SAMES

SOCIÉTÉ ANONYME DE MACHINES ÉLECTROSTATIQUES

SAMES

GRENOBLE - FRANCE

**SOCIÉTÉ ANONYME
DE MACHINES
ÉLECTROSTATIQUES**

SOCIÉTÉ ANONYME AU CAPITAL
DE 92 000 000 DE FRANCS

GRENOBLE - 29, Avenue Félix-Viallet

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Guy LORIN
Founder and President

a working team...

For many years now, the use of high voltage direct current in science and technology has been steadily increasing. It is finding applications in a wide range of fields, extending from particle accelerators to dust precipitation, and including electron optics, X rays, mineral sorting, electrostatic painting, television (particularly projection on large screens), testing of electric strength (both destructive or non-destructive), ignition of internal combustion engines, etc...

It is a curious paradox that electrostatic machines have been abandoned in favour of a system where an alternating current generator is followed by stages of rectification and smoothing.

Electrostatic machines were designed specifically to produce direct current at very high voltages but they had never been produced on an industrial basis.

It is at Grenoble, where the spirit of adventure still flourishes, that this problem of industrialisation has been tackled and solved.

This success was the fruit of a happy union. From the outset, there was a team of scientists, technicians and business men who collectively were able to contribute all the necessary qualities for the project, including a willingness to persevere until the task had been completed. Their skill and far-sightedness has been amply rewarded. Electrostatic machines are now in being and in production. They are just as rugged as electromagnetic machines, and less costly than the classical system with rectifiers. They easily outclass existing systems as regards size and also as regards the safety of both operators and associated equipment. Considerable effort was necessary to attain this result.

Now the pioneering period of basic research is over. The success which has crowned the efforts of this team is due largely to the spirit of close co-operation which is shared by its members who include :

- *the University of Grenoble, always ready to collaborate with the Science and Industry,*
- *the « Laboratoire d'Electrostatique et de Physique du Métal » of the « Centre National de la Recherche Scientifique » under the leadership of the distinguished scientist Professor Louis NEEL, « Membre de l'Institut », who has allowed Professor Noël J. FELICI to carry out his remarkable work on electrostatic machines,*
- *the engineers and technicians of the S.A.M.E.S. who have kept their faith in ultimate success in spite of many difficulties encountered on the stony path between the original idea and the final goal of production on an industrial scale.*

From the day of its creation, the S.A.M.E.S. has never ceased to grow. New developments lie ahead, brought much closer by the setting-up early in 1955 of the Accelerator Department and by the new factory equipped. The company is thus advancing and keeping abreast of the new opportunities offered by the atomic era.

The very close co-operation between the « Centre National de la Recherche Scientifique » and Professor Noël J. FELICI, the support which several eminent companies have given us and the sterling quality of our engineers and technicians are our guarantee for a rich future, in which one of the oldest branches of science comes to the aid of some of the boldest undertakings of our modern age.

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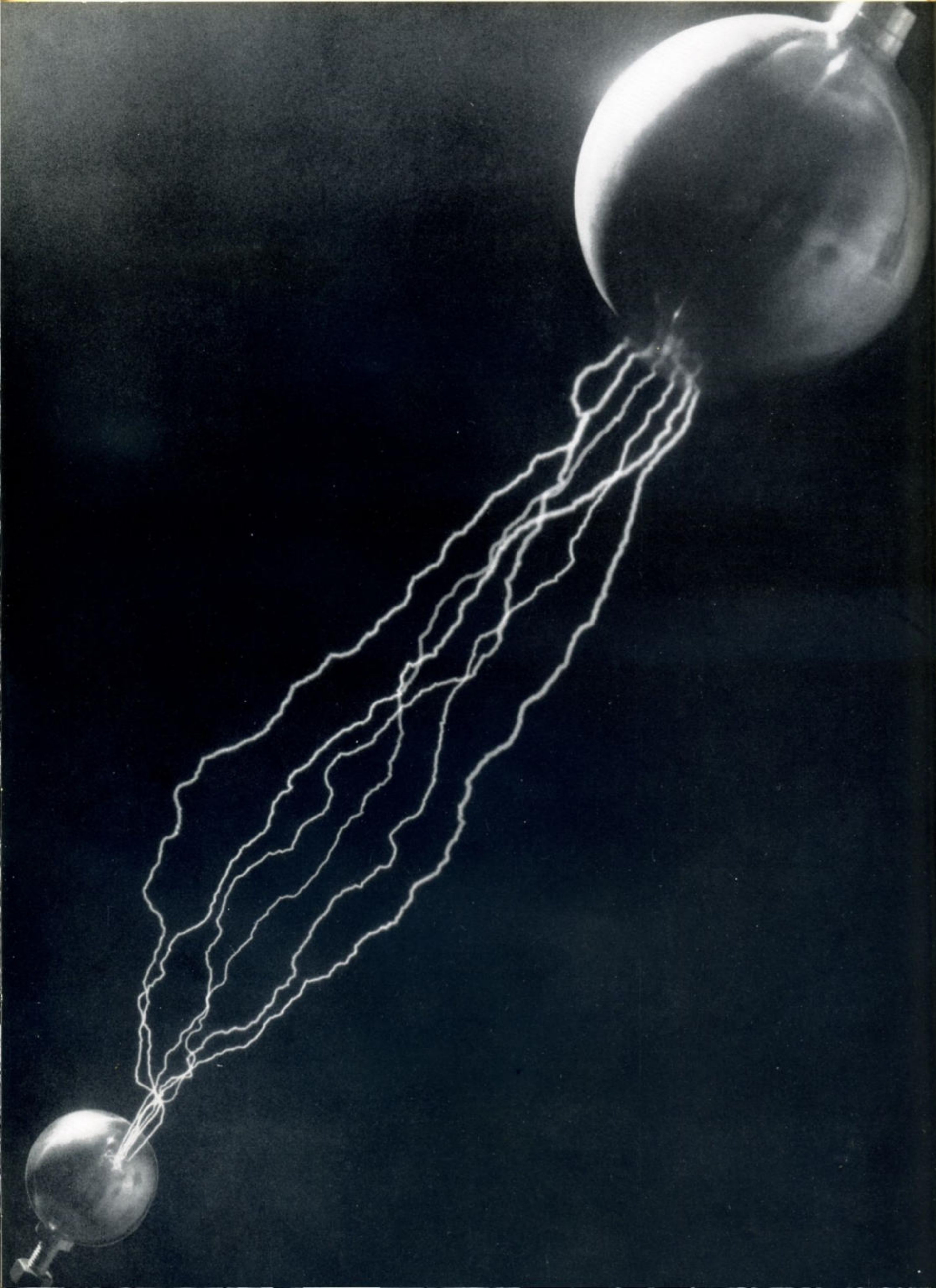


a doctrine...

ELECTROSTATICS
vs
ELECTROMAGNETICS

The lack of industrial applications for electrostatic generators is certainly one of the paradoxes of modern electrical engineering. Electromagnetic generators, which are particularly suitable for supplying heavy currents at moderate voltages, have enjoyed the widest possible use in the engineering world, but electrostatic generators have never been considered when the complementary problem of high voltages and moderate currents as been tackled. However, it is exactly for this purpose that they are naturally suited, as the principle of reciprocity indicates.

Noël J. FELICI
Chairman
of the Scientific and Engineering
Liaison Committee

This anomaly can be explained by the fact that the influence machine was unfortunate enough to have become available at a time when neither fundamental physical knowledge nor technology was ready to use it in a practicable machine. It was actually in 1865-70, a half century before the first experiments on ionisation in gases, that three gifted German physicists, TOEPLER, HOLTZ and MUSEAUS, displaying remarkable intuition, produced the influence machine ; ionisation phenomena are, however, the keys to the working of electrostatic generators. Let us imagine that the dynamo had been invented, not 50 years after, but 50 years before AMPERE and the electro-magnet.

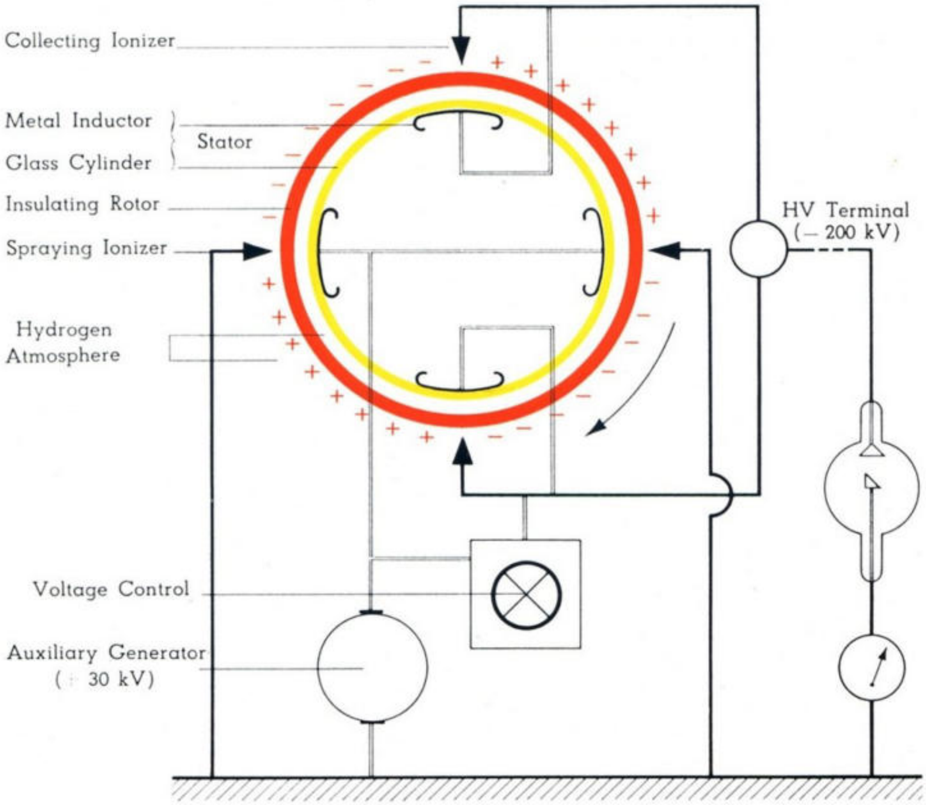
It is now clear why countless physicists and inventors could add nothing for decades to that which HOLTZ's intuitive genius had produced and why, by history repeating itself in a curious way, this surprising advance ended by bringing discredit on an apparatus which was apparently impossible to perfect. Among other similar examples, it is interesting to mention that of

The difference in manufacturing these two machines of similar power brings to light twenty years of progress in electrostatic.

HEMPEL who, 20 years after HOLTZ, found, in placing a Toepler machine in compressed air at a pressure of a few atmospheres, that the pressure and the nature of the ambient gas exerts a considerable influence on the production of electricity by influence machines; such results as these, which could not have been fully understood without an adequate knowledge of ionisation phenomena, were not followed up and, in 1905, were even discussed in slighting terms by WOMMELSDORF.

It is sometimes said that a technique or an industrial product has appeared too late on the market. One might say exactly the opposite of the influence machine. Just as the steam turbine described twenty centuries ago by HERON of ALEXANDRIA found no application because gas dynamics and metallurgy were unknown, HOLTZ's machine had to suffer a long period of eclipse before the physics and technology of insulators was sufficiently advanced to make it a practicable industrial tool.

This is precisely the task which was undertaken in Grenoble in 1942, and it is important to stress the entirely new attitude in which the problem was faced. There had been a trend, which began 10 years before in the U.S., to use the electrostatic generator as a tool for scientific research, in order to produce voltages which other techniques had so far failed to attain. On the other hand, in Grenoble, the inherent defects of the instrument had to be corrected so that an " industrial " machine could be produced, which would be capable of competing with the more conventional methods. This was to attack the most difficult aspect of the problem, but it was also the only way which could lead to a real success. While the practical worth of an industrial (or even a scientific) instrument is determined by the quality of its technology, it is also true that technology cannot exist without a large commercial market: infinitely more difficult than invention, technology must effectively be hammered out on the production line, and its true worth cannot be evaluated after one sample has been made, but only when a production run has been completed (faults which develop in service obey only the laws of probability).



THE S.A.M.E.S. FOUR POLE GENERATOR

PRINCIPLES OF OPERATION

- Moving in the field due to the excitation "inductors", electric charges are sprayed by the "ionisers" onto the rotor and they are then carried by the latter in a tangential electric field.

- During this displacement, the potential of the charges increases, while mechanical work is being converted to electrical energy.

- After moving a distance corresponding to half a "pole pitch", the charges are removed from the rotor by the output ionisers and they then flow into the external circuit.

DETAILS OF MACHINE

- Operation in extremely pure hydrogen under pressure (10 to 20 atmospheres) ensures good insulation and, at the same time, a high ionic mobility.

- The cylindrical form of the basic parts of the machine means that very high mechanical accuracy is possible.

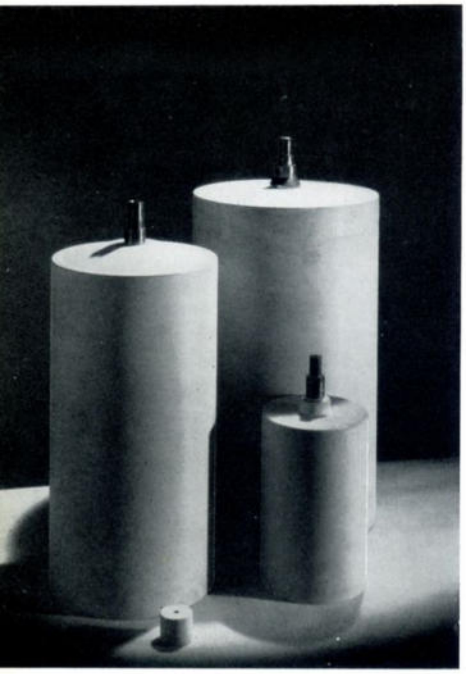
- By using a fairly thick cylindrical stator made from a material which is slightly conducting (10^{12} ohm/cm approx.), local concentrations of electric field are avoided.

PHYSICAL ASPECTS OF THE PROBLEM

Naturally, before establishing techniques, it was necessary to review the physical basis of the fonctionning of the influence machine, no form of which had shown any promise of industrial exploitation. All this led to researches on various topics, and it is of interest here to review some of the more important aspects of these.

Atmosphere of Hydrogen

It was known in 1942 that HEMPEL's compressed atmosphere was absolutely essential in order to obtain a reasonable power, but the gases which were advocated at that time were quite incompatible with the long lives of several thousands of hours which was required for any industrial application. Neither air nor the electro-negative gases (oxygen, freon, sulphur hexafluoride) which have the highest electric strength, are suitable as insulators in cases where they are permanently ionised by the normal working of the machine, because the formation of highly active products (ozone, chlorine, etc.) eventually causes the destruction of the internal parts of the machine. It is an essential condition for the industrial operation of an influence machine to use a gas which has a sufficiently high electric strength, but which can also be readily ionised and is free from harmful chemical action; it was not until 1951 that it was found that hydrogen (preferably pure) at a moderate pressure (10-20 atmospheres) paradoxically combine all these required properties.



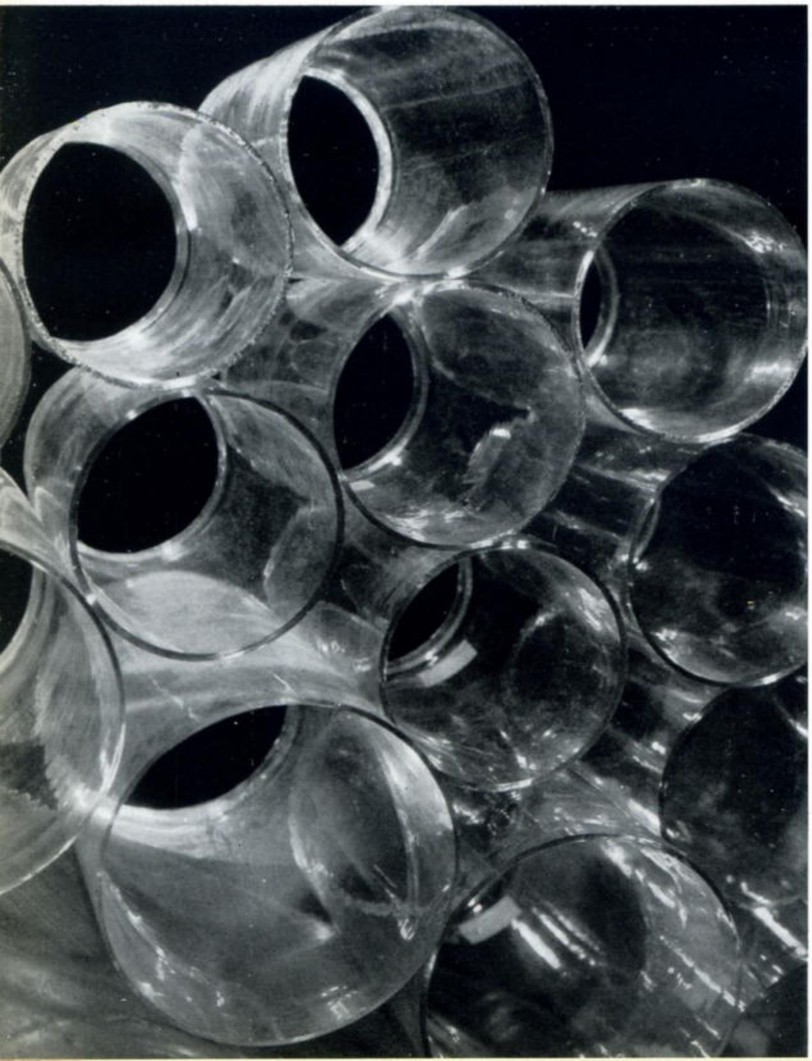
Cylindrical Configuration

The old-fashioned influence machines existed in many forms; moving electrodes, fixed, multiple, turning in opposite directions, grouped in various ways, etc.; more recently, the very old system of an endless belt had been readopted very successfully for the generation of high voltages. A careful study has shown that a cylindrical configuration, which is usual in electromagnetic machines but hitherto very rare in electrostatic machines, is the only one which combines ease of construction with accurate alignment. Some will possibly miss the old multiple flat discs of plates of the old machines, but these gave such an impossibly low efficiency, due to their uncertain geometry, that the single cylinder of a modern machine yields as much or even more power than an entire group of discs occupying the same volume.

The material used for the rotating cylinder has necessitated a considerable amount of special tests, because very few substances were able to withstand the ionisation produced by the charge and discharge " combs ". Although the problem becomes less severe in an atmosphere of pure hydrogen, it has taken several years to evolve a plastic of a relatively low price and which retains its physical dimensions and can withstand ionisation at maximum intensity for an indefinite period.

Stator of special glass

As regards the fixed assembly of " inductors " or stator, the solutions which had hitherto been employed were quite inadequate. Experiments showed that a cylinder which is slightly conducting, having metallic poles placed opposite the ionisers (or charge sprayers) gives remarkable results. Here also however, a very protracted engineering study was necessary before a slightly conducting material was found which was also a practical material. After many tests on bakelite, varnishes, etc., we finally chose a special glass, whose conducting properties could be perfectly controlled ; besides being inexpensive, it also has the advantage of retaining its physical dimensions to a remarkable degree.



There would be a good deal more to discuss if one wished to enumerate all the problems which had to be overcome before arriving at a final industrial solution. For example the traditional " combs " consisting of a number of points were replaced by a steel blade of suitable thickness, etc...

Further advances were made in the theory of electrostatic generators. A number of inherent characteristics were discovered which had a favorable effect, and the systematic application of these has contributed considerably to the very satisfactory performance of the final designs.

SOME FIGURES

What are the working possibilities of the machines which have been evolved after a long and expensive period of development? Some idea of the final performances obtained may be gained by the consideration of some typical values of the important factors which determine the power output of the generators : the useful charge density on the cylinder, the mean value of the electrostatic field in the gap and the peripheral speed of the cylinder.

The useful charge density obtained is of the order of **60 e.s.u.** in a commercial machine, and **90 e.s.u.** has been reached in the laboratory.

The allowable peripheral speed in actual operation is **45 metres/sec** and an ultimate value of **70 metres/sec** can be attained.

We can easily calculate the current obtained per pair of poles per cm length of cylinder : with 40 metres/sec and 60 e.s.u. the current is **0.16 mA/cm,** and with the extreme values of 70 metres/sec and 90 e.s.u., one obtains **0.42 mA/cm.**

The mean tangential field in the generators now in service is about 50 e.s.u. or 15 kV/cm ; but this value has been doubled in recent tests, and it is very probable that the admissible value may soon be raised.

Power

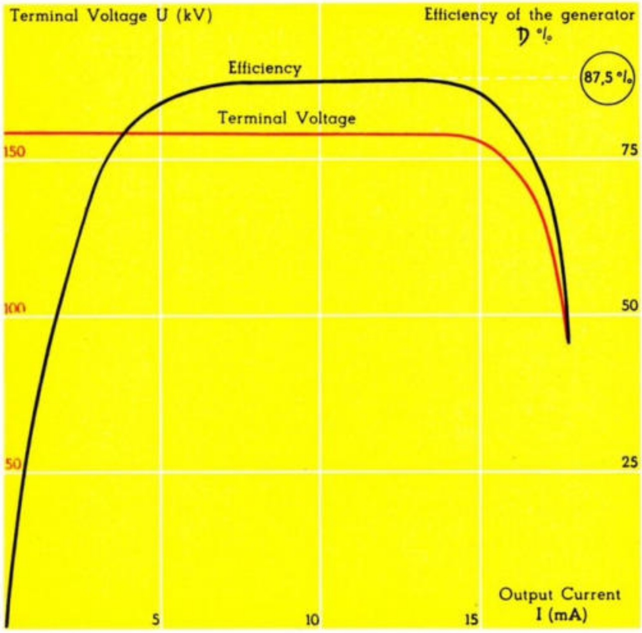
The mean tangential force in service is of the order of 3,000 dynes/cm^2, which, at 45 metres/sec., gives 1.3 watt/cm^2. The maximum value of tangential force which has been reached is 6,000 dynes/ cm^2 and this, at the maximum speed of 70 metres/ sec., gives 4.2 watts/cm^2.

The figures given above are very different from those which one usually encounters in electrostatics. They permit considerable outputs to be obtained with very compact machines. With a density of 1 watt/cm^2, one kilowatt can be obtained with a cylinder only 18 cm in diameter and 18 cm long.

Because of the restriction imposed by the tangential field, it is necessary to resort to multi-pole construction, provided that very high voltages are not required. 4, 6 and 8 pole machines are now in current production.

Efficiency

The efficiency is also unusually high. For output voltages greater than 100 kV, it is over 90 %. Below 100 kV, the figure is between 80 and 85 %. The efficiency of the driving motor is therefore the dominating factor, which is at first sight surprising.



Terminal voltage and efficiency of a 2 kV generator as a function of load current.

Even at high peripheral speeds, the gas friction represents a negligible loss, which is again one of the advantages of hydrogen (in other gases at the same pressure, the heating due to friction at 40 metres/sec would be prohibitively high).

Voltage and current output

Output currents of 15 mA can readily be obtained at the present time and it is possible to envisage outputs of 30 to 40 mA without undue difficulty.

On the other hand, the maximum obtainable voltage with a single generator lies between 600 kV and 1,000 kV, which is sufficient for most applications. For atomic physics however, where greater voltages are required, it would be preferable to use several standard units connected in series, rather than attempt to construct a very large machine with its attendant difficulties. This may be rather an unexpected attitude, but it is in conformity with the S.A.M.E.S. policy of using components and materials which have been well tried and proved, rather than construct a machine whose performance would be difficult to predict.

Series operation of electrostatic generators, which has been the subject of a long study, is just as satisfactory as the series connection of batteries and accumulators. One can connect a number of machines together, being governed only by the overall insulation of the whole installation, without the performance of individual machines being affected. This is very different from the well-known arrangement of rectifiers in cascade connected by condensers (Cockroft and Walton). A group of generators connected in series is controlled by suitable adjustment of only one of the group at one end of the chain, the voltage and current outputs of the others are automatically controlled by the single machine.

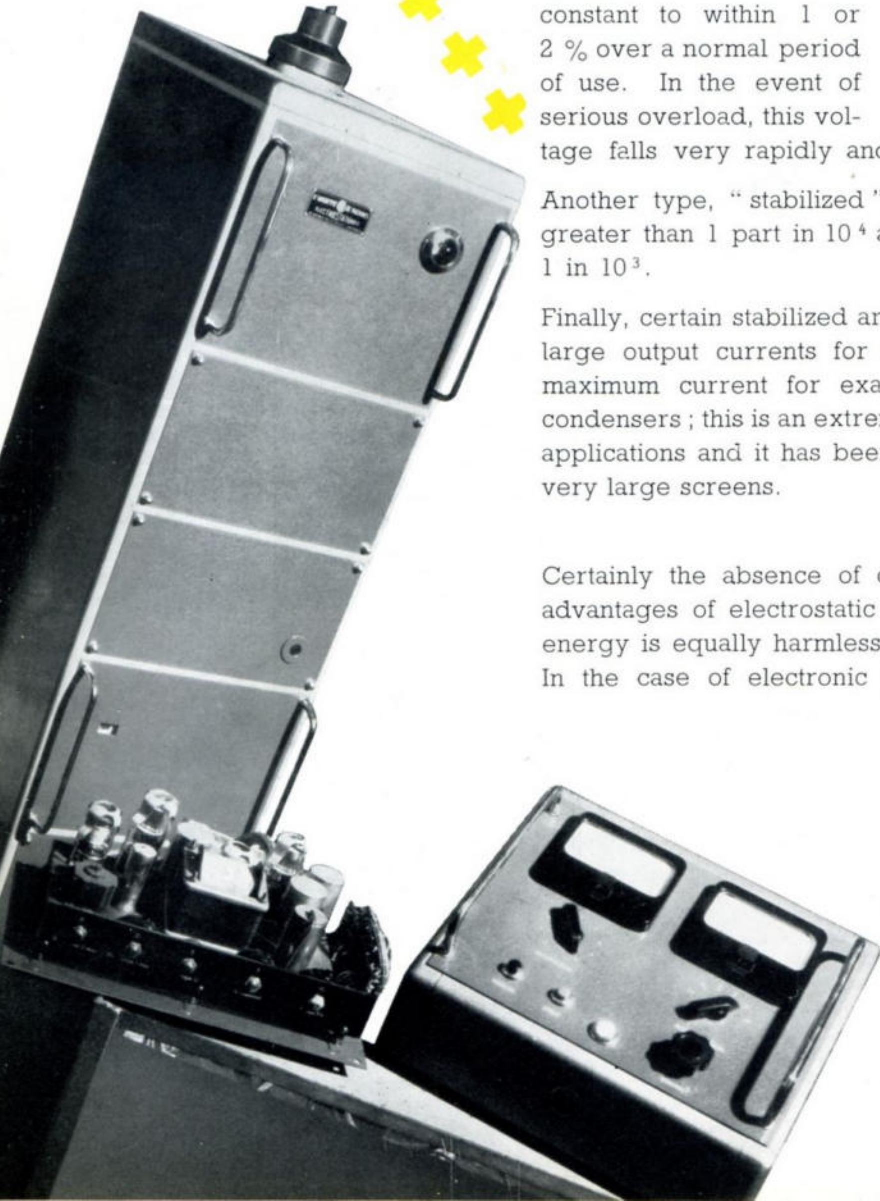
VOLTAGE CONTROL
and
SAFETY OF OPERATION

The regulation of generators has also been very carefully studied because, even though elaborate laboratory methods had been devised for belt machines, none of these were suitable for commercial operation.

The generators now in use have an output voltage which can be varied as desired, and remains constant to within 1 or 2 % over a normal period of use. In the event of serious overload, this voltage falls very rapidly and this ensures complete protection.

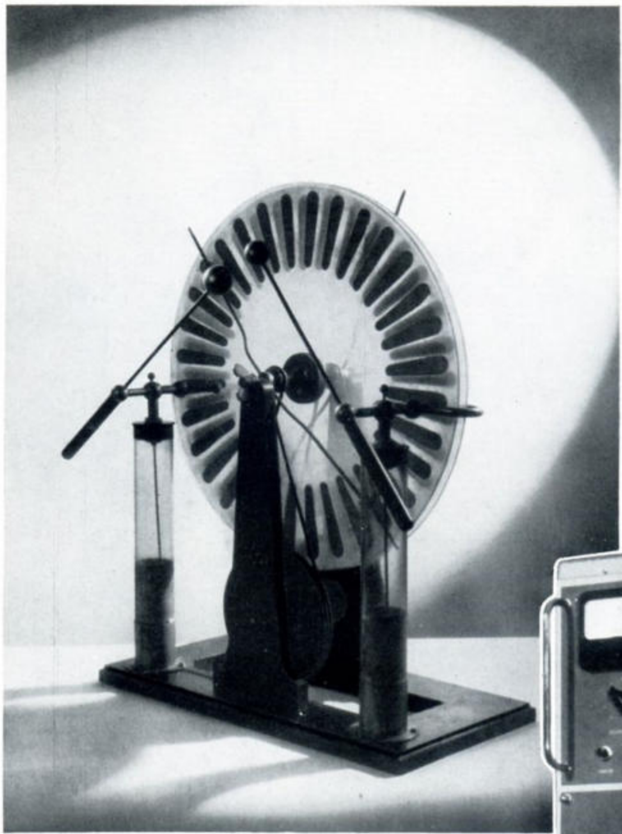
Another type, " stabilized ", has a short term voltage stability greater than 1 part in 10^4 and a long term stability greater than 1 in 10^3.

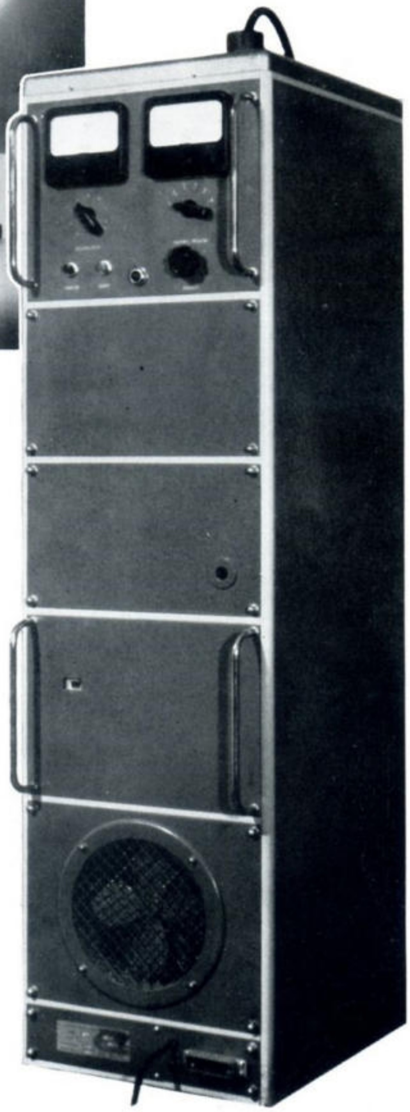
Finally, certain stabilized arrangements permit, in addition, very large output currents for short periods (5 times the normal maximum current for example) without using large storage condensers ; this is an extremely useful property for some special applications and it has been used with success in television on very large screens.



Certainly the absence of condensers is one of the important advantages of electrostatic generators : a sudden discharge of energy is equally harmless for both the operator and the load. In the case of electronic tubes, one can work close to the

from
one century





to
the other...

breakdown voltage without danger, and this is often desirable where a high efficiency is required.

The absence of alternating components and the automatic limitation of the current means that the apparatus is completely safe.

One often hears criticism of rotating converters in electrical engineering, because it seems more rational to pass from electrical power to a different form of power by a completely electromagnetic method, rather than through the medium of mechanical work. This point of view, which is not unreasonable in the case of high currents and medium voltages, is less valid in our case:

- Instead of special transformers of complicated construction, the electrostatic generator only requires an induction motor, which is simple and rugged;

- The complete electrical isolation from the mains supply has several important advantages:
  - short circuiting of high voltage is less dangerous, because the available power of the mains is not fed into the mechanical motor-generator connection,
  - fluctuations of main voltage and frequency have a negligible effect upon the output voltage,
  - the control of the generator becomes extremely convenient to arrange,

  (these properties are very valuable when one wishes to obtain an accurately fixed voltage);

- Unlike low voltage d.c. machines, electrostatic generators have no sliding contacts or brush gear, and this eliminates one of the major sources of wear.

To sum up, it would appear that the new electrostatic generators are destined to take a place in electrical engineering which is complementary to the classical dynamo, with the added attractions of greater simplicity and flexibility.

Roger MOREL
Chief Engineer

realizations...

Starting off from the important fundamental ideas described in the previous pages, the S.A.M.E.S. has designed and constructed electrostatic generators for a wide range of applications.

It is intended in the pages which follow to deal with the practical aspects of the generators : with their construction and their use.

After a short account of the technical developments which led to the machines with insulating carriers, some details of current models are sketched. Next, it has been considered of interest to enumerate the principal advantages to the users of these machines, and some typical applications are described. In conclusion, there is a brief discussion of a particular example, which is the application of the machines to nuclear engineering.

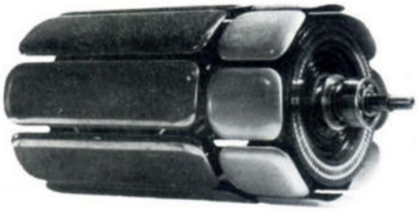
TOWARD THE INDUSTRIAL ELECTROSTATIC GENERATOR

In an electrostatic generator, high voltages are obtained by the mechanical displacement of charges which are held on a moving element called a " carrier ". As, in electrostatics, both conductors and insulators can equally well be charged, there are two types of generators :

- machines having carriers which are conductors,
- machines having carriers which are insulators.

It is quite understandable therefore that the S.A.M.E.S. was undecided as to which of the two to choose, before the advantages and disadvantages of each had been fully understood.

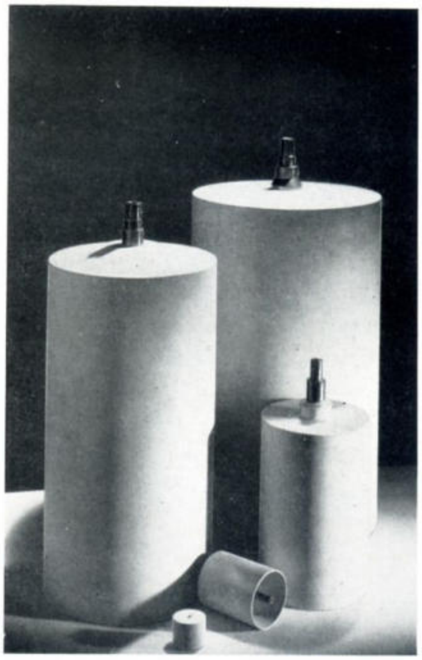
Generators with conductor carriers



At first, the technique adopted was to use conducting carriers because initially it was simpler to make calculations and predict results with this scheme. In the event, it was found that, although encouraging from the point of view of efficiency, this configuration was not entirely suitable for industrial applications, because of the method of commutation which it entailed; this would have required very frequent overhaul, which was not acceptable in industrial use.

Generators with insulator carriers

The main effort was therefore directed towards the insulating carrier. In this case, ionic commutation, obviously frictionless, soon made it possible for the long lives to be obtained which



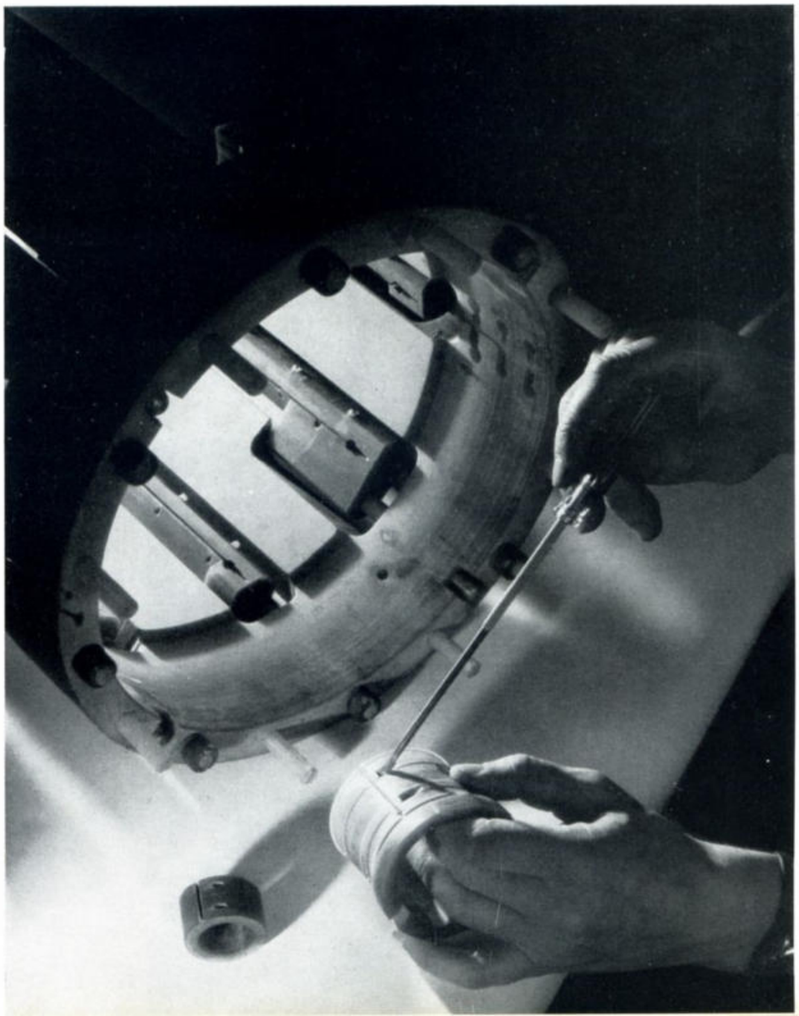
The two rotors shown here above lay stress on the large-scale investigations which have been carried out by the S.A.M.E.S. in order to work out an industrial conception of the electrostatic generator.

were quite comparable with those normally encountered in industry. The steady flow of charge and the use of the hydrogen atmosphere favoured the working of the new generators. Modern plastics have been developed, which were particularly suitable for use in this type of machine, and these materials have been used to a considerable extent. The idea of a machine with a cylindrical insulating carrier, which permitted assemblies having circular symmetry, led to a considerable simplification in production methods.

At present therefore, the insulating carrier technique is being generally adopted in all except a few cases where conducting carriers are used for small special purpose generators.

Quite apart from the generator itself, the ancillary equipment, excitation, voltage control, protection, technology and the actual introduction of the machines to the users have been studied, and many advances have been made.

It can be said that the S.A.M.E.S. electrostatic generators are capable of providing a novel and practical solution to many problems.

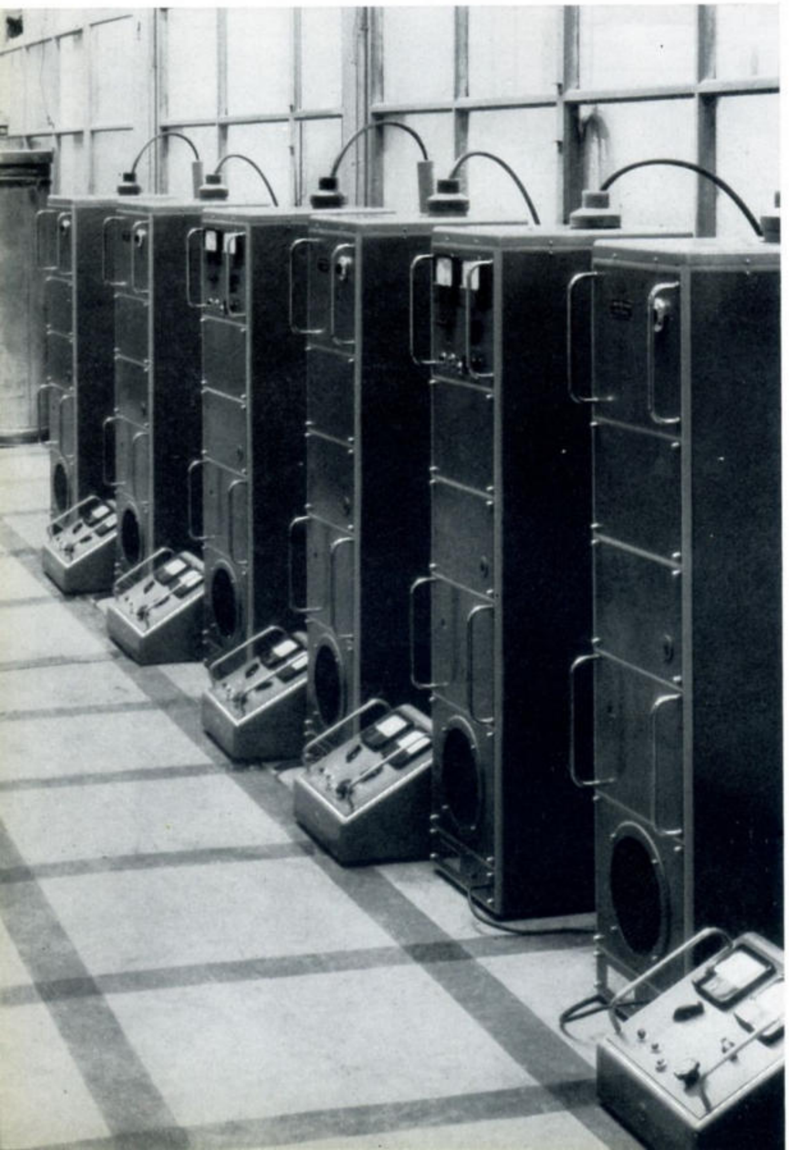


THE RANGE OF SAMES GENERATORS

Rapidly, machines of very different types were constructed in order to cover a power range from a few watts to over 2 kw. But it was necessary to produce standard generators with a maximum standardization on an industrial scale. The SAMES was called to give its production a double orientation: wherever possible advocating the use of standard generators, but constructing special generators where these were necessary.

The standard generators

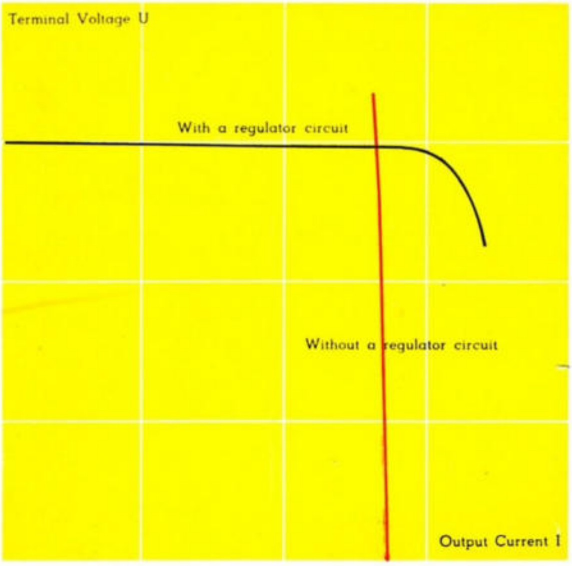
The task of drawing up a range of standard types which could be quoted in a catalogue and could cover a wide range of requirements might appear to be a difficult one when one is dealing with electrostatic generators, which are usually thought of as belonging to scientific laboratories rather than to the industry.



Although at first, many difficulties were encountered when trying to determine the needs of prospective users (needs which were sometimes only vaguely or inaccurately known), eventually a list emerged which covered most of the requirements with a limited number of types.

The work of standardization continues, but already a certain number of standard SAMES generators have been selected and are proving their usefulness in painting, electrostatic detearing, electrical testing, laboratory use etc...

VOLTAGE REGULATION OF GENERATORS



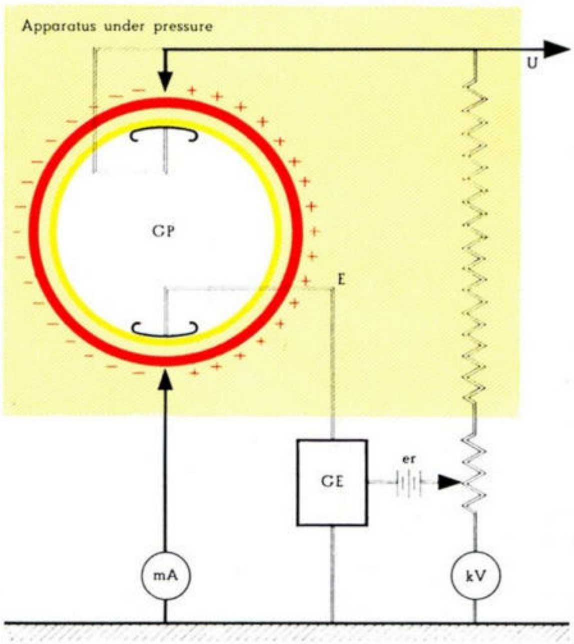
load characteristics of a machine with and without a voltage regulator circuit

THE REQUIREMENTS

With constant excitation, an electrostatic generator supplies a constant current and so its characteristics are not suitable for most practical applications, which require a constant voltage sensibly independent of the output current.

The purpose of the regulation system, essential for all electrostatic generators, is to relate the excitation voltage directly to the output voltage. The excitation must be such that the current generated (which is proportional to the density of ions sprayed on the rotor) is always equal to the current required by the external circuit. The terminal voltage will then remain constant.

The S.A.M.E.S. generators are provided with electronic regulators, specially suited to industrial requirements. The regulators also permit adjustment of the high voltage to any desired value, by control of the low voltage elements of the machine.



PRINCIPLES OF OPERATION

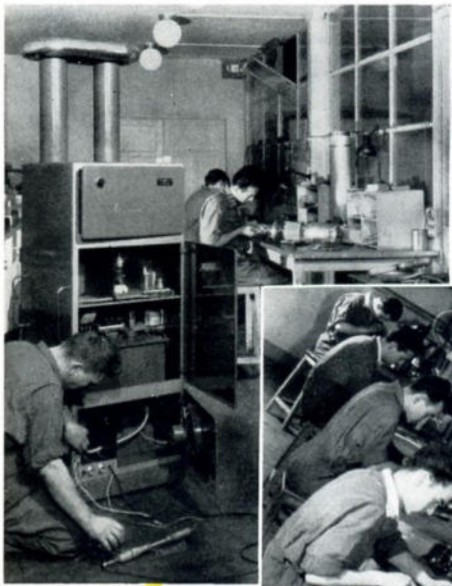
A fixed fraction of the high voltage (U) is compared with a reference voltage (er) (about a hundred volts, obtained either from a battery or a gas-filled stabilizer tube, depending on the accuracy required). The difference potential is then applied to the auxiliary excitation generator (GE), the output voltage (E) of which is a function of the difference voltage. This feedback from output voltage to excitation voltage results in the desired load current characteristic for the main generator (GP).

The auxiliary generator (GE), the output voltage of which is controlled by an electronic valve circuit, can either excite the generator (GP) directly or through another small auxiliary electrostatic generator, which serves both as a voltage multiplier and as an amplifier of voltage charges.

In general, all these units have been standardized and may be used with generators (GP) of different powers.

STABILIZATION OF HIGH VOLTAGE

Stabilization may be defined as precision regulation. It is accomplished by an extension of the normal regulation system with a high gain introduced in the feedback chain (using a d.c. amplifier) and this enables a high degree of voltage stabilization to be achieved. Because of the high gain, special precautions must be taken (e.g. small time-constants, careful choice of coupling condensers) to ensure that the system is stable and does not oscillate.



Finally, the generators are made from components which are themselves standardized as far as possible. For example, depending on the number of poles (2, 4 or 6) a basic generator gives the same power but with different combinations of voltage and current. The high-voltage bushings, excitation units, voltage control and switch-gear are the same for machines which vary widely in output and applications.

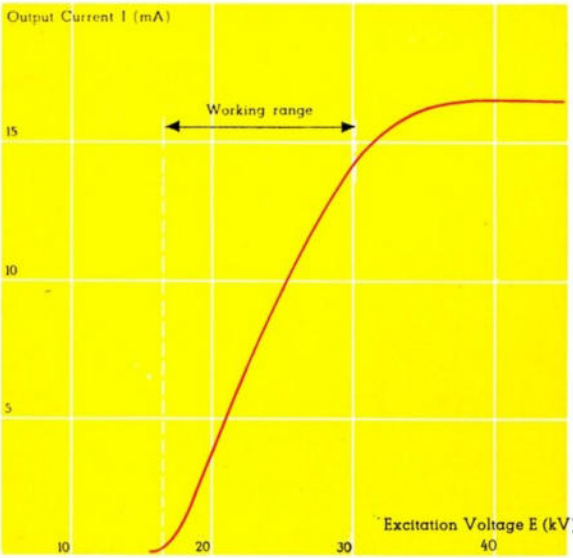
It is useful to record in the following table the essential characteristics of some of the standard generators of different types.

Type	**Useful output power (watts)**	**Max output voltage (kV)** *	
110	50-60	110 60 45	The same standard generators exist in "stabilized" form. The voltage can then be adjusted, the stability being 1 in 10^3 or up to 1 in 10^4 (short term). Typical applications: non destructive testing of insulation.
140	350-400	300 200 160 110 75	
240	2 000	200 150	

* Different models, depending on number of poles.

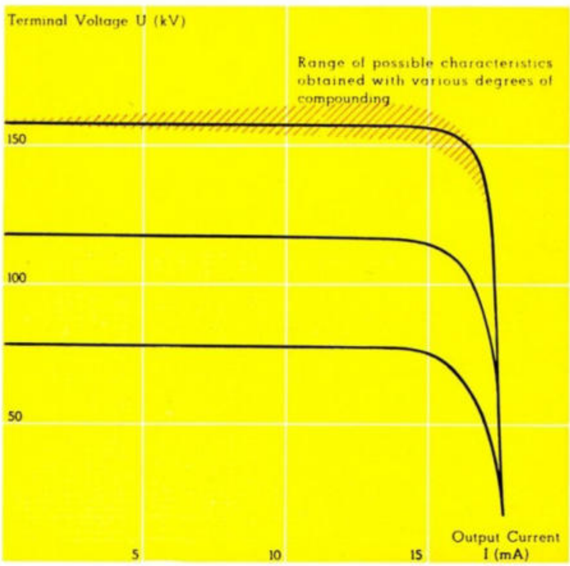
All the machines have a certain number of features in common, in particular :

- operation possible from 50/60 c/s, single or 3 phase,
- terminal voltage sensibly independent of output current,
- smooth control of voltage over a wide range,
- control panel either built-in or remoter,
- electronic voltage control,
- continuous metering of high voltage and output current.



VARIATION OF OUTPUT CURRENT AS A FUNCTION OF THE EXCITATION VOLTAGE

Beyond the "starting threshold", the current increases very rapidly and finally reaches a saturation value. The purpose of the regulation circuit is to provide a continual adjustment of the excitation voltage to fulfil the immediate needs of the external circuit.



TYPICAL LOAD CHARACTERISTIC OF A GENERATOR WITH A REGULATION CONTROL CIRCUIT

The voltage remains sensibly constant and then "breaks" suddenly when the current exceeds the maximum (predetermined) value, thereby avoiding all risk of an overload).

Within the normal working range, it is possible to reduce the voltage drop with increase of load current (voltage regulation). It is even possible to make the voltage drop negative, resulting from a "compounding" action on the generator.

The generators for special purposes

Despite the standardization of machines and components, it is clear that there is an extremely important market for equipment for certain special applications, which can be manufactured singly or in large numbers :

- apparatus for particular applications, which are well defined e.g. : ignition systems for internal combustion engines, voltage supplies for image converter tubes or television tubes, etc.
- special apparatus which, because requirements are widely scattered or relatively limited, need only be made singly or in very limited numbers, such is the case with generators for nuclear applications.

In these fields, the laboratories, design offices and technical services of the SAMES are placed at the service of customers.

THE INHERENT ADVANTAGES OF ELECTROSTATIC GENERATORS

Quite apart from economical considerations which place the electrostatic generator in a privileged position because of its low " cost per kilovolt ", there are obvious technical advantages which make it superior to the classical high voltage unit with rectifiers ; these advantages include among others :

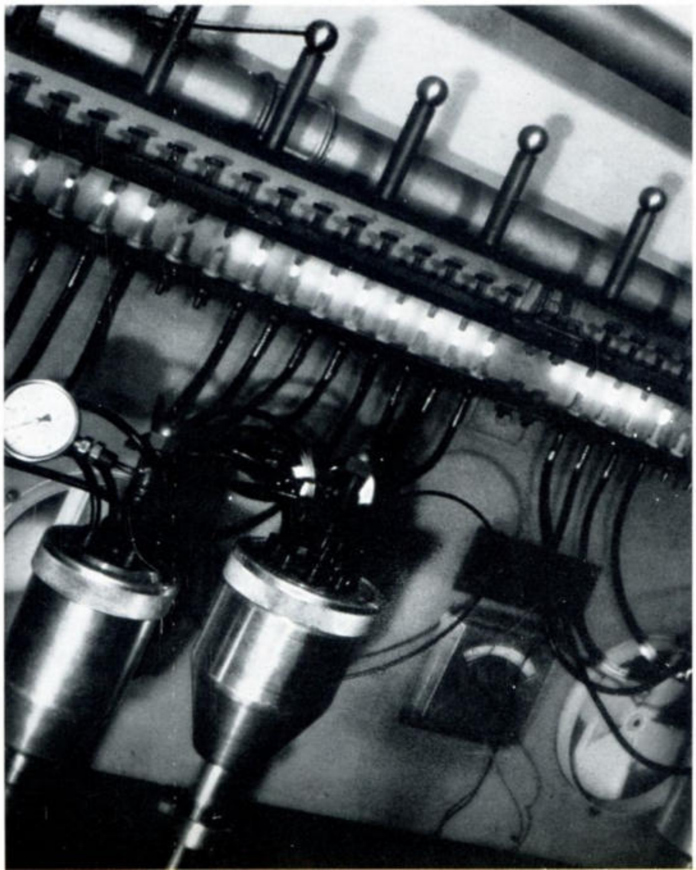
- the absence of large smoothing condensers and the steady flow of charge which avoids all storage of energy which might be dangerous or inconvenient ;
- the complete elimination of large current overloads even in the case of complete short-circuit ;
- complete safety for operators and for the equipment supplied by the generator, as result of the above factors ;
- complete constancy of current, with no alternating components which are found with rectifier power supplies ;
- easy stabilization of the full load voltage regulation to a very low value possible if so desired ;
- extreme lightness and compactness of the generators in proportion to their power and, in particular, their voltage output ;
- complete independance of any electrical power source possible, in applicating small models provided with manual operation.

SCOPE AND APPLICATIONS OF ELECTROSTATIC GENERATORS

The uses of the machines are bound up with those for high voltage d.c. ; moreover, it is not unreasonable to suppose that the development of the latter field may materially be assisted precisely because of the existence of an **industrial electrostatic generator.**

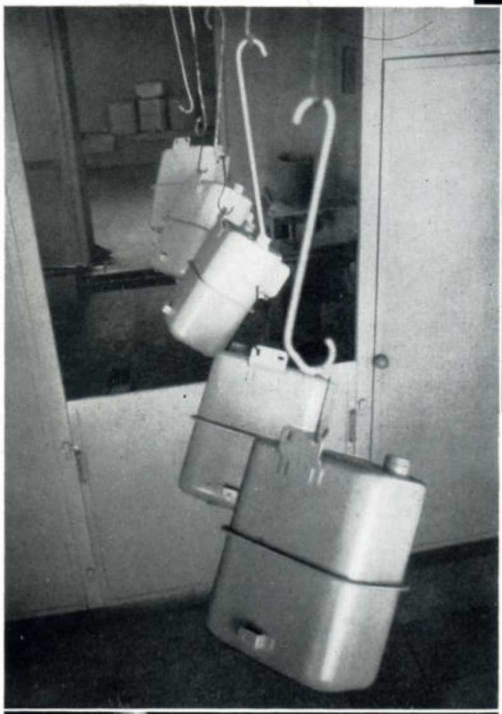
The range of apparatus which the S.A.M.E.S. produces, or will produce in the years to come, must satisfy requirements which extend from a few kilovolts to several megavolts, with powers ranging from watts to kilowatts. The machines have to possess great flexibility as regards stabilization and control.

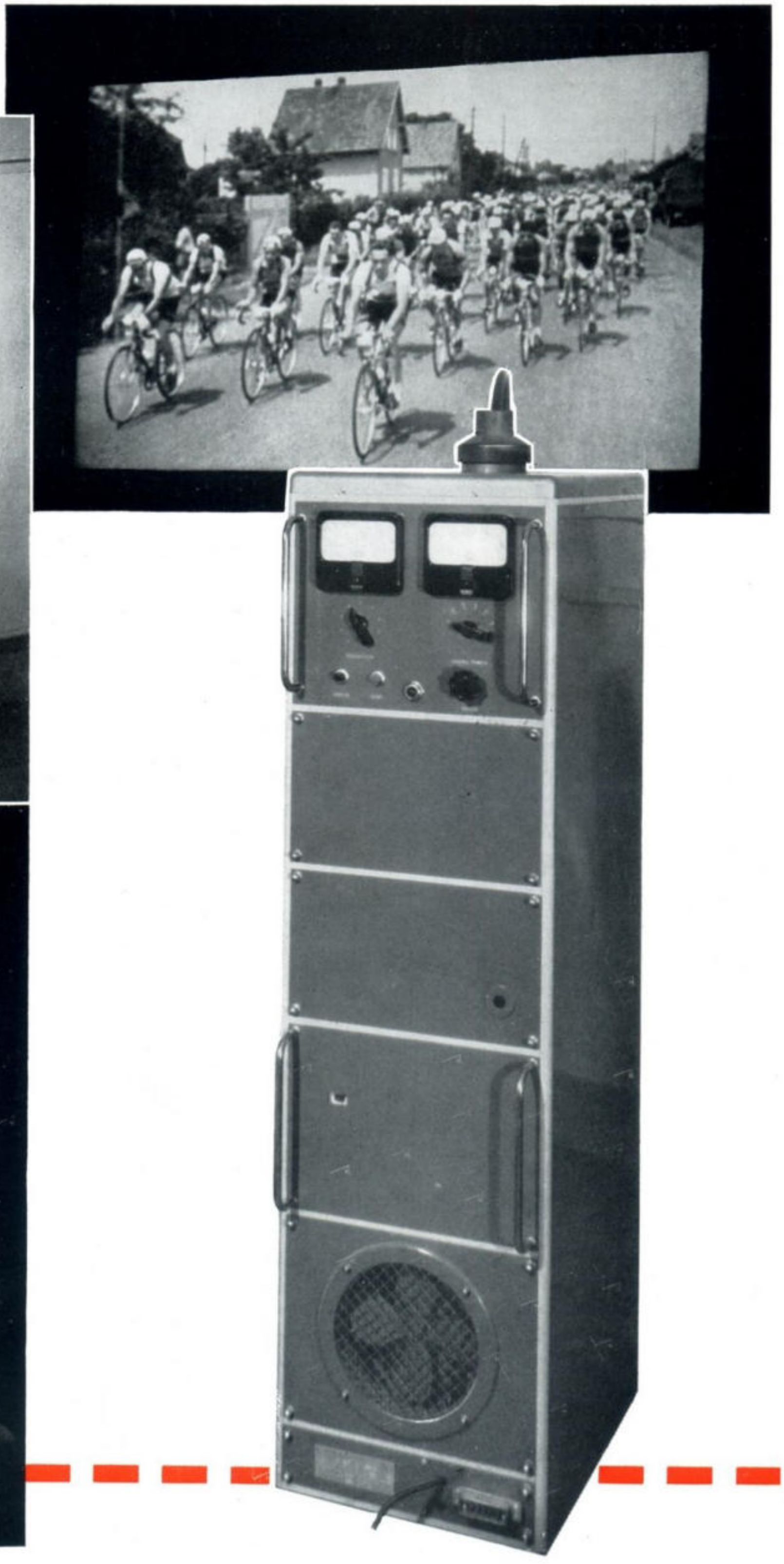
If, for certain applications, the electrostatic generator may sometimes be in competition with the rectifier power supply, it does have a field of application peculiar to itself : that of high voltages and moderate currents. It is always difficult to establish frontiers because the performance of electrostatic generators will continually be improved and factors which have no connection with voltage or current might favour one system or the other.



To fix ideas, let us say that the possible field of application of the S.A.M.E.S. electrostatic generators now extends from 40 kV to several megavolts with currents from 30 μA to 30 or 40 mA. These frontiers, which are only approximate, may be extended in the future and there is already a trend in the direction of low voltages where demands are made for very high stability, low weight and safety of operation.

The following table gives some typical applications which have already been met.





ELECTROSTATIC PRECIPITATION

- Electrostatic painting
- Electrostatic detearing
- Crop dusting
- Manufacture of abrasive paper
- Flocking of cloth
- Mineral separation
- Sorting of particles...

ELECTRONICS *

- Television
- Radar
- Image converters
- Electronic tubes
- Sterilization...

X RAYS **

- Radio-therapy
- X Ray-crystallography
- X Ray-metallography...

ELECTRICAL TESTING IN LABORATORIES AND WORKSHOPS

- Cable testing
- Measurement of electric strength of insulation
- Non destructive testing for maintenance purposes ***
- Impulse plants...

NUCLEAR APPLICATIONS

- Particle accelerators
- Neutron generators...

MISCELLANEOUS

- Electrostatic ignition of internal combustion engines
- Direct medical applications by physiological effects
- Education...

* With the impressive developments in electronics, there is a corresponding trend towards requiring higher voltage.

** The use of A.C. instead of D.C. for economic reasons may no longer be necessary with the possibility of using electrostatic generators.

*** These methods require extremely high voltage stability.

APPLICATIONS TO NUCLEAR PHYSICS

The SAMES electrostatic generators have an important part to play in the domain of nuclear physics which has now left the confines of the laboratory to enter the realms of education, industry and medecine.

Many devices have been produced in the last few years, such as cyclotrons, synchrotrons, which can impart high energies to particles. However, the first of the big guns in the atomic armoury, the high voltage accelerator tube, is still an useful research tool for various applications where the energies required are less than a few MeV. The simplicity compared with alternative machines, its flexibility, ease of focusing of the beam, the high stability of voltage and energy which can be obtained, all combine to make the high voltage accelerator tube supplied by an electrostatic generator a very convenient precision instrument.

It can also be used as a practicable industrial neutron source suitable in education and training for nuclear work in industry or in research laboratories. It is a tool which can be used for the production of radio-isotopes, which are being used in ever increasing amounts as tracers.

Soon after 1930, the growing needs of nuclear physics led to use the principles of electrostatics in order to obtain the very high voltages which were required. The belt generator has since found a large number of applications and is an extremely important instrument in this field. Nevertheless, this type of generator, which was intended primarily for laboratory use, has proved less suitable for industrial needs, which are so demanding as regards reliability and ease of maintenance.

During the same period, alternative methods of supplying ion tubes were used consisting of stacks of rectifiers in voltage multiplier circuits (Greinacher, etc...). These installations were able to supply larger currents than those obtained from belt generators, but they are bulky, difficult to stabilize and the large internal capacity is often an inconvenience.

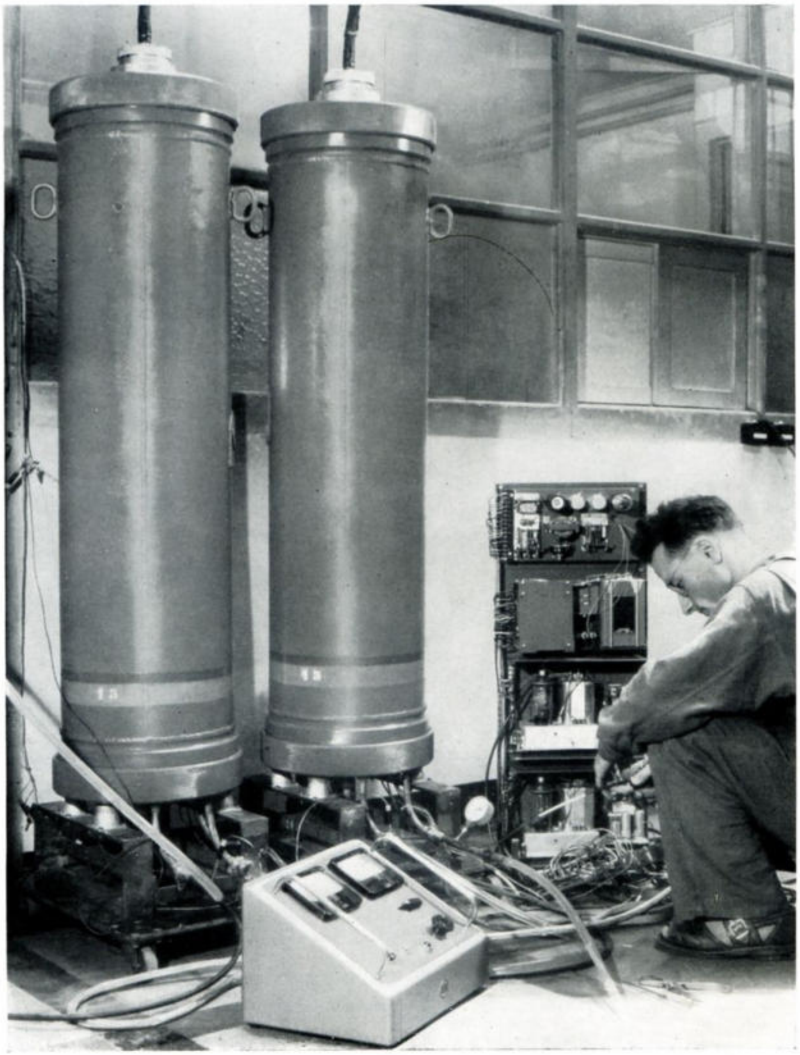
A new method of supplying accelerator tubes is thus desirable. It should combine the advantages of the two previous methods:

- convenience and possibility of high stability obtained with the belt machine,

- the high power and long life of the rectifier stack equipment.

The S.A.M.E.S. electrostatic generator presents both these advantages and this has led the S.A.M.E.S., after careful consideration of the existing method, to create an " Accelerator Department ".

This department was first entrusted with the task of designing and constructing electrostatic generators for ion and electron accelerator tubes. However, it has since become necessary to extend the scope of the department, so that now the S.A.M.E.S.



will be in a position to supply either the high voltage generator alone or a complete installation, with the accelerator and its associated generator.

The S.A.M.E.S. is the first French Company to put this equipment on the market.

The programme

After market research and a rationalization of the widely differing needs of customers, the S.A.M.E.S. has concentrated an equipment with a relatively high output current (some milliamps), always retaining the advantages of electrostatic generators.
The following generators and accelerator tubes figure in our programme * :

300 kV	—	1 or 2 mA
600 kV	—	5 mA
2,000 kV	—	5 mA

These are not limiting figures, but should be considered effectively as initial standard types from which different models could be developed.

Simplified apparatus with a lower power and simple controls could be foreseen, and also very high power equipment (1 or 2 MV, 20-30 mA) which could be used for large scale production of radio isotopes.

These equipments are provided with electronic stabilization which ensures that the voltage applied to the tube is within the desired limits (between 5 parts in 10^3 and a few parts in 10^4). Finally, the voltage regulation is extremely good and the nominal voltages indicated above are those obtained in full load.

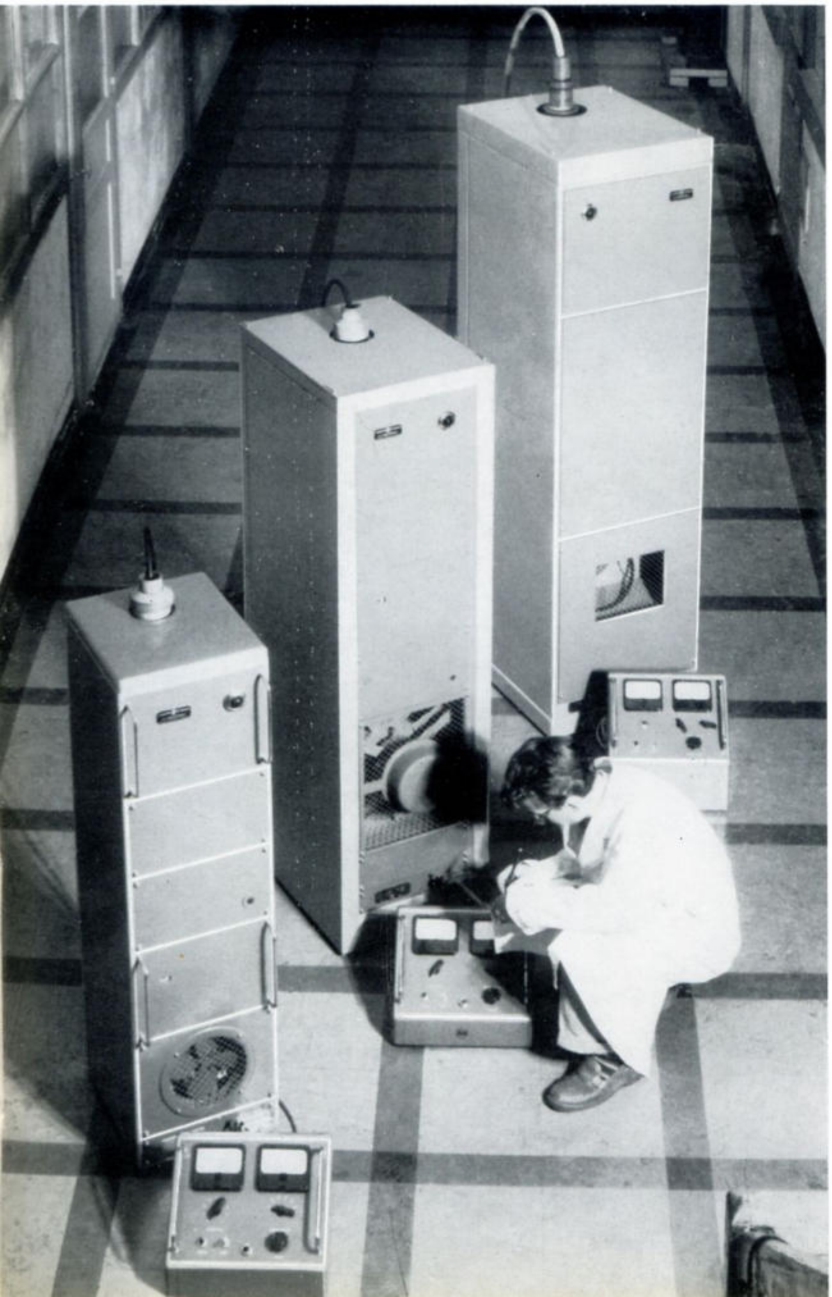
Supplying ion or electron accelerator tubes

Quite apart from considerations of price, bulk and weight (all in its favour), the electrostatic generator with its negligible self-capacity is extremely suitable for work with ion or electron tubes. Comparative tests with both X Ray tubes and ion accelerator tubes have always agreably surprised operators who were

* 600 kV covers the following nuclear reactions : Deuterium-Tritium, Deuterium-Deuterium, Deuterium-Lithium. 2,000 kV is suitable for the reaction Deuterium-Beryllium.

accustomed to rectifier power supplies: operation is more regular and smooth, voltage can be applied more rapidly and much higher voltages can be obtained. These advantages are not unexpected because:

- the steady flow of charge, automatically controlled by the electronic stabilization system, means that there is no dangerous accumulation of energy in a condenser;
- the absence of condensers and the complete impossibility of violent discharges means that the multiple perturbations (which always appear in a tube which is working at the highest voltages) do not develop into dangerous discharges;
- the internal discharges which do take place are not noticeable; instead of having a destructive effect, they have a beneficial "formative" one on the tube;
- thus, a large safety factor is no longer necessary and one is not any more forced to avoid working the tube at its maximum voltage;
- despite the absence of condensers, a higher voltage stability can be obtained than is possible with rectifiers.



The machine located on the right side will supply electrical current to a generator of neutrons.

LABORATOIRE CENTRAL DES INDUSTRIES ELECTRIQUES

FONDÉ PAR DÉCRET DU 24 FÉVRIER 1882, MODIFIÉ LE 7 JUIN 1942
ÉTABLISSEMENT NON ASSUJETTI A L'INSCRIPTION AU REGISTRE DU COMMERCE

Avenue GÉNÉRAL-LECLERC à FONTENAY-aux-ROSES (Seine) MIC : 28-80

CERTIFICAT N° 92 262-B FEUILLET 1

DÉLIVRÉ : A Société Anonyme de Machines Electrostatiques
" S.A.M.E.S. "
29, Avenue Félix Viallet - GRENOBLE (Isère)

OBJET :ESSAI D'ENDURANCE D'UN GENERATEUR ELECTROSTATIQUE S.A.M.E.S. type CD 150-2.

Caractéristiques nominales du générateur et but de l'essai.-

Tension maximum à vide: 160 kV - Courant maximum: 2 mA.

Le générateur comportait un pupitre de commande à distance sur lequel un milliampèremètre et un kilovoltmètre indiquaient de façon permanente le débit et la tension.

L'essai consistait en une épreuve d'endurance de la machine débitant en marche continue une intensité de 2 mA sous une tension de 150 kVA, la durée prévue de l'essai étant 2.000 heures.

Conditions de l'essai - charge.-

Le générateur débitait sur une charge constituée par un ioniseur à effluves réglé pour absorber une puissance de 300 W sous 150 kV.

Le débit (2 mA) et la tension (150 kV) fournis par le générateur avaient fait l'objet d'une vérification directe à l'aide d'instruments de mesure branchés sur la charge.

Le générateur fonctionnait en permanence de jour et de nuit sauf interruptions accidentelles non imputables à la machine telles que: coupure de secteur ou accroissement excessif du courant absorbé par la charge provoquant le fonctionnement du dispositif de protection incorporé dans le pupitre de commande.

Résultat.-

Après 2.000 heuresde fonctionnement la génératrice était toujours capable de débiter son courant nominal (2 mA) sous sa tension nominale (150 kV).

Fontenay-aux-Roses, le 5 Juillet 1955.

Le Chef du Service,

RKiesp

LABORATOIRE CENTRAL DES INDUSTRIES ELECTRIQUES
FONDE PAR DECRET DU 24 FEVRIER 1882
5 JUIL 1955
N° 92.262-B

Le Directeur du Laboratoire Central des Industries Electriques,

F Esclangon

F. ESCLANGON

Pour éviter tout usage abusif qui pourrait en être fait, les certificats du Laboratoire ne pourront être utilisés dans un but de publicité commerciale qu'avec l'accord écrit du Laboratoire.

Des duplicata du certificat original peuvent être délivrés sur demande.

Facsimile of the record of a reliability trial of a 160 kV — 2 mA generator carried out in the LABORATOIRE CENTRAL DES INDUSTRIES ELECTRIQUES (L. C. I. E) in Paris

Bernard BONJEAN
Chairman of the Board

The first promotors of the S.A.M.E.S. had to be rather bold to invest their money when starting up a company based on a technique which was so new that it seemed to belong to the laboratory field instead of industry. The main step to be done was to trust French inventors. Should we not be persevering enough and should we not be able to incur risks ?

For many years, the share-holders and directors of the S.A.M.E.S. have persevered and taken risks.

Should their efforts now bring success, they are very happy to have been the initiators of a fertile collaboration between inventors, industrial and financial businessmen and to show everybody that in France something new can be created in new fields. We are proud and happy about this success because we do not doubt that our technique can fulfil successfully all requirements in a field in which we are offering daring and new designs.

Doing this, we feel we have served the engineering world.

B. Bonjean

Page-setting
done by
NEYRPIC Information Department

Photographs taken by
Georges ROLLET of Photopress

The printing work has been
done by the
IMPRIMERIE GENERALE

Grenoble
July 1955

Printed in France — D. L. 294 — 3e trimestre 1955

SOCIÉTÉ ANONYME DE MACHINES ÉLECTROSTATIQUES