RADIATION FURNACES OF PAST CENTURIES

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The carbon-arc image furnace, whose use as a laboratory instrument is described in this issue (page 161), has had numerous predecessors. The use of lenses or concave mirrors to focus the sun's rays for lighting kitchen fires or altar flames was known to antiquity [1]). In the 16th and 17th centuries radiation furnaces had found a place in the equipment of metallurgists and alchemists. In 1540 Biringuccio [2]) mentioned a mirror roughly a foot in diameter with which a gold ducat could be melted. Glauber [3]) in c. 1650 indicated the size of mirror required for specific purposes: 1 span (= 9 inches) for igniting wood, 2 spans for melting tin, lead and bismuth, 4 or 5 spans for melting gold and silver and also for forging iron. Robert Hooke even planned to base a kind of temperature scale on this scheme.

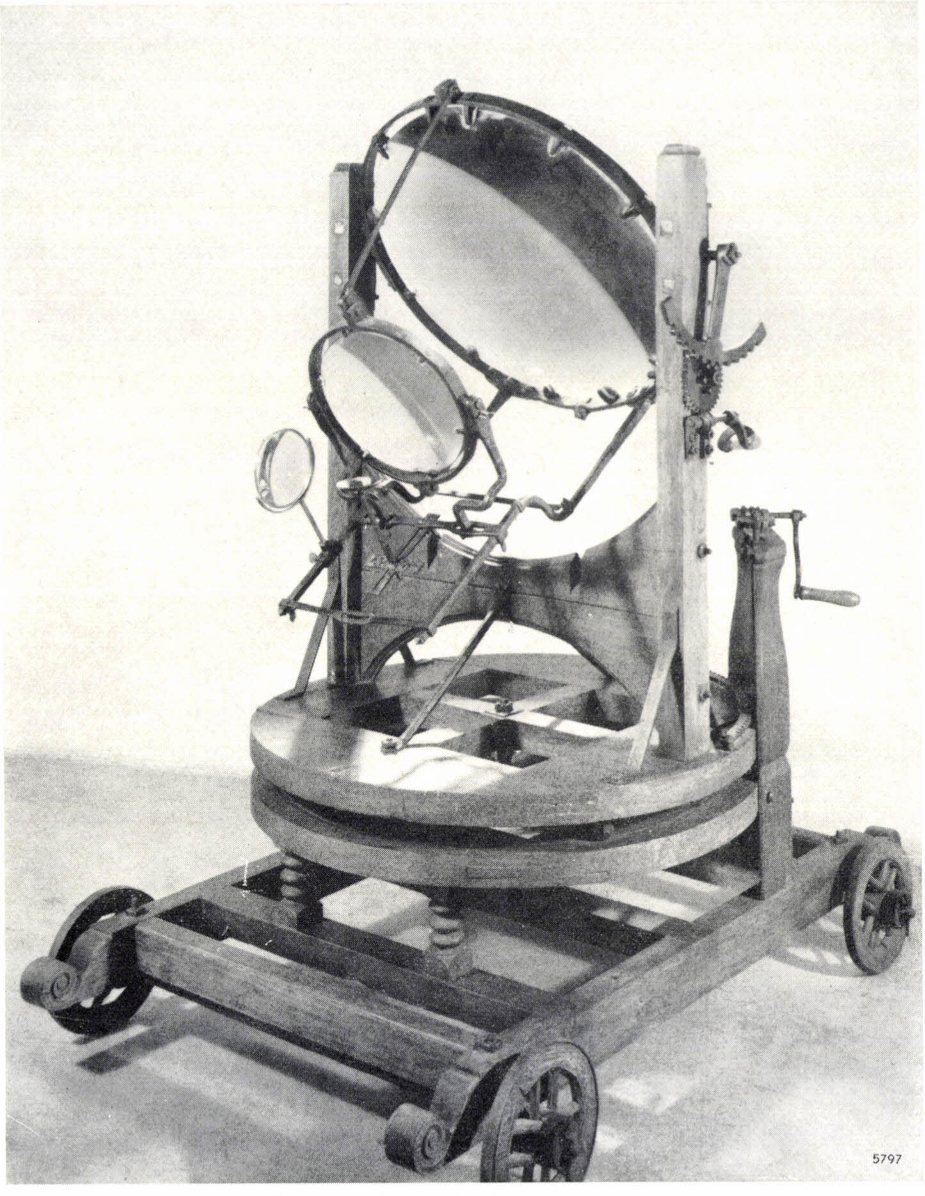

Fig. 1. Burning-glass instrument built by E. W. von Tschirnhaus towards the end of the 17th century. (Reproduced by courtesy of the Deutsches Museum, Munich.)

[1]) Various sources are mentioned by R. J. Forbes, Studies in ancient technology, VI, Brill, Leyden 1958.
For some of the particulars mentioned here we are indebted to Professor Forbes personally.

[2]) V. Biringuccio, De la Pirotechnia libri X, Roffinello, Venice 1540.

[3]) J. R. Glauber, Opera mineralis, Amsterdam 1651.

At the end of the 17th century, the century in which the first lens systems for telescopes had been built and considerable progress made in the grinding of lenses, mirrors were for a time outstripped by lenses. This was largely due to the work of the German mathematician and physicist E. W. von Tschirnhaus (1651-1708) [4]). He had occupied himself with the improvement of "burning mirrors" since 1679, and in 1687 he is reported to have made a gigantic mirror 130 cm in diameter, beaten from sheet copper. He then apparently realized that he could do better with lenses than with the imperfectly focussing mirrors (the art of grinding parabolic mirrors had not yet been perfected), which were moreover difficult to handle. He set up a glass works, where larger pieces of glass were cast than