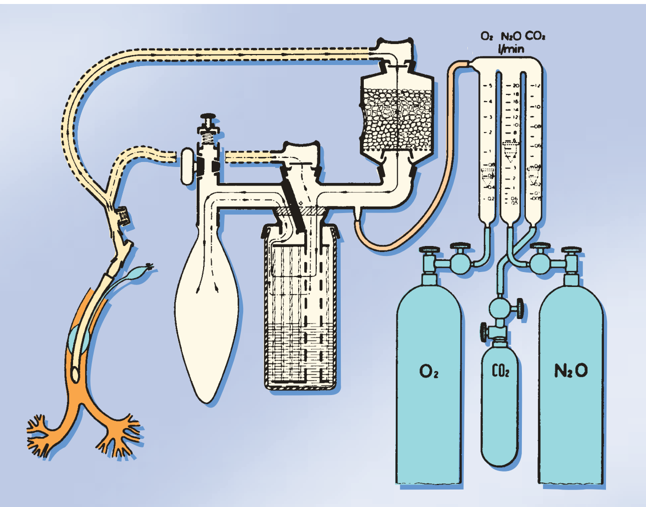
Romulus had also been modified on the inside. The circle system (Circle System I) had a number of improvements:

The Dräger Romulus circle system anaesthetic machine of 1952 was designed primarily for the home market. Its twin, Remus, identical in construction but designed for smaller gas cylinders, was developed for export.

15 468

- The range of the pressure relief valve had been extended to +30 cm water gauge and its adjustment had been improved.
- The inspiratory and expiratory valves had been designed to work without springs, and so had lower breathing resistance.
- The ether drip-feed device had been replaced with a vaporizer which gave more accurate control of dosage.
- To facilitate manual ventilation, a bellows with a simple volume limiter could be connected instead of the breathing bag.

The Remus anaesthetic machine, a twin brother to the Romulus, was designed by Drägerwerk specifically for the export market which they were slowly opening up. The only way in which it differed from



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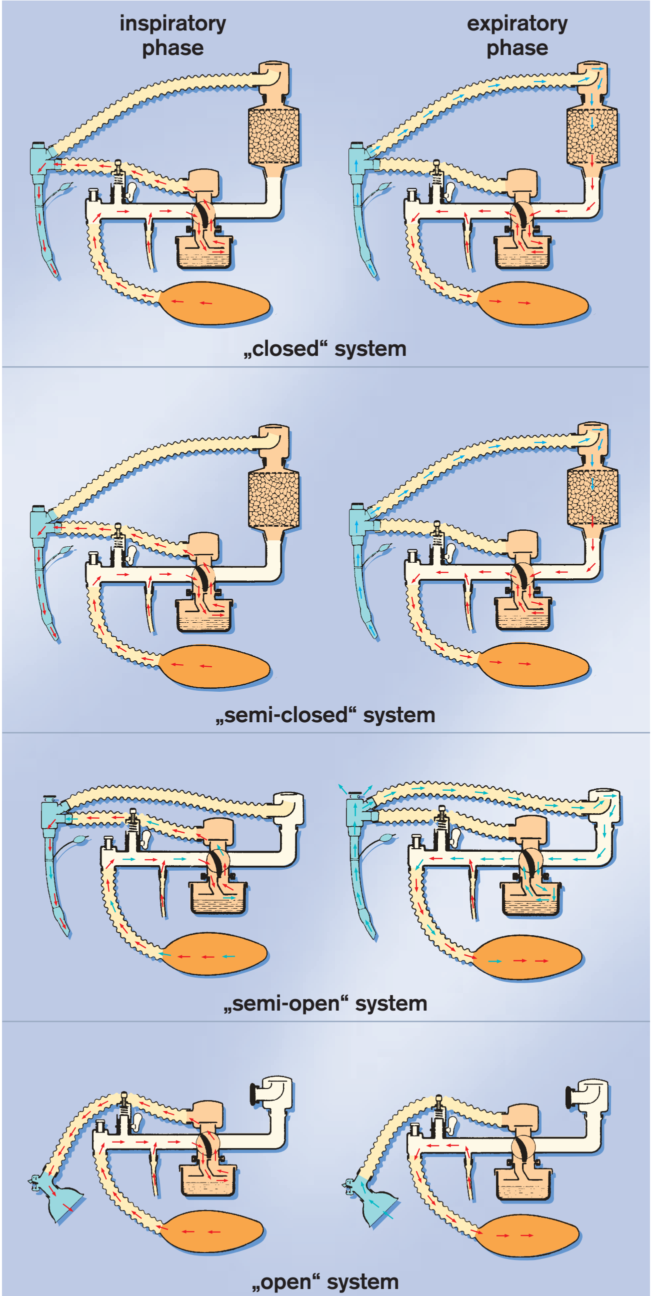
Operating diagram for Circle System I.

On 6th February, 1952, Elizabeth II is proclaimed queen and accedes to the throne in Britain at the age of 23.

its twin was in the size of the cylinders that went with it, as it was fitted with smaller gas cylinders (two of oxygen and two of nitrous oxide, C_3H_6 or He).

At the beginning of the Fifties, the era of the economic miracle in Germany, German anaesthesia slowly became „emancipated“, so that Dräger began to receive requests for customized machines for particular purposes from customers in Germany and abroad. New variations in the design and equipment of anaesthetic machines were always being found whenever this was technically and economically feasible. Soon, Romulus and Remus, the two cabinet machines which were hardly cheap, were followed by the **Agrippa** 1, 2 and 3 range of machines. In principle these were a simplified, and, therefore, cheaper successor to Model F after 1948. The Agrippa models differed from each other merely in the number of gases available:

- Agrippa 1 (formerly Model M) for oxygen/ether
- Agrippa 2 (formerly Model N) for oxygen/nitrous oxide/ether
- Agrippa 3 for oxygen/nitrous oxide/cyclopropane/ether



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20 840
20 841
20 842

Operating diagram for Circle System Ia.

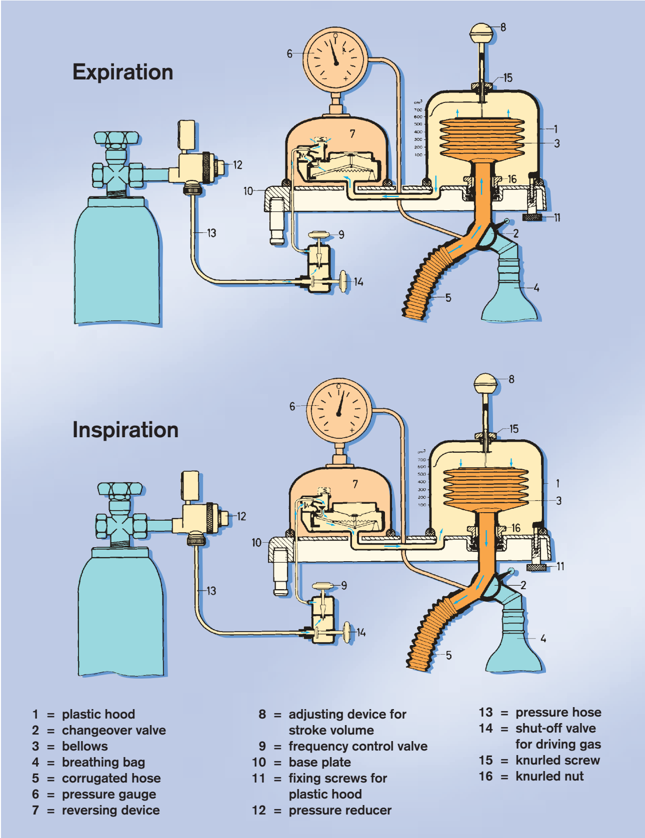
The 1952 Dräger Agrippa range, successor to Model F.

15 484

The machines of the Fifties

The Pulmomat
The Dräger Pulmomat appeared in 1952. This was a new type of ventilator which operated automatically and was driven by compressed oxygen. It was designed as an additional unit to be connected to any Dräger anaesthetic machine with a circle system. Its function was described in detail in a contemporary brochure:

„Automatic method with the Pulmomat
Using the Pulmomat, patients can be ventilated consistently and completely automatically, even during lengthy surgery, so significantly easing the burden on the doctor who would have had to ventilate the patient by manual methods otherwise. An accurately adjustable volume of gas (between 100 and 700 cc) is forced into the patient’s lung (inspiration) and then sucked out at low negative pressure (expiration). The support given to expiration by the negative pressure is of particular importance in open thorax surgery, as the elastic forces which cause spontaneous breathing are then reduced. The blood circulation is also assisted by the filling of the right ventricle during the negative pressure phase. Suction of up to -10 cm water gauge helps to overcome the expiratory resistance – particularly in endotracheal anaesthesia – leaving less residual air in the lung. The pressure gauge on the Pulmomat allows control of ventilation pressures in the lung and the mean airway pressure. Pressure values can be controlled accurately when the patient is being ventilated with the Pulmomat breathing bag (during the transition phase before the onset of breathing failure or when spontaneous breathing is being re-established).“



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Operating drawing of 1952 for the Dräger Pulmomat.

This machine, which operated on the old Pulmotor principle, was very rapidly accepted by anaesthetists. It provided a great deal of assistance especially during lengthy anaesthesia when muscle relaxants had been used. The Pulmomat soon became standard equipment with Dräger anaesthetic machines and, with minor improvements such as an increase in tidal volume to 1000 ml, it was made and sold right into the Seventies.

Breathing systems on demand

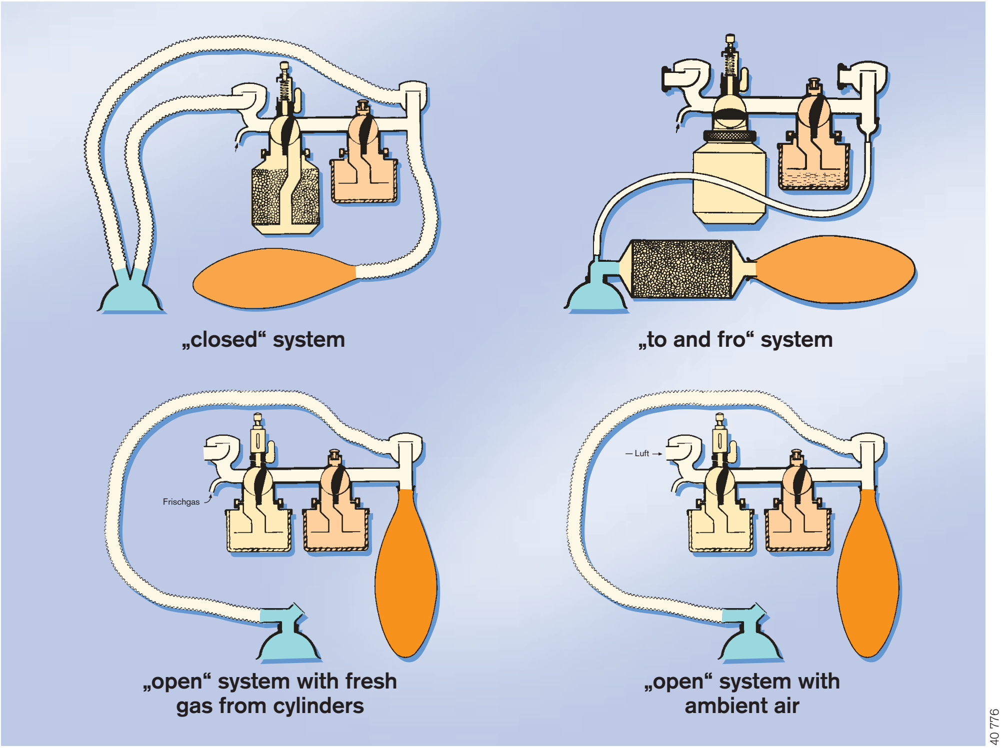
Dräger offered its Oscillation System as an item of supplementary equipment, especially to overseas supporters of the „to and fro“ system. This had different sizes of absorber for adults and children, and there was even one for infants and neonates. It could be used with any Dräger anaesthetic machine from Model F onwards.

Various items of supplementary equipment were available for the „semi-open system“ – and were also suitable for all Dräger apparatus, of which the following three are examples:

- The Magill System which did not have valves, which was British practice at the time, though it did have optional, coarsely variable, partial rebreathing.
- The Dräger Semi-Open System which was accurately controlled by inspiratory and expiratory valves and so did not have rebreathing, but did have a manual ventilation option.
- A Valveless Kuhn System which was especially designed for children and neonates, and did have a manual ventilation option.

A new circle system
The **Fabius** range, which was developed in the mid-Fifties, was originally designed for the military medical corps as a portable anaesthetic machine (see also page 74 – Anaesthesia machines for special use). Fabius was offered to the anaesthetist working with casualties as a portable anaesthetic machine. From 1956 onwards, the hospital version of Fabius also offered a choice of different gas cylinders.

What was really different about Fabius, as opposed to other Dräger machines, was the circle system.



Circle System II and its operation in different modes.

This Circle System II had an absorber which could be switched off during anaesthesia, either completely or partially, by a conical rotary valve. Adjustable (partial) rebreathing was therefore possible. The circle system was also designed to be changed over very easily so that it could operate as a semi-closed system, or a semi-open system with fresh gas, or on the „draw-over“ principle with ambient air.

The Spiromat anaesthetic machine

Since there were distinct advantages for the surgeon, as well as for the patient, in relaxing the breathing muscles during anaesthesia for thorax surgery, anaesthetists became increasingly involved in assisting and controlling ventilation.

17 947

The Dräger Fabius anaesthetic machine, originally designed as a portable machine, 1956.

Much experience was gained during the international polio epidemic at the end of the Forties and in the early Fifties. During this time, a large number of ventilators were developed in America and in Europe – and of course at Dräger – which operated more or less automatically.

Dräger transferred this expertise into anaesthesia technology and into the development of the **Spiromat 5000 anaesthetic machine** which was launched in 1959: it was designed as a combination of the Spiromat 4900 long-term ventilator and the Romulus anaesthetic machine. This electrically-driven machine had to be made intrinsically

The Dräger Anaesthetic Spiromat machine in clinical use in 1959.

safe and explosion-proof as it was going to be used in the operating theatre. With the Spiromat 5000 anaesthetic machine, an experienced anaesthetist could match ventilation parameters closely to the invividual needs of the patient and the operation.

- Accurate selection and adjustment of tidal volume between 50 and 1000 ml.
- Ventilation frequency adjustable from 10 to 40 per minute.
- Pressure reserve (+45 mbar) to ensure constant tidal volume, even when breathing resistance increased.
- Adjustable mean airway pressure for ventilation.
- Inspiratory:expiratory time ratio could be selected and set between 1:1 and 1:2.

An extract and two illustrations from a contemporary brochure show how the machine worked:

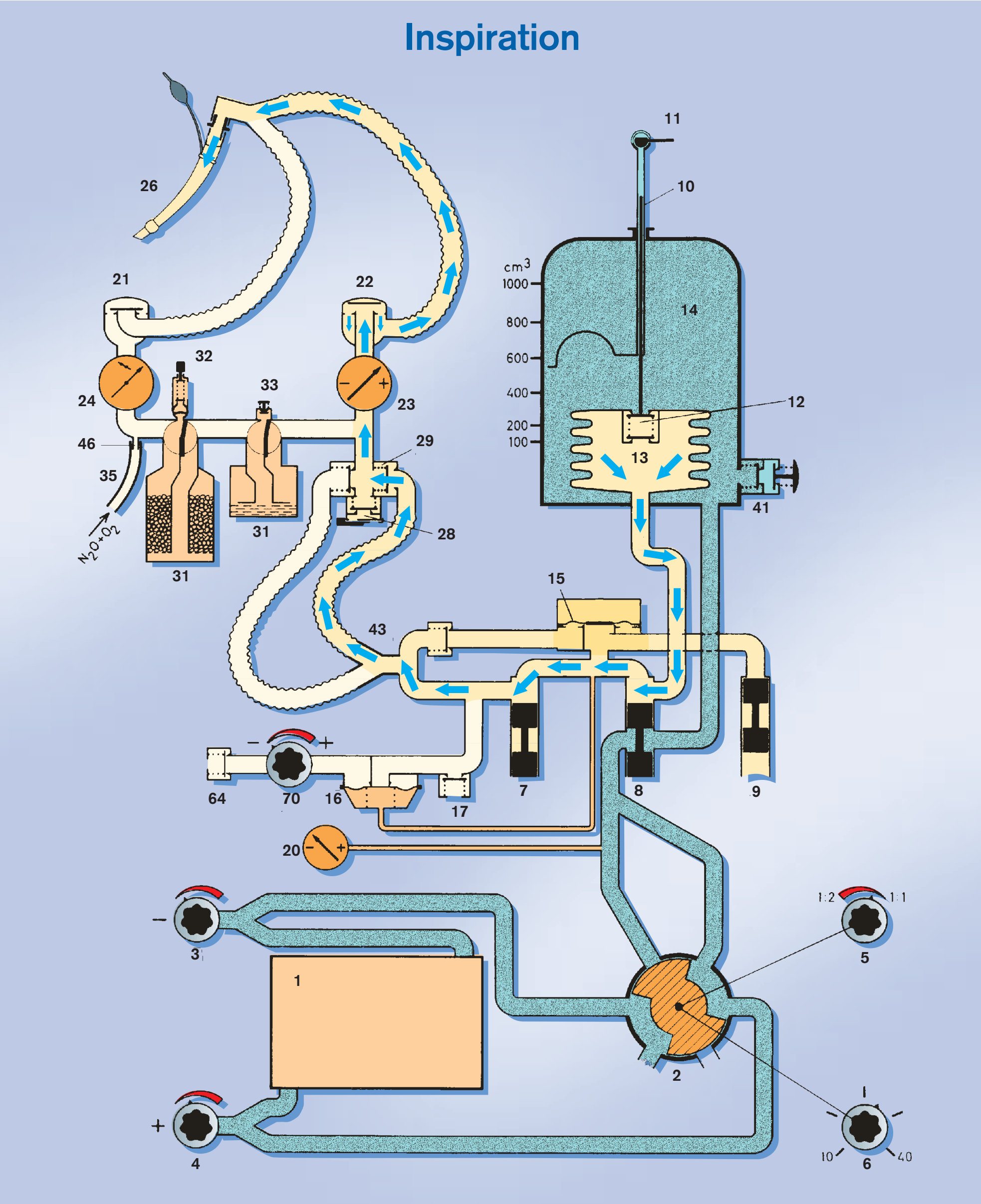
„An electrically-powered blower (1) inside the machine produces compressed air which is routed via a mechanically-controlled switching valve (2) to a plastic hood (14) where it operates the bellows (13).

In the closed or semi-closed system, the bellows (13) is filled with anaesthetic gas. When the bellows is compressed by the pressure the anaesthetic gas contained in it passes through the inspiratory valve (22) and the inspiratory hose to the patient. At the end of inspiration, the switching valve (2) stops the flow of compressed air and connects the suction side of the blower to the air space under the plastic hood, thus producing negative pressure under the hood. This negative pressure expands the bellows so that expiration takes place.

The gas expired by the patient flows through the expiratory hose, the expiratory valve (21) and the volumeter (24) and, after mixing with the fresh gas flowing through hose (35) arrives back in the bellows via the absorber (30) and the valve block (29). The expired CO_2 is bound in the absorber and at the end of expiration the excess anaesthetic gas escapes through the valve (12).

In the semi-open system, the bellows (13) is filled with either fresh air or anaesthetic gas. The bellows is compressed by the pressure under the plastic hood, and the gas inside is delivered to the patient through the inspiratory valve (22) and the inspira-

The race to the moon has started. In September 1959 the Soviets land a rocket on the moon successfully and plant the Soviet flag.



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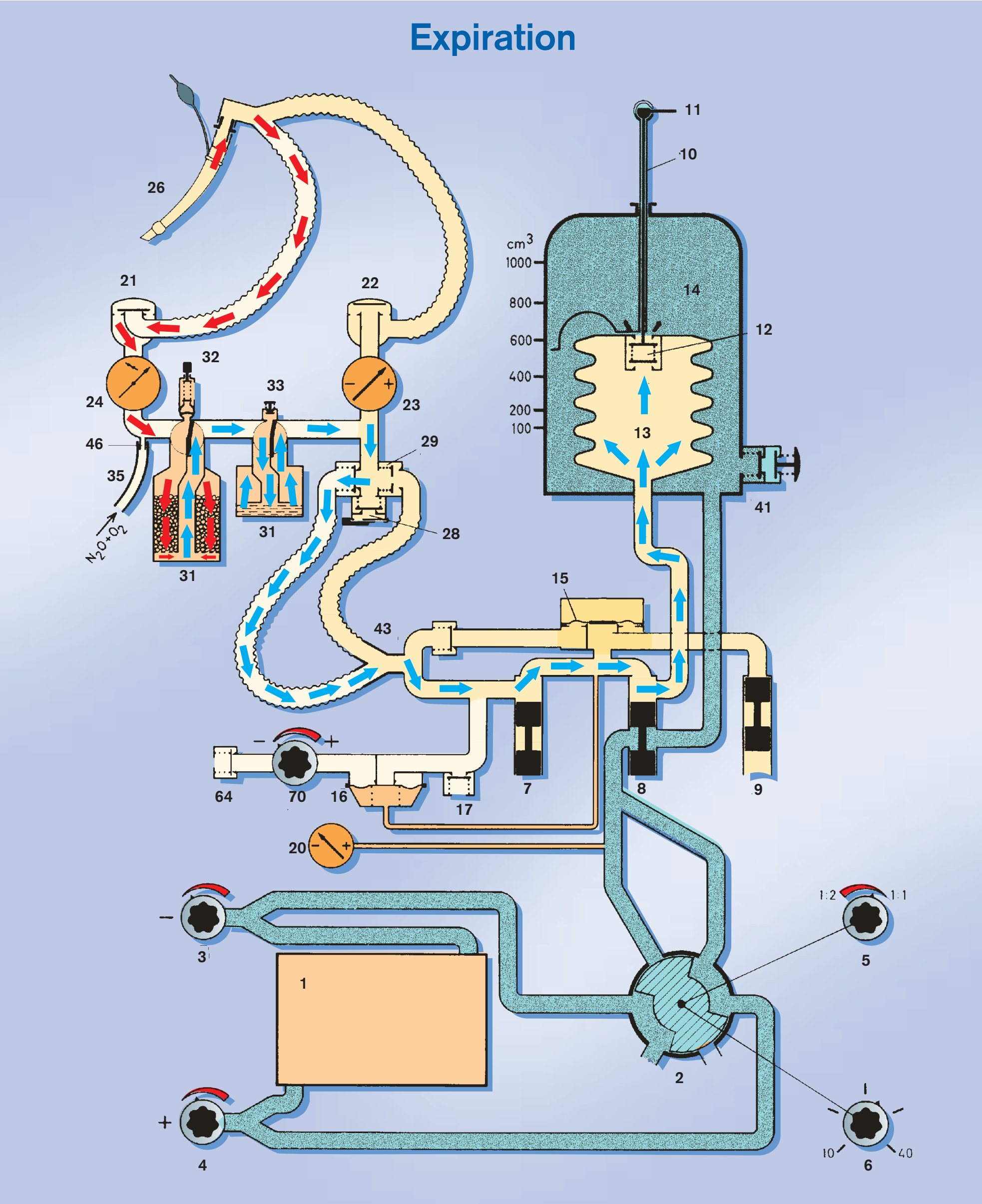
Operating diagram of Anaesthetic Spiromat 5000 in the inspiratory phase.



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Operating diagram of
Anaesthetic Spiromat 5000
in the expiratory phase.

tory hose. At the end of inspiration, the switching valve (2) stops the flow of compressed air and connects the suction side of the blower via the air space under the plastic hood to the expiratory hose and to the expiratory valve (21) to cause expiration. The expired air escapes via the blower to the outside, while the bellows is simultaneously being expanded by the negative pressure building up under the plastic hood and filling with air through the valve (36) or with anaesthetic gas from the bag (37), via a fine dust filter and bacterial filter (18).

The ratio between inspiratory time and expiratory time and the frequency of the switching valve (2) is determined by a stepless mechanical drive and it can be altered with rotary knobs (5 and 6).
The working pressure is set with two rotary knobs (3 and 4). The positive pressure in the system is automatically limited by a safety valve (17) to 45 cm H_2O, and cannot exceed this even at extremely high gas flows. The tidal volume is determined by the stroke of the bellows. It is measured during expiration with the Volumeter (24) and can be changed with the setting device (10).

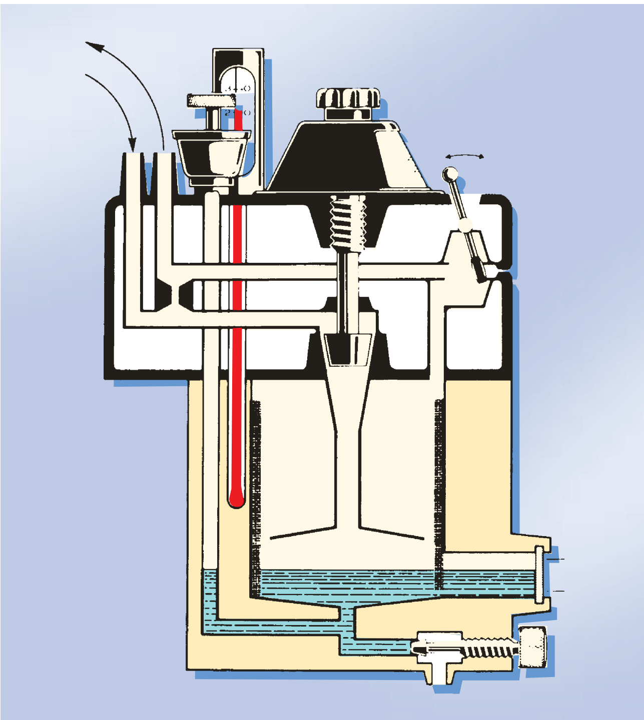
The Spiromat anaesthetic machine is particularly suitable for ventilating infants, as it can help to overcome the increased breathing resistance caused by narrow catheters."

In December 1959, 12 nation states sign a treaty in Washington declaring the Antarctic a neutral zone for friendly research projects.

Halothane in anaesthesia

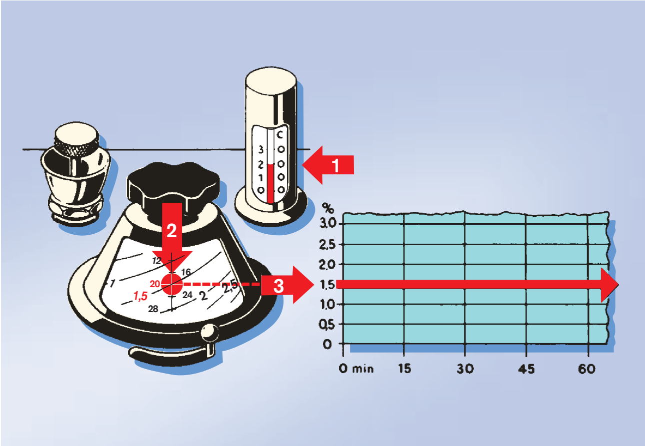
The principle and the Dräger Vapor
Between 1958 and 1960 anaesthesia was presented with a new anaesthetic agent, halothane, a halogenated hydrocarbon. Halothane possessed some completely new and highly welcome properties so that ether soon became virtually redundant.

The most important advantage of halothane is that it is not flammable at the concentrations of



41 029

Operating drawing for Vapor.



41 030

Operating procedure for Vapor:
1 read temperature
2 align concentration curve with temperature value
3 accurate flow control and a constant concentration.

oxygen and nitrous oxide which are used in anaesthesia in total contrast with explosive ether. However, because it has a very narrow concentration range for clinical applications it has to be administered in accurate doses, again in complete contrast to „harmless“ ether. This problem had to be solved, but traditional humidifiers and vaporizers could not provide an answer. Dräger therefore designed **Vapor**, a halothane vaporizer which controlled the concentration with an accuracy which had never before been achieved.

Vapor was designed to be connected to any Dräger anaesthetic machine produced since 1948 and, from 1960 onwards, it became an integral component in the new „Roman emperor“ generation of machines (Sulla, Titus etc.).

The following extract from the original brochure described Vapor as follows:
„The Vapor is connected to the basic machine in such a way that all the fresh gas flows through it and is enriched with halothane. The Vapor delivers the concentration set in vol.% with great accuracy, even during lengthy anaesthesia and the pressure changes which occur in artificial ventilation.
Because it has a wide flow range from 0.3 to 12 L/min

of anaesthetic gas, it may be used to give accurate doses in closed or semi-closed systems when the fresh-gas flow is very low and there are, therefore, only small amounts of halothane. The concentrations can be continuously adjusted from 0.3 to 5 vol.%.

The heat required for vaporization is supplied by a copper block which covers the vaporizing chamber. (Experience in the early years had shown that its weight could be reduced from 25.4 kg to 13.8 kg). Copper has great heat capacity and also very high thermal conductivity. The copper block is large enough to provide sufficient heat for routine evaporation in practical use. A mercury thermometer has been incorporated in the Vapor so that the values it shows may be used when setting the % scale.

A built-in pressure compensator ensures that the concentration supplied by Vapor remains constant even during artificial ventilation when positive and negative pressure occurs. If there is no compensation for alternating pressure, the halothane vapour in the vaporizing chamber would be compressed during the positive pressure phase and expanded during the negative pressure phase, so that the concentration could rise to twice the value set."

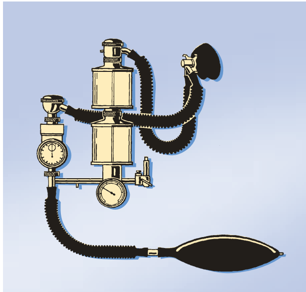
The „Roman emperors"
One could say that, in 1960, the Octavian anaesthetic machine was designed around Vapor. It was, in all senses of the word, a weighty competitor for Romulus. **Octavian** had a built-in Vapor for halothane, with the halothane being mixed into the fresh-gas flow for safety reasons. Circle System III also came into being with Octavian.

On the 9th November, 1960, John F. Kennedy is elected President of the United States by the narrowest of margins – 0.1 percent of votes.

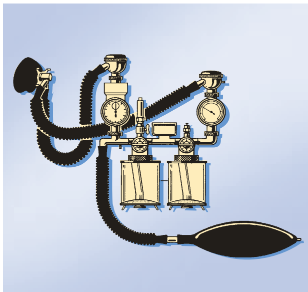
23 932

The Dräger Octavian anaesthetic machine during surgery, 1960.

The Ether Vapor was also produced as a variant of the Halothane Vapor to appease the supporters of ether anaesthesia and a further variant on the Ether Vapor was also produced which could either be built into the flow control section of Octavian or attached to older anaesthetic machines. During ongoing development, the ether vaporizer was removed from the original Circle System (see page 56) and replaced with a second absorber. In this way, Dräger engineers brought the Circle System up to date for halothane technology as Circle System IV.



Operating diagram for Circle System III …



… and Circle System IV.

In response to pressure from its overseas agents for a Boyle machine, Dräger produced the **Tiberius** anaesthetic machine in 1961. It was made in a way that was characteristic of the British school of anaesthesia. Tiberius had four legs and a table top with a cross-beam over it on which the vaporizers for the different anaesthetic agents – switched in series – could be mounted. As a special Dräger feature, Tiberius could have a Vapor installed on the table top and also a small cupboard with drawers to house accessories.

The three Agrippa models produced at the start of the Fifties were now outdated, but modernising their relatively simple, and therefore inexpensive, column design was considered worthwhile so that **Sulla** was produced in 1963. It was a basic unit which could be adapted to suit different users with various additional items of equipment:

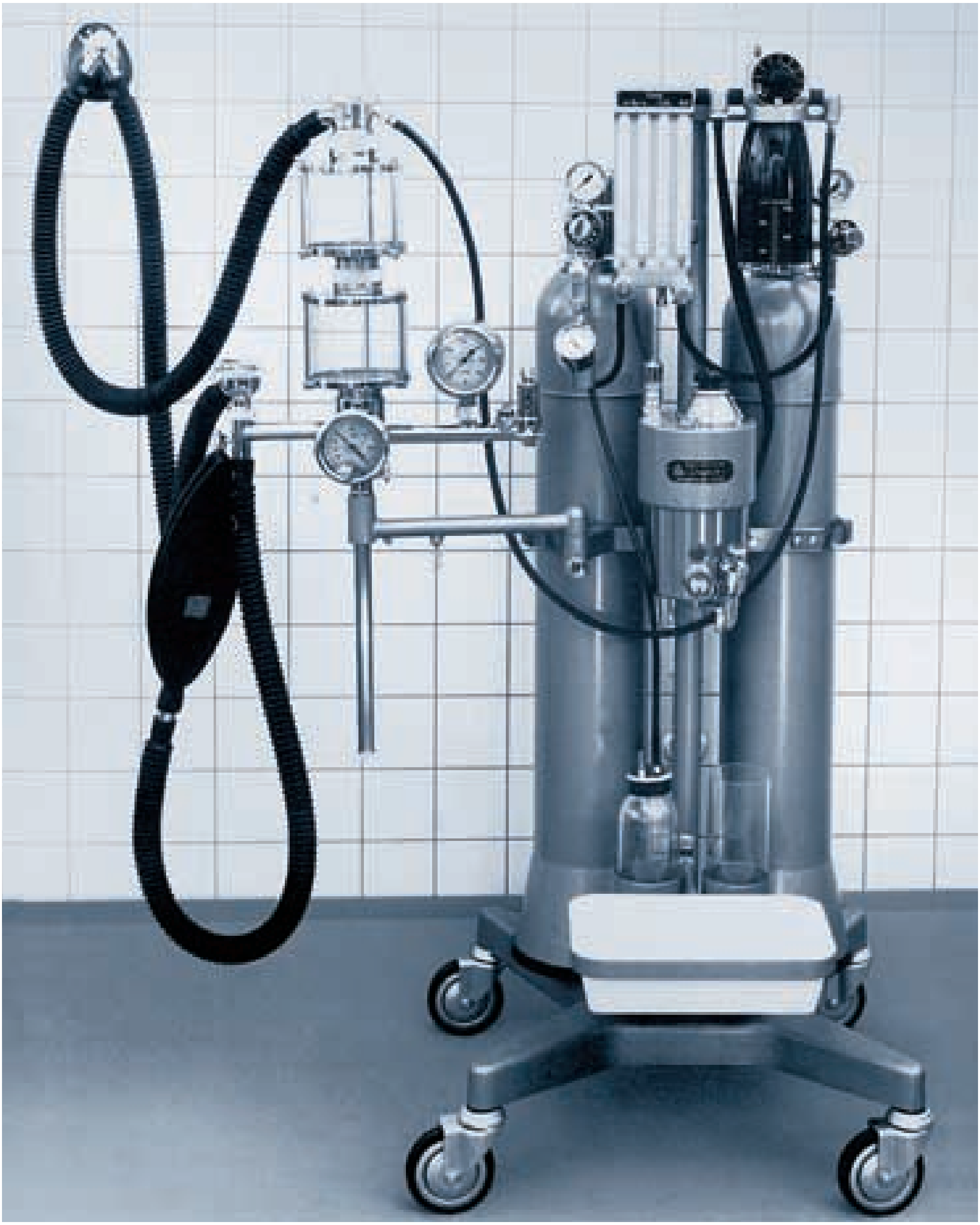
Cyclopropane (as a third gas), ether vaporizer, Halothane Vapor, semi-open systems of different types, Circle System III or IV, manual ventilation facility and Pulmomat.

21 062

In 1961, Dräger introduce the Tiberius anaesthetic machine, continuing the successful „Roman emperor“ series.

The modular concept was so popular and so successful that Sulla became the top-selling anaesthetic machine in Europe in the years which followed.

The modern operating theatre
During the early Sixties, facilities for anaesthesia became more and more sophisticated for both patient and anaesthetist. For example, there was a steady trend for hospitals to provide for induction and recovery to take place in separate induction



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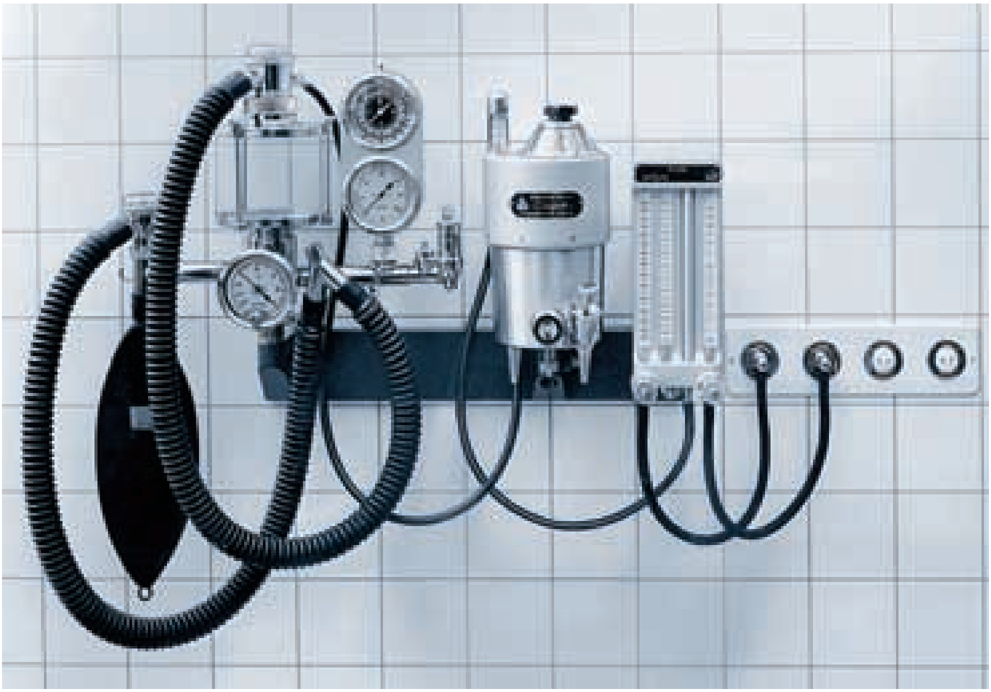
Sulla anaesthetic machine, 1963.

and recovery rooms next to the operating theatre, rather than in the theatre itself. This meant that the induction room also had to have an anaesthetic machine and, since space was usually at a premium, Dräger realised in 1966 that it made good sense to bring together all the fittings necessary for anaesthesia induction – that is flowmeter block, Vapor and Circle System – on a fixture



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In 1963, Dräger introduce their first wall-mounted anaesthetic machine.

24 939

In 1966, Dräger launched a wall-fitted anaesthetic machine for building-in in hospitals.

which was firmly mounted on the wall. Hence the first Dräger wall-mounted anaesthetic machine was born. It was supplied with oxygen and nitrous oxide from a central medical gas pipeline system which was in widespread use by then.

The space-saving concept was taken further by a Hamburg architect who was designing a new, large hospital. His plans required an anaesthetic machine „built into the wall" and so another version, the Dräger wall-fitted anaesthetic machine, was launched in 1966.

This machine consisted of a painted steel (later stainless steel) insert about 13 cm deep with the usual anaesthetic equipment fitted flush into a tiled wall.

Anaesthetic developments in the field of ventilation – particularly in intensive care treatment – meant that the Spiromat 5000 anaesthetic machine had to be completely redesigned. Drägerwerk launched the **Spiromat 650** anaesthetic machine in 1966. This sizeable machine (enormous by today's standards) met all the technical requirements of ventilation practice at the time.

A selection of the options for settings it offered during, after, or even independently of, anaesthesia are listed below:

- controlled ventilation
- assisted ventilation
- tidal volumes from 20 to 1500 ml per stroke
- ventilation frequency from 8 to 70 per minute
- electrically-controlled ventilation frequency
- ventilation pressures adjustable from -15 to +100 mbar
- controllable mean airway pressure
- adjustable ventilation pressure waveform
- ventilation time ratio (inspiration:expiration) selectable from 1:1 to 1:4

24 964

New in 1966: the Dräger Anaesthetic Spiromat 650 was the result of the ongoing development of the Anaesthetic Spiromat 5000, which dated back to 1959.

Anaesthesia machines for special use

Mobile anaesthetic machines
Anaesthetic apparatus for use in the field dates back to the 1914-1918 war and has a special place in the history of anaesthetic machines at Dräger. Only a few specimens of the Roth-Dräger hand-held 145 N device were likely to have been used in German Army field hospitals. (It was packed in a wooden case and could be connected to a standard 10 L oxygen cylinder.)

It is probable that more widespread use would have been hampered by the difficulties in supplies of oxygen. Whilst the British used their Oxford Vaporizer (ether/air in a draw-over system) and the Americans had their Heydbrinck (oxygen/nitrous oxide/ether in a circle system) even in front-line field hospitals, little is known about German anaesthetic field apparatus during the 1939-1945 war.

After the end of the war in 1948, Drägerwerk received its first order to develop anaesthetic field apparatus – from the French Occupation Army. The apparatus was built to the instructions of a French field surgeon stationed in Baden-Baden, who was interested in anaesthesia. The result was the Model L portable anaesthetic apparatus which used oxygen/nitrous oxide/ether in a circle system and could be dismantled. About 120 appliances were supplied at that time, all under reparation requirements, not as foreign currency earners.

Only with the founding of the Bundeswehr (Federal Army of the Federal Republic of Germany) in the Fifties did young anaesthetists with experience

41 405

Known as the Ether Cato for short, the „Small Field" anaesthetic machine, 1958.

from the war years begin to demand modern anaesthesia methods, and equipment to match, for front-line surgical units.

The most important name that must be mentioned is that of Professor Rudolf Frey, then Senior Physician for Anaesthesia at the Surgical University Clinic in Mainz and adviser to the Bundeswehr. The **Small Field Anaesthetic Apparatus** was produced as the result of close co-operation with the relevant Development Unit in the Bundeswehr Procurement Office in Koblenz. Inside Dräger this was called the Ether Cato for short. Dräger chose to produce a machine which was similar to the English EMO for three reasons:

1. It was important to eliminate supply problems for oxygen;
2. Small, easy-to-pack apparatus was required which was maintenance free;
3. The design had proved itself in British use.

After extensive trials, the apparatus was first delivered to the Bundeswehr in 1958, and by 1962, 750 had been supplied.

From the outset, all the experts had agreed that the First Aid apparatus had to be followed quickly by a full anaesthetic machine which could meet all technical demands, since even front-line field hospitals were routinely practising major surgery (including thorax surgery) from about 1950 onwards.

As a consequence, the **Large Field Anaesthetic Apparatus** appeared very soon afterwards. To all intents and purposes, this was Fabius in functions and use, and it was, in fact, known inside Dräger as Fabius M. However, the apparatus was designed to be dismantled and packed away with an ample supply of accessories, ready for use in the field. Anaesthesia for children and infants was not ignored either, as appropriate accessories were supplied. Fabius M, like its civilian brother, was based on the principle of oxygen/nitrous oxide/

The „Large Field“ anaesthetic machine, also known as Fabius M, 1958 too.

ether in a circle system. It could also be used for semi-open operation, that is without soda lime. This handy equipment was supplied to the Bundeswehr and to Civil Defence organisations at the end of 1959. By 1964 the Bundeswehr had acquired about 750 machines and the Civil Defence had about 1200.

27 662

Unpacked and assembled ready-for-use, the „Small Field“ anaesthetic machine, 1967.

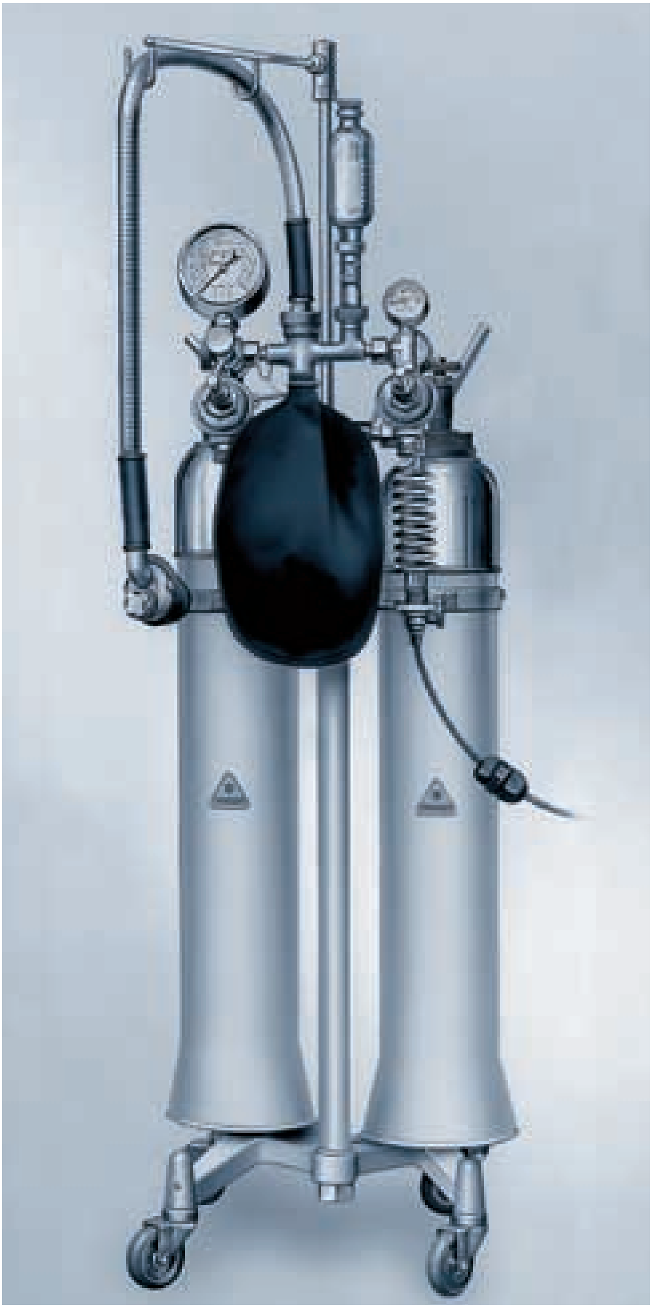
27 660

The „Small Field“ anaesthetic machine securely packed in a compact box for transport, was also known as the Halothane-Cato.

The unstoppable move in anaesthesiology away from ether to halothane, which started at the beginning of the Sixties, also meant new thinking for the Bundeswehr. In 1966 the result was a new small anaesthetic field machine, known inside Drägerwerk as the Halothane Cato 10. The halothane vaporiser was based on the Vapor principle, but it was modified for the „draw-over system“ to reduce breathing resistance in the inspiratory and expiratory tract. An elaborate ventilation valve was also added to the machine so that ventilation pressures and tidal volume, measured on the Volumeter, could be controlled. The oxygen content of the draw-over air could also be increased to 30 percent, with an oxygen enrichment device, and pure oxygen could be used in an emergency. The Bundeswehr were supplied with about 1100 of these units over about 10 years.

A brief account of nitrous oxide in dentistry
Inhalation anaesthesia has played, and is continuing to play, an important role in hospital and field surgery and also in other fields of medicine. This is particularly true of nitrous oxide, which was discovered as an anaesthetic agent 150 years ago and first used in dental surgery. Prof Hans Killian, discussing this subject in his book „The adventure of anaesthesia“ (page 20), writes:

„There is no doubt at all that nitrous oxide anaesthesia is actually the oldest anaesthetic process since it was discovered by Horace Wells, a dentist who wanted to make prostheses and had been looking for an anaesthetizing agent so that stumps and decayed teeth could be extracted painlessly,



9994

In 1928, Drägerwerk developed models B and C for use in dentistry.

since this was an essential preliminary to the production of dentures. If he was forced to pull teeth out without numbing the pain when the patient was fully conscious, the patient was liable to take his money and run well before the prosthesis was ready“.

It is also known that Professor Hans Pflüger, then Head of the Teaching Hospital for Dentistry and Orthodontics at Eppendorf in Hamburg, was the first to promote nitrous oxide as an anaesthetic agent in dental surgery. He urged Drägerwerk to produce a suitable, simplified version of Model A, based on the version which he knew and had been using in the Eppendorf surgery, and, as a result, a nitrous oxide anaesthetic machine for dentistry, known as **Model B**, was launched at the very end of the Twenties.

This machine soon found its way into dental surgeries as well as into teaching hospitals. The complete freedom from pain and mental stress, even during lengthy surgery, was an extremely important benefit for both patient and dentist. The fact that patients woke quickly from the anaesthetic, with no side effects, was also very beneficial.

Model B operated with oxygen and nitrous oxide in a semi-open system. A small, simple ether drip-feed device could also be used to deepen anaesthesia when necessary. A machine without this additional ether device was marketed as **Model C**.

12 989

This Model D nitrous oxide anaesthetic machine was used in dental surgeries after the Second World War.

From 1936 onwards both machines experienced a boom which was brought to a halt by the outbreak of war. Although nitrous oxide and oxygen both continued to be available, the manufacture of the machines was prohibited as „not essential for the war effort“.

In 1946, a new beginning in dental nitrous oxide anaesthesia was made in Germany with Model D. Identical in function with Model B/C, Model D differed only in the way it was made, which was influenced by the availability (or, rather, non-availability) of certain materials in the early post-war years.

The photo shows the Lübeck dentist, Dr Hartwig Drücke, at work in 1948 – an extraction under nitrous oxide anaesthesia with Model D.

41 848

15 461

The Model K nitrous oxide anaesthetic and analgesia machine, 1952.

To assist the dentist, or the assistant in charge of the anaesthetic machine to deliver the correct dose of gas, an automatic system for controlling the flow to the lung was incorporated in **Model K** from 1952. This was, in fact, a system that had been used in Dräger breathing equipment as early as 1903. With this automatic pneumatic system, the operator merely had to set the oxygen concentration required on a scale in volume percent. The total volume was then adjusted automatically to each tidal stroke.

A demand valve of this kind was, of course, much more complicated to make than a constant flow control system. Nevertheless, in 1954 Drägerwerk still decided that it was appropriate to give Model K a more attractive exterior to harmonise with the

16 169

Model K2, 1954, one of the last nitrous oxide anaesthetic and analgesia machines used in dentistry.


16 164

The Marius simple nitrous oxide analgesia machine, 1953.

environment of the dental surgery. This modified version, which was identical in function with Model K, was known as Model K2.

As the element of risk involved in the use of full nitrous oxide anaesthesia in dental practice became more widely understood in the early Fifties, a number of experienced pioneers began to exploit the preliminary stage of anaesthesia, i.e. analgesia. The Zurich dentist, Dr Paul Vonow, was one of these. In 1953 he designed a simple and relatively inexpensive machine in co-operation with Drägerwerk. This was the nitrous oxide analgesia machine, **Marius**.

Marius operated with a constant flow control system for oxygen and nitrous oxide (but no ether!), but with a minimum limit value for oxygen and a maximum limit value for N_2O, so that the oxygen concentration administered could not drop below 20 vol.%. Models D, K and K2 were largely replaced by this machine in the years that followed and Marius maintained its position in both the domestic and foreign market right up to the middle of the Sixties.

Thereafter the rather complicated machinery for gas anaesthesia and analgesia in dental practice was overtaken, and then replaced, by injection anaesthesia, a process which has itself become more sophisticated over the years.

Fitted with a different flow control system and appropriate masks, Marius was also used for minor surgery and in ENT departments as a small anaesthetic machine for routine operations. In this form, it was known as the Pavor.

Nitrous oxide analgesia in obstetrics
One other area of inhalation anaesthesia in which Dräger has played a role is that of nitrous oxide/ oxygen analgesia for pain relief during childbirth. Professor Gauss, a gynaecologist from Würzburg, suggested the idea of designing a special machine to Drägerwerk (1939/40). The War prevented the co-operation proceeding beyond the first prototype – one which was, nevertheless, used very successfully at Würzburg.

It was 1950 before Dräger was able to return to this area and then several German gynaecologists became involved in developments. The result was

The New Zealander, Hilary, and his team are the first to conquer the 8840 metre summit of Mount Everest. An expedition to conquer the highest mountain in the world would have been unthinkable in 1953 without the use of breathing equipment.

15 453

Model E nitrous oxide anaesthetic machine for childbirth, for obstetric use, 1951.

the **Model E** nitrous oxide anaesthetic machine for childbirth which was based on experience gained with Professor Gauss's prototype. In its design and function, the demand valve was very similar to **Model K** and it was extremely easy and safe to

15 464

Model H nitrous oxide anaesthetic machine, 1952, lightweight version.

use. The machine was placed at the patient's bedside by a doctor or midwife who opened the oxygen and nitrous oxide cylinders and set a relatively high oxygen concentration. After a brief explanation, the patient could be left to use the machine herself. When she felt the next contraction, she could hold the mask to her face and breathe through it calmly. The fast-acting analgesia would provide pain relief after a few breaths. The patient could then decide for herself when to remove the mask – until the next contraction.

The midwife could also provide effective pain relief for the patient during the actual childbirth, without the analgesia impairing the patient's ability to cooperate. An ether accessory could provide full anaesthesia if required for a surgical procedure, such as an episiotomy following childbirth.

16 663

Model E2 nitrous oxide analgesia and anaesthetic machine, 1957, at a bedside providing pain relief during childbirth.

Demand was also growing for this type of pain relief to be available for home births and all that was required was a portable version. In 1952 Dräger met this demand with **Model H**, which was housed in a convenient light metal case, which also included one 2 L cylinder each of oxygen and

24 969

The modern clinical concepts of wall-mounted machines found acceptance also in gynaecology: wall-mounted Model E2 nitrous oxide analgesia and anaesthetic machine, 1964.

15 567

Trichloroethylene Inhaler, „Göttinger Model“.

nitrous oxide. A trolley and standard 10 L cylinders were provided for ward use.

In due course, Model E became **Model E2** through a process of minor modifications and technical „cosmetics“, though it was identical to its predecessor as far as function and use were concerned.

The E2 wall-mounted model, marketed in 1964, also differed from the E2 version only in its appearance. It was launched in response to calls to „move it away from the floor“ and „no more awkward gas cylinders on the machine“. It was mounted at a suitable point on the wall close to the patient and supplied with oxygen and nitrous oxide from a medical gas pipeline system.

Soon after, at the beginning of the Fifties, trichloroethylene in its pure form which was suitable „pro narcosi“ played a secondary role in obstetrics and dentistry, namely as an analgesic for pain relief during childbirth and painful dental treatment. It was applied with the simplest of inhalers, and inhaled by mouth or by nose. Trichloroethylene Drägerwerk participated in this – in inhaler for dental hindsight – short-lived fashionable anaesthesia idea with its „Göttinger model“ (following the concepts of Prof Hosemann and Dr Hickl) as well as the analgesic „Trimenth“ (in ampoules) which was a highly refined trichloroethylene with menthol added to mask the odour.

The outcome of progress in electronics and electrotechnology in the technical development of Dräger’s anaesthetic machines will be described in Volume II of our chronicle. It will cover the recent past and will bring this historical view of 100 years of Dräger anaesthetic technology to a close.

15 574

Trichloroethylene inhaler for pain relief during childbirth.

15 565

Trichloroethylene inhaler for dental anaesthesia.

Chronological survey

1889 Invention of pressure regulator; as beer pressure controller and oxygen controller, the pressure regulator laid the foundations of Drägerwerk's success
Page 10/11

1902 German Reich patent for drip-feed apparatus
Page 12

1902 Development of first anaesthetic apparatus in Germany: hand-held apparatus 145 N, also known as the Roth-Dräger
Page 14

1910 Roth-Dräger Mixed Anaesthetic Apparatus
Page 16

1911 A world first: anaesthetic machine with artificial ventilation, the Roth-Dräger-Krönig
Page 20

1912 Dräger-Combi, a new type of combination for mixed anaesthesia, positive pressure anaesthesia and artificial respiration
Page 23

1924 Development of the first circle system in the world, initially used for narcylene
Page 30

1926 Model A, the first batch-produced circle system for nitrous oxide
Pages 31/32

1928 Models B and C, specially for use in dental surgeries
Pages 80/81

1934 Tiegel-Dräger anaesthetic apparatus for anaesthesia with superheated ether vapour
Page 35

1935 Type MU positive pressure mixed anaesthetic apparatus
Pages 38/39

1946 Model D oxygen-nitrous oxide anaesthetic machine; a move towards a new ergonomic approach in the development of anaesthetic apparatus; for the first time, most controls are fitted in a console
Pages 41, 82/83

1948 Model F anaesthetic machine for oxygen, nitrous oxide and ether; with bronchial suction which is independent of motor or electric power
Page 41

1950 Model G, designed specially for the international market, with the option of connecting up to five gases
Page 44

1951 Model E nitrous oxide anaesthetic machine for use during childbirth, in obstetrics; almost identical with Model K
Page 88

1952 Model H a light, portable anaesthetic machine for home obstetric use
Pages 91

1952 Model K, for use in dental surgeries, with built-in automatic flow control
Page 84

1952 Dräger introduce Romulus, a refinement of Model F and an optimally ergonomic, „integrated“ anaesthetic workstation; also available as Remus, with slight modifications for the international market
Page 47

1952 Agrippa range of models
Page 50

1952 Introduction of Dräger Pulmomat, an automatic ventilator for all anaesthetic machines; significantly eases the anaesthetist’s task
Page 53

1953 Marius nitrous oxide analgesia machine for use in dentistry
Page 86

1956 Fabius, with the recently-developed Circle System II, which made partial re-breathing possible
Page 55

1957 Model E is modified slightly and launched as Model E2
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1958 „Small Field“ anaesthetic machine, also known as the Ether-Cato
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1958 „Large Field“ anaesthetic machine
Page 76

1958 First prototypes of Vapor, an anaesthetic agent vaporiser
Page 63

1959 Anaesthetic Spiromat 5000, an electrically operated anaesthetic machine
Page 57

1960 Octavian, with built-in Vapor for Halothane humidification
Page 65

1961 With Tiberius, the Dräger-Vapor becomes batch produced
Page 67

1963 Sulla, the successful Dräger anaesthetic machine which remained in production – with appropriate technical modifications – until 1996
Page 67

1964 Model E 2 becomes available for clinical use in a wall-mounted version
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1966 Anaesthetic Spiromat 650
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