

SMOKE GENERATOR FOR IN VITRO RESEARCH

Nils Rose

Borgwaldt Technik GmbH, Schnackenburgallee 15, 22525 Hamburg, Germany

Abstract:

In close co-operation with BAT Southhampton, a smoking machine was developed, which generates cigarette smoke for in vitro research.

The machine, which is called RM20S, is based on the rotary principle of the RM200A. It is able to smoke four different brands simultaneously under ISO conditions. The machine dilutes the smoke up to 1:1.5 Mio and forwards the dilution into the cell chambers. The fully automated process offers the possibility to supply the cell chambers with smoke for several hours.

The general advantage of the rotating principle is that all necessary tools like loader, lighter and so on are only needed once. The cigarettes are subsequently moved to the respective position. The smoke ring offers four cigarette holders, which are moved into five positions: loader, lighter, smoke position, diluting, glow detection and extraction.

The machine is equipped with four independent stepper motor driven syringes with each having a 5/4-direction-control-valve for selecting the flow direction. The syringes and valves are designed such that residua does not effect the function. The hood and air flow control allows to smoke under ISO 3308 conditions.

The machine is controlled by several micro processor systems which operate according to the master slave principle. For operation the machine is equipped with a terminal with display, keyboard and printer.



Figure 1: Smoking machine RM20S

Introduction:

In vitro research regarding the influence of cigarette smoke on cells became more and more important in the last years.

In close collaboration with BAT Southampton, Borgwaldt Technik GmbH developed a smoking machine, which generates cigarette smoke for this work.

The machine is based on the proven technology of the rotary operating RM200/20 family. It can smoke four different brands concurrently. The cigarettes are smoked under ISO-conditions. The smoke is diluted and the mixture is forwarded to the cell-chambers.

The machine works fully automatically and is able to smoke up to 20 cigarettes successively on each of the four ports. This function makes it possible to provide the cell chambers with diluted smoke for several hours.

Structure:

The RM20S is designed as a fully automatic 4-channel rotary smoker. It is based on the proven technology of the RM200/20 family. Due to the fact that the machine is equipped with the same hood and air flow guide as the RM200/20H it is possible to smoke the cigarettes in compliance with ISO 3308. The air flow guide is mounted on a hinged frame to gain ideal access to the smoking ring.

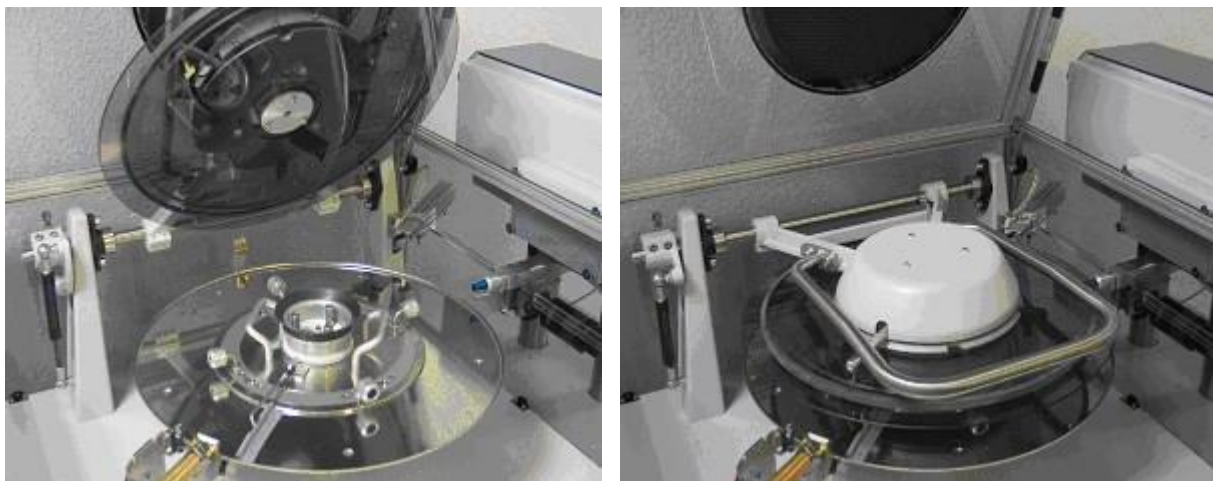


Figure2: Air flow guide. Left: open, right: closed.

All 4 channels of the machine are operating completely independent. That enables the machine to smoke four different brands with different parameters at the same time. Changeable parameters are: puff profile, puff volume (5-140 ml), puff duration (up to 2 sec), cigarette length (65-100 mm) and lighting power (50-100W).

The general advantage of the machine's rotating principle is, that all necessary instruments, for example electric lighter, are only needed once and the cigarettes are moved to the single positions. The smoking ring has got four cigarette holders, which can be moved into 5 different positions. These positions are: loading-position, smoking-position, diluting, glow detection and butt extraction-position. The electrical lighter and the butt length detector are located in the smoking position. Next to the cigarette holders, the smoking ring is equipped with an open position. This port is used to flush the tubing with ambient air right after puffing the cigarette and for the first dilution of the smoke.

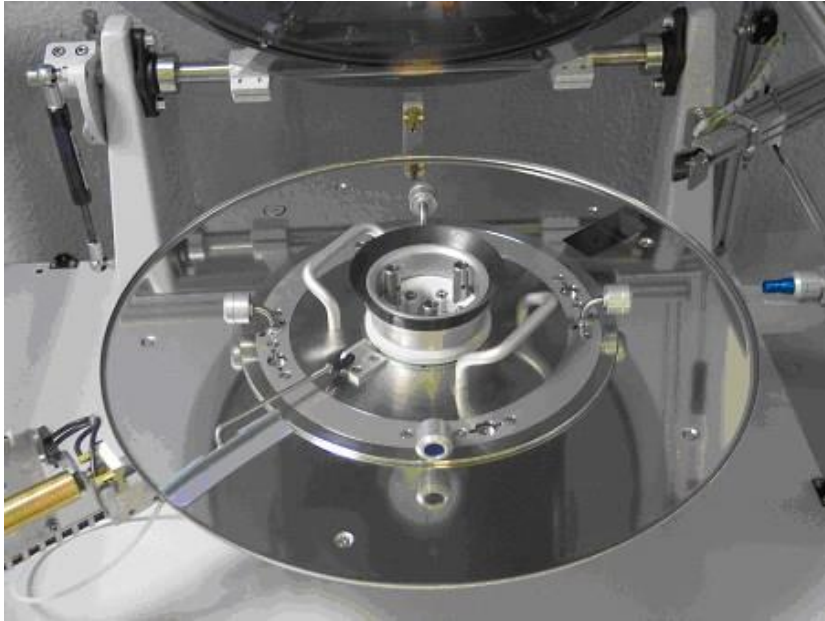


Figure3: Smoking ring with sensors and actuators

Also integrated is an anemometer to measure the air flow for flow-adjustment, an electrical lighter, a burning control unit, a butt-length-control, a butt extractor and a collecting bin for the butts. The loading device is supplied with eight cartridges for 20 cigarettes each.

All activities are controlled by a several microprocessor controller which work in accordance to the master-slave-principle. For operation the machine has a terminal with display, keyboard and printer.

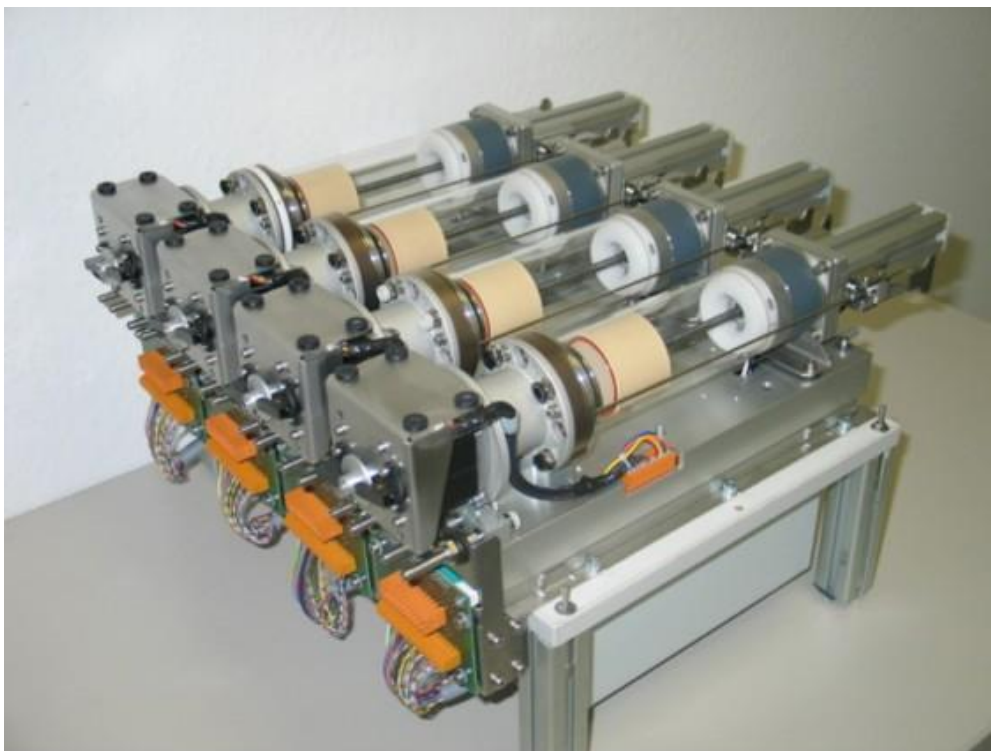


Figure 4: Syringe assembly

The four vertically arranged syringes are mounted on a hinged frame in the front of the machine to gain optimal access for cleaning and maintenance. Using a sliding keyway the syringes can be easily disconnected and withdrawn as a single module in an instant. Service and maintenance work then can be carried out on the bench top. The syringe is stepper motor driven. It can replicate different puff profiles. Ten puff profiles are pre designed. Nine of these profiles can be easily modified by the operator.

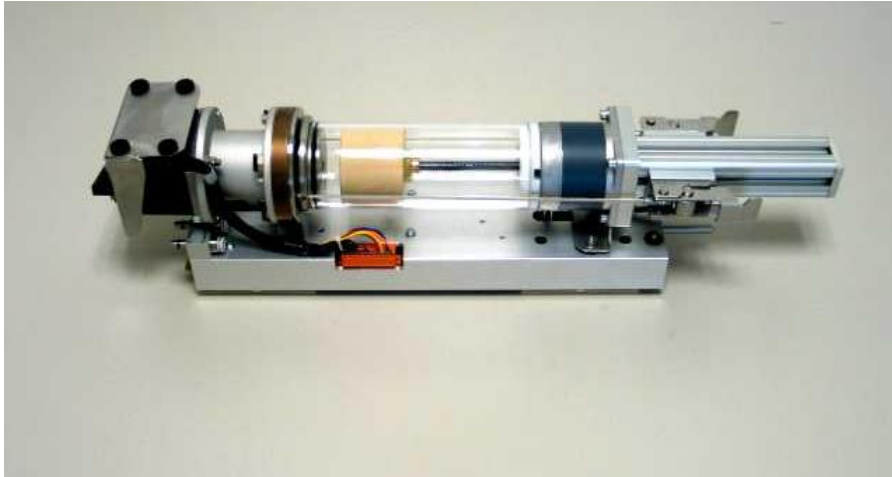


Figure 5: Syringe

The piston speed can be set between 0.1 and 80 mm per second. This generates a flow rate of 0.2 up to 157 ml / sec. The Puff volume can be set between 5 and 140 ml at a 2 sec puff duration.

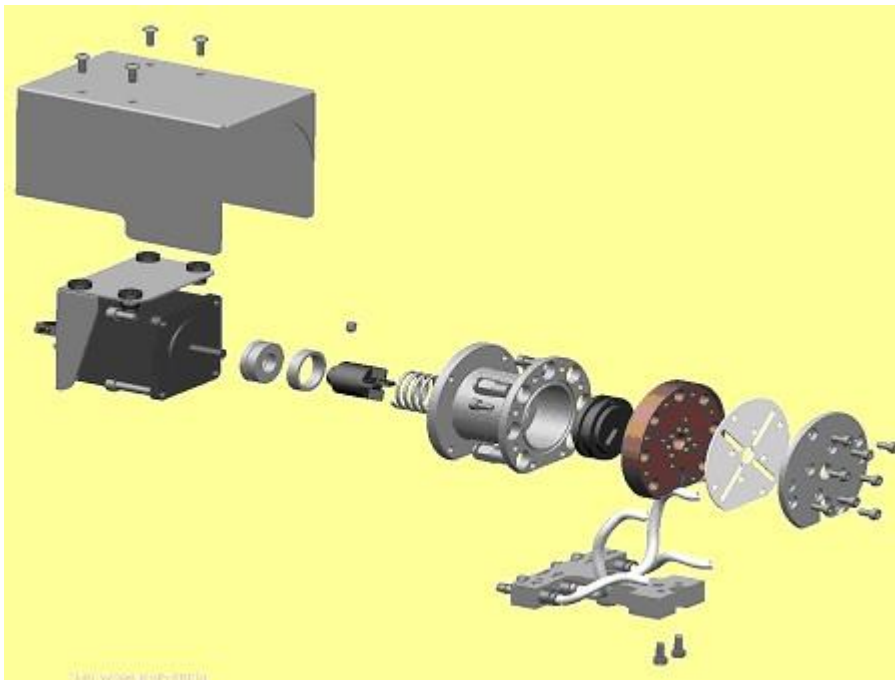


Figure 6: Exploded view of the disk valve

To direct the gas phase within a smoking machine, standard valves, designed for pneumatic applications are commonly used. Not being designed for this purpose, these valves need a lot of attention and are a constant source for failure and service. If whole smoke needs to be directed, commercially available valves cannot provide the security and reliability of operation that is required. The valve needs to be of a chemically inert material.

For this special application a new rotary 5-4-way disc valve was developed. It is equipped with a stepper motor driven valve disc. The valve is directly operating in the head of the syringe. This grants a low impedance and a minimal dead volume.

Process Flow:

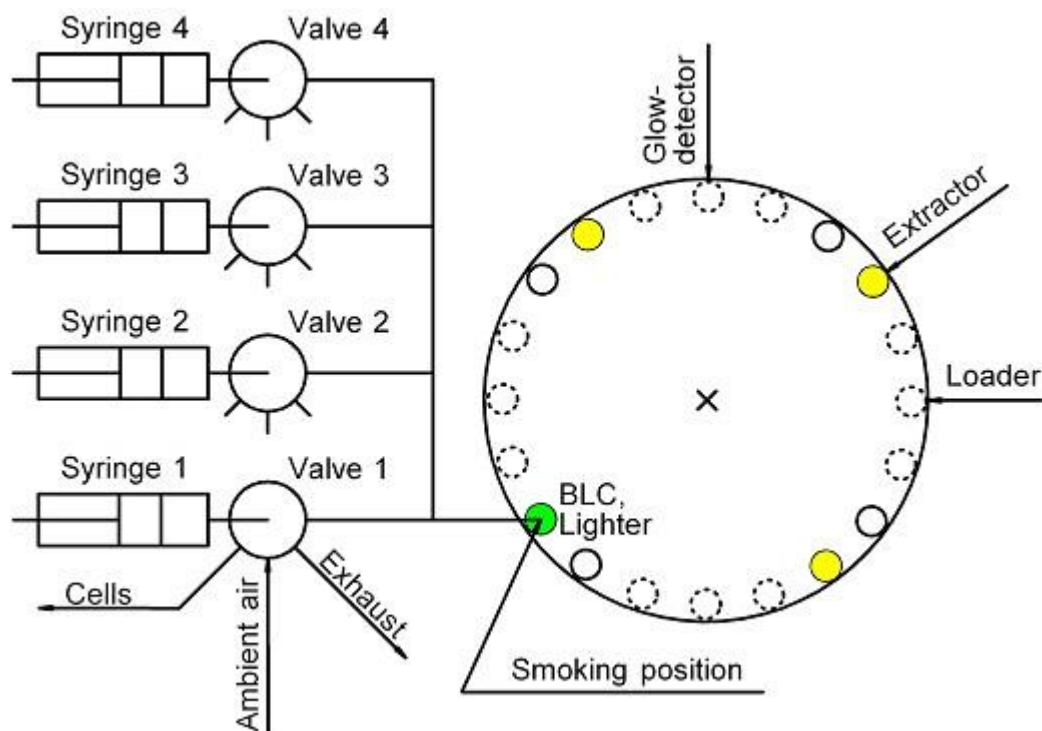


Figure 7: Schematic representation of the RM20S

After inserting all smoke parameters for cigarettes and dilution and after loading the cigarette filled cartridges, the cigarette loading process starts. When the first cigarette reaches the smoking position, it is lit. Then the cigarette is moved into the next position. Now the open position of the smoking ring is connected to the syringe and the syringe can draw ambient air and flush in the smoke from the connection tube.

The smoke in the syringe is then partly blown into the exhaust system. Afterwards the syringe draws fresh air for diluting the smoke by switching the valve into the corresponding position. The procedure of drawing in and blowing out is repeated until the desired dilution is reached.

Due to the syringe volume of 140 ml, a dilution from 1:1 up to 1:1,5 Mio can be reached within a couple of seconds. The diluted smoke will now slowly be blown out

to the cell chambers. The motor controlled valve at the head of the syringe establishes the necessary connections.

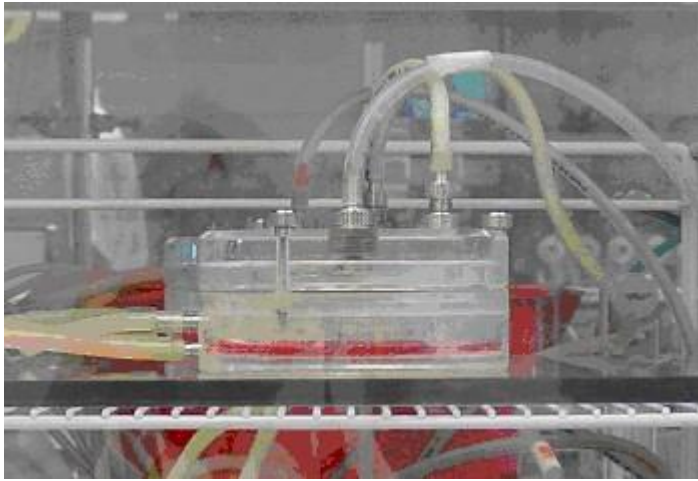


Figure 8: Cell chamber



Figure 9: Incubator with cell chambers

The whole procedure takes 60 seconds. During that time the smoke ring has turned exactly one revolution, so that the first cigarette is in the smoking position again. When the cigarette has reached its butt length the puff is terminated and the cigarette will be extracted. Within this round a new cigarette is loaded at the loading position and lit afterwards at the smoking position. This guarantees an ongoing process and enables a smoke generation for several hours.

Summary:

The RM20S is a highly versatile automatic smoke generator for in vitro research work.

Due to the fact that the machine uses the same the hood and the air flow guide as the RM200 / RM20H it is possible to smoke the cigarette in compliance with ISO 3308. The RM20S is able to smoke four different brands with different parameters concurrently. The fully automatic process allows a continuous fumigation of four in vitro cells at the same time for several hours. The dilution of the smoke can vary between 1:1 and 1:1.5 million.

References:

1. ISO 3308:2000 (BS5668-1:2000) "Routine analytical cigarette smoking machine – Definitions and standard conditions" (Generally derived from CORESTA Recommended Method No. 22)
2. ISO 7210:1997 (BS 5668-2:1997) "Routine analytical cigarette smoking machine – Methods of non-routine evaluation" (Generally derived from CORESTA Recommended Method No. 22)
3. ISO 4387:2000 (BS 5202-14:2000) "Methods for chemical analysis of tobacco and tobacco products - Cigarettes - Determination of total and nicotine-free dry particulate matter using a routine analytical smoking machine" (Generally derived from CORESTA Recommended Method Nos. 23 and 24)
4. ISO 3402:1999 (BS 5743:2000) " Tobacco and tobacco products - Atmosphere for conditioning and testing" (Generally derived from CORESTA Recommended Method No. 21)