any one had managed to do before, he developed special grinding methods, and he hit on the idea of combining a large lens with a smaller one (the "collective"), which improved focussing. In February 1694 he stated in a letter to Leibniz that he had succeeded in melting with his lenses several substances which were previously considered to be unmeltable. Among these substances was clay; this discovery enabled him to make porcelain, which had been imported from China for centuries but which no one in Europe had previously known how to imitate [5]).

Tschirnhaus' great lens systems were greeted with much enthusiasm, and were sold to physical societies in various European countries, where they were used for scientific or pseudo-scientific ends. One went to Holland, apparently (Leibniz wrote about it to Huygens in 1694); Tschirnhaus sent two to Paris — one of them with an enormous lens 94 cm in diameter and weighing 74 kg; other lenses went to London, St. Petersburg etc. Several of these lens systems are preserved. The Lomonosov Museum in Leningrad still houses the lens of the equipment Tschirnhaus had sent there, with a diameter of 57.5 cm and still in its original wooden housing. The Mathematisch-Physikalische Salon in Dresden also has several pieces of Tschirnhaus equipment [6]). But particularly well preserved is the complete Tschirnhaus "burning glass" in the Deutsches Museum, Munich, which is shown in *fig. 1*. This has an objective lens 75 cm in diameter.

A somewhat smaller instrument (objective lens about 37 cm diameter) is to be found in the Museo di Storia della Scienza in Florence [7]). Benedetto

[4]) For the details given below see especially: J. S. T. Gehler, Physikalisches Wörterbuch, Leipzig 1787, and the more recent publication: R. Wunderlich, Brenngläser als Hilfsmittel chemischen Forschens, Chymia **2**, 37-43, 1949.

[5]) E. W. von Tschirnhaus, De magnis lentibus seu vitris causticis eorumque usu et effectu, Acta eruditorum (Leipzig) 1697, pp. 414 et seq.

[6]) For details see: E. W. von Tschirnhaus und die Frühaufklärung in Mittel- und Osteuropa, Ed. E. Winter, Akademie-verlag Berlin 1960, especially the articles by O. Volk (pp. 247-265) and V. L. Cenakal (pp. 285-307).

[7]) Maria L. Bonelli, The burning glass of Benedetto Bregans of Dresden, "Florence" **11**, No. 2, p. 22, 1960.

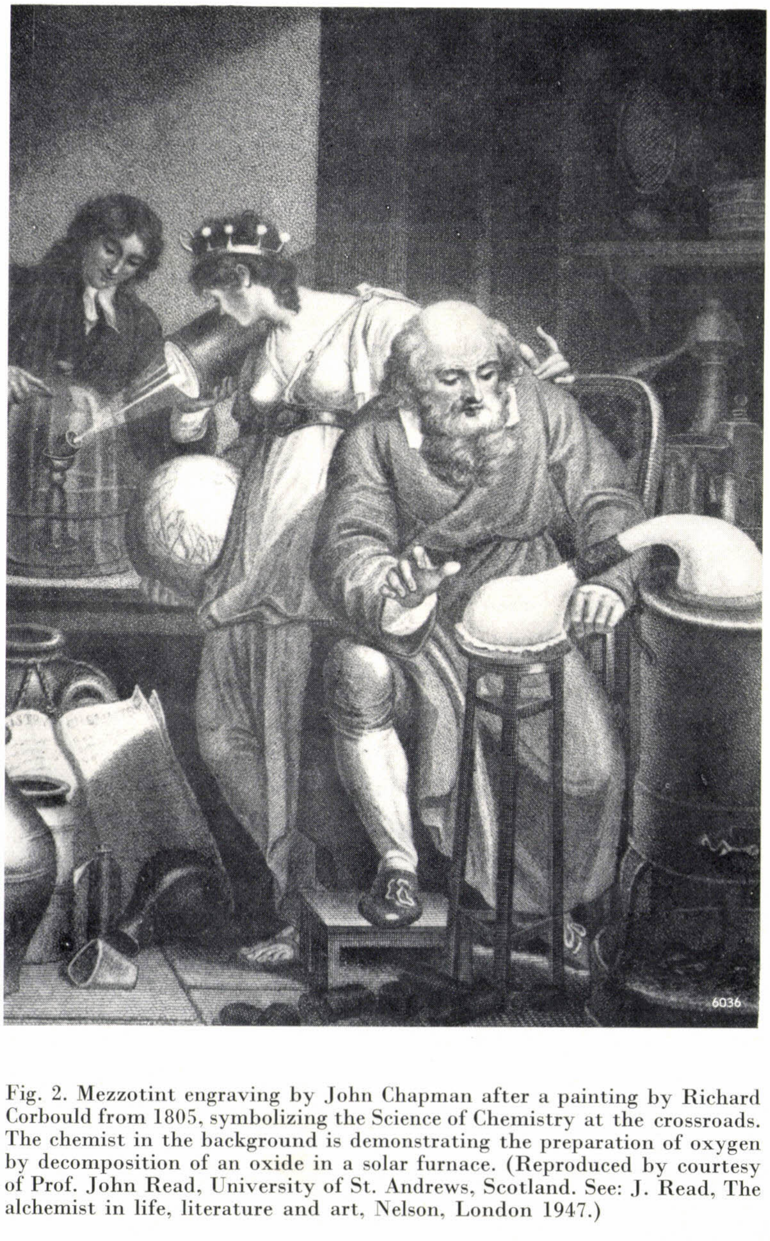

Fig. 2. Mezzotint engraving by John Chapman after a painting by Richard Corbould from 1805, symbolizing the Science of Chemistry at the crossroads. The chemist in the background is demonstrating the preparation of oxygen by decomposition of an oxide in a solar furnace. (Reproduced by courtesy of Prof. John Read, University of St. Andrews, Scotland. See: J. Read, The alchemist in life, literature and art, Nelson, London 1947.)

Bregans brought this from Dresden in 1690; it thus probably came from Tschirnhaus' workshop, too. In 1710 Bregans presented his burning glass as a gift to Grand Duke Cosimo III of Tuscany. It is interesting to note that the Florence instrument was put to use a century later for a scientific investigation undertaken by Humphrey Davy and his assistant at that time, Michael Faraday. Davy and Faraday visited Florence in 1814, and Davy profited from the opportunity to use the burning glass for studying the the experiment in his diary. His report begins: "Today we made the grand experiment of burning the diamond, and certainly the phenomena presented were extremely beautiful and interesting". The diamond in the experiment was placed in a perforated platinum crucible in the middle of a glass sphere filled with pure oxygen (volume 22 cubic inches). Under the heat of the solar image produced by the "Duke's burning glass" for three quarters of an hour — with interruptions to cool the glass

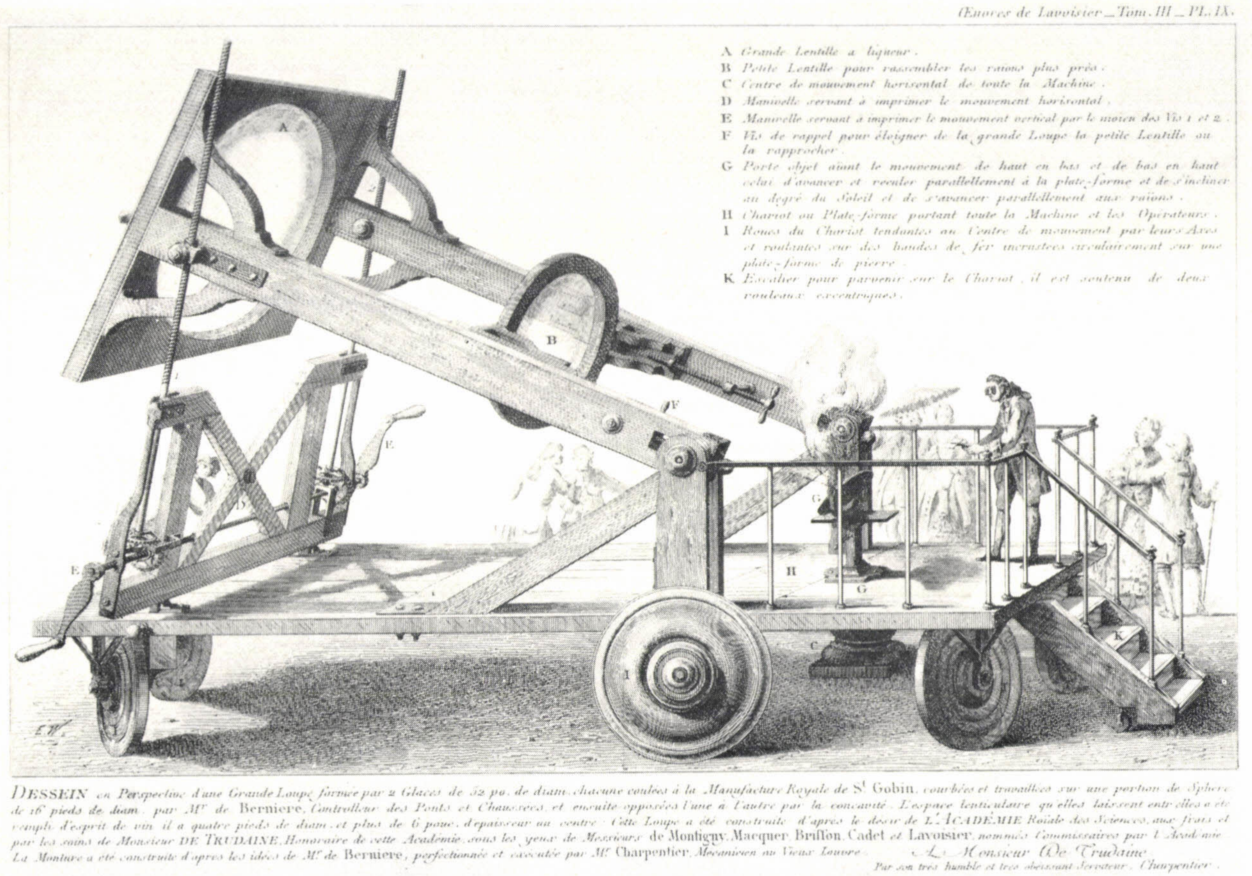

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Photo Deutsches Museum, Munich

Fig. 3. Etching by Charpentier from 1775, showing the burning device with a great liquid lens built in 1774 to order of the Académie Royale des Sciences, Paris, for the investigations of Lavoisier *et al.* The lens consisted of two spherically curved cast-glass plates which fitted closely together, the space between them (4 feet in diameter, more than 6 inches thick in the middle) being filled with alcohol, and later with turpentine. (From: Oeuvres de Lavoisier, Vol. III, Paris 1865.)

combustion of diamond — a subject which had already occupied Cosimo III, and which Lavoisier *et al.* had thoroughly investigated starting in 1772, partly with the aid of the Tschirnhaus burning glass in Paris [8]). Faraday gave a detailed description of sphere — the diamond seemed gradually to shrink and become opaque, and finally caught fire, whereupon it burnt away in a few minutes without further heating.

The etching reproduced in *fig. 2*, after a painting by Corbould from 1805, gives a nice idea of what the experiment described may have looked like. At that time the science of chemistry was on the threshold of a new era, the phlogiston theory of combustion

[8]) See Abbé Rozier, Observations sur la Physique, sur l'Histoire Naturelle et sur les Arts, Vol. **2** (1772), pp. 108-111 ("Résultat de quelques expériences faites sur le diamant par MM. Macquer Cadet et Lavoisier de l'Académie Royale des Sciences").

having just been discredited. The picture shows Chemistry, allegorically represented as a beautiful maiden wearing a coronet, hesitating between the old and the new, symbolized as age and youth. The young chemist is demonstrating the preparation of oxygen in a solar furnace using a lens system. This experiment was done in a very similar way by Priestley [9]) — himself still an obstinate supporter of the phlogiston theory — in 1775.

The burning glass had beaten the concave mirrors for a while, because the mirrors were even more difficult to make, and more difficult to handle: it was found to be virtually impossible to keep the mirrors continually focussed on the object to be heated in long experiments. It was however realized that the performance of the burning glasses was limited by their chromatic and other aberrations and by the optical flaws in the great masses of glass. In order to eliminate these flaws in the glass, the Académie Royale des Sciences commissioned a big *liquid lens* (*fig. 3*) for Lavoisier *et al.* as late as 1774. But by that time the technique of grinding *parabolic* mirrors was beginning to be mastered (J. Short 1710-1768, W. F. Herschel 1738-1822 [10])), and although, as we have seen above, use was still made of the existing solar furnaces using burning glasses for a long time, the days of the picturesque big lens systems were drawing to a close.

S. GRADSTEIN *).

[9]) J. Priestley, Philosophical Transactions Vol. **65**, 1775, letters of 15th March, 1st April and 29th May. The burning glass used by Priestley is still preserved at Dickinson College, Carlisle, Pa. (U.S.A.).

[10]) An interesting alternative was developed by Buffon, who showed in 1747 that a large number of suitably arranged *flat* mirrors could be used instead of a concave mirror (Kircher had put this idea forward in 1646), and that the same experiments could be done with these as with the great burning glasses. He managed to melt a silver object at 20 feet with an arrangement of 117 mirrors. An arrangement of this type used by Buffon is preserved in the Conservatoire des Arts et Métiers, Paris. This method is again being used today, notably for a gigantic Russian installation for making use of solar energy.

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ABSTRACTS OF RECENT SCIENTIFIC PUBLICATIONS BY THE STAFF OF N.V. PHILIPS' GLOEILAMPENFABRIEKEN

Reprints of those papers not marked with an asterisk * can be obtained free of charge upon application to the Philips Research Laboratories, Eindhoven, The Netherlands, where a limited number of reprints are available for distribution.

2870: K. Reinsma: The inherent filtration of X-ray tubes (Radiology **74**, 971-972, 1960, No. 6).

If the inherent filtration of an X-ray tube is known, it is possible to determine the extra filtration required to reach the prescribed total. For a given voltage the radiation quality of an X-ray beam, expressed in mm Al half-value layer, depends markedly on the waveform of the voltage (constant potential or full-wave rectified). Further, there is a marked difference in the equivalent inherent filtration, depending on whether it is determined from dose measurements or from the radiation quality. For the latter case, a set of curves is given showing radiation quality as a function of equivalent inherent filtration (mm Al) for various voltages from 50 to 150 kV constant potential, and 50-100 kV full-wave rectified.

2871: H. F. L. Schöler, E. H. Reerink and P. Westerhof: The progestational effect of a new series of steroids (Acta physiol. pharmacol. neerl. **9**, 134-136, 1960, No. 1).

In order to study the influence of stereochemical changes upon the pharmacological properties of steroids, a number of steroid hormone analogues have been prepared which have the same configuration of the C-9 hydrogen atom and the C-10 methyl group as present in lumisterol$_2$ (see No. **2856**). The activities of the compounds administered subcutaneously and orally at three dosage levels were compared with that of progesterone administered subcutaneously, also at three dosage levels. Photographs taken of the uterine sections were ranked according to the degree of change in the shape of the mucous-membrane epithelium.

2872: F. C. de Ronde, H. J. G. Meyer and O. W. Memelink: The *P-I-N* modulator, an electrically controlled attenuator for mm and sub-mm waves (IRE Trans. on microwave theory and techniques **MTT-8**, 325-327, 1960, No. 3).

The construction and performance of a millimetre-wave modulator are described. The main part of the modulator consists of a *P-I-N* germanium structure inserted into a rectangular waveguide. A modulation depth of 11 dB could be obtained at frequencies up to 5 kc/s, this modulation being caused for the greatest part by attenuation.

2873: H. C. Hamaker: Attribute sampling in operation (Bull. Inst. Int. Statistique **37**, 265-281, 1960, No. 2).

The features of practical interest in attribute sampling procedures are discussed and on the basis of the arguments brought forward some modifications in existing sampling tables are proposed which, it is believed, would render these tables of still greater practical value. Some of the topics considered are sample size efficiency, the AQL (acceptable quality level) concept, the relation between lot size and sample size, advantages of a constant sample size, and tightened and reduced inspection. At the end the main conclusions are summarized and a modified sampling standard is proposed as a basis for discussion.

2874: B. Okkerse: De bereiding van dislocatievrije germaniumkristallen (Ingenieur **72**, O 21- O 26, 1960, No. 29). (The preparation of dislocation-free germanium crystals; in Dutch.)

The paper gives a method for the preparation of dislocation-free germanium crystals. Dislocations in germanium crystals are generated by sources which are activated by the thermal stresses during the growth of the crystal. By decreasing the diameter of the seed crystal to about 1 mm these stresses can be reduced. Consequently the seed crystal can be made dislocation-free, and then a dislocation-free crystal may grow on this seed crystal. The relevant properties of dislocations and various techniques for detecting dislocations are reviewed. Some properties of dislocation-free germanium crystals are discussed. See also Philips tech. Rev. **21**, 340-345, 1959/60.

R 411: J. H. N. van Vucht: Ternary system Th-Ce-Al (Philips Res. Repts **16**, 1-40, 1961, No. 1).

A report of an investigation of the ternary system Th-Ce-Al, including a review of data on the binary systems Th-Al, Ce-Al and Th-Ce and on the element cerium. No ternary compounds were found in the system Th-Ce-Al. This investigation was primarily undertaken to determine the structure of "Ceto", a non-evaporating getter; this structure is described.

R 412: P. C. Newman, J. C. Brice and H. C. Wright: The phase diagram of the gallium-tellurium system (Philips Res. Repts **16**, 41-50, 1961, No. 1).

The phase diagram of the gallium-tellurium system has been investigated by differential thermal analysis and direct observation of melting points under controlled tellurium pressures. The results of these investigations, which are confirmed by X-ray analysis, show that besides the two compounds already known (GaTe and Ga_2Te_3), there exist two other compounds Ga_3Te_2 and $GaTe_3$. These two compounds, however, are not stable at room temperature. A hexagonal unit cell for $GaTe_3$ with $a = 6.43$ Å and $c = 14.20$ Å is reported. The melting points of GaTe and Ga_2Te_3 are 835 ± 2 °C at 6×10^{-2} torr Te-pressure and 792 ± 2 °C at 2 torr, respectively. Upper decomposition limits for Ga_3Te_2 and $GaTe_3$ are 753 ± 2 °C and 429 ± 2 °C.

R 413: J. D. Fast and M. B. Verrijp: Internal friction in lightly deformed pure iron wires (Philips Res. Repts **16**, 51-65, 1961, No. 1).

The internal friction (damping of free torsional vibrations) of pure (99.99%) iron wires is measured before and after they have been subjected to a very small plastic deformation. The damping after deformation is found to be strongly dependent on the amplitude of the deformation, the temperature at which it was carried out, and the temperature of measurement. Wires which are deformed at temperatures below —30 °C show a spontaneous increase of damping with time, while those deformed at higher temperatures show a spontaneous decrease. In the latter case the logarithm of the damping is found to be a linear function of t^p, where t is the time and p a constant between 0.2 and 1.0 which varies from experiment to experiment. Further experiments carried out with increased concentrations of vacancies and carbon atoms have shown that the spontaneous decrease of the damping is due to the diffusion of point defects towards dislocations, and the anchoring of the latter by the former. The spontaneous increase of the damping is probably due to the dispersion of local concentrations of dislocations.

R 414: L. Schmieder: The behaviour of the mercury high-pressure arc under mechanical vibrations (Philips Res. Repts **16**, 66-84, 1961, No. 1).

If a high-pressure mercury-vapour lamp is allowed to vibrate sinusoidally in a direction perpendicular to the axis of the discharge, the arc voltage rises. If both the frequency and the velocity amplitude of the vibration exceed certain values, the arc will be quenched. This can be explained by assuming that the mechanical vibration gives rise to forced gas flow, which results in a certain loss of energy from the arc by convection. If the lamp is suddenly given a (constant) acceleration, it takes some time before the resulting Poiseuille flow pattern becomes constant. This transient time explains the existence of a critical frequency for the quenching of the discharge. Above this frequency, the gas behaves like a frictionless fluid because of its inertia. The convection losses are then proportional to the velocity amplitude of the mechanical vibration. The "mechanical stability" of the arc is defined as the velocity amplitude needed to quench the arc at frequencies above the critical frequency. Calculations show that this quantity is proportional to the diameter of the tube and inversely proportional to the mass of gas per unit length of tube. The experimental results agree quite well with these calculations.

R 415: J. A. W. van der Does de Bye: Signal-to-noise ratio of a *p-n*-junction radiation counter (Philips Res. Repts **16**, 85-95, 1961, No. 1).

X-ray quanta can be counted with the aid of a *P-N* diode of low capacitance, biased in the reverse direction. The quanta give rise to pairs of holes and electrons in the space-charge layer between the *P* and *N* regions. The charges on these particles can be completely collected and measured, thus making X-ray spectroscopy possible. This paper deals chiefly with the influence of the noise on the detection of the signal produced with the aid of a thermionic amplifier with *RC* pulse shaping. For a given choice of the circuit involved, the noise is mainly determined by the diode current I_g and the shot noise of the first amplifier tube. The quantity $C^2R_{eq}I_g$, where C is the total input capacitance and R_{eq} the equivalent noise resistance of the first amplifier tube, may be used as a quality factor for the *P-N* counter. This quality factor can be used to calculate the minimum quantum energy at which detection of X-rays is possible (6 keV) and the width of the spectral lines (3 keV), i.e. the minimum energy difference between two quanta which can still be distinguished. The experimentally determined values were 9 and 4½ keV respectively.

R 416: M. Koedam: Cathode sputtering by rare-gas ions of low energy (Philips Res. Repts **16**, 101-144, 1961, No. 2).

It is well known that a metal emits atoms when it is bombarded with gas ions; this phenomenon is known as cathode sputtering. It was first observed, more than a hundred years ago, in a gas discharge between two (cold) electrodes. This thesis (Utrecht, March 1961) describes measurements carried out with mono-energetic gas ions striking the metal surface at right angles. The energy of the ions varied between 40 and 1500 eV. Chapter I contains a summary of the most important literature. Chapter II describes the apparatus, and some measurements carried out to determine the energy distribution of the gas ions. Chapter III is devoted to the determination of the number of atoms released by the cathode sputtering. After a summary of previous methods follows a detailed description of the method used in the present investigation: the sputtered metal is collected on a glass plate, and the amount determined from the optical transmission of glass plates plus metal layer. This chapter also contains a comparison of the structure of layers of silver (and copper) formed by sputtering and by evaporation. The experimental results are given in chapter IV. The sputtering yield (atoms/ion) was determined as a function of the energy of the gas ions (which varied between 40 and 250 eV) for polycrystalline silver. The angular distribution of the sputtered atoms was determined for monocrystalline copper bombarded with gas ions of energies up to 1500 eV. It was found that the ⟨110⟩ and ⟨100⟩ directions are preferred directions, while the angular distribution also depends on the nature and energy of the bombarding ions. The experimental results are discussed and compared with those of other authors in chapter V. The existence of preferential directions for the sputtering and the variation of the angular distribution with the ion energy are explained.

R 417: A. J. W. Duijvestijn and A. J. Dekkers: Chebyshev approximations of some transcendental functions for use in digital computing (Philips Res. Repts **16**, 145-174, 1961, No. 2).

Description of iterative methods for finding the best approximation to continuous functions in a given interval by means of a truncated polynomial or a truncated continued fraction. The article also describes direct methods for obtaining approximations to such best approximations.

R 418: B. H. Schultz: On the study of volume recombination of excess charge carriers in semiconductors with the aid of photoconductance (Philips Res. Repts **16**, 175-181, 1961, No. 2).

A method is described for the elimination of surface effects in determinations of the recombination time of holes and electrons in semiconductors by means of photoconductance measurements. Moreover, the measurements indicate directly whether the value found for the recombination time is reliable or not.

R 419: B. H. Schultz: Recombination at copper and at nickel centres in *p*-type germanium (Philips Res. Repts **16,** 182-186, 1961, No. 2).

The rate of recombination of excess holes and electrons at copper centres in germanium depends on the temperature. If the germanium also contains some antimony, which partially compensates the acceptor action of the copper, a different dependence on the temperature is found. All the experimental results can be explained by assuming that recombination occurs not only at copper ions, but also at neutral copper atoms. The contradiction between the results obtained by previous workers is hereby resolved. A similar contradiction which is also found with nickel could not be resolved. The data obtained in the present investigation agree with those of Wertheim, but not with those of Kalashnikov and Tissen.

R 420: L. J. van der Pauw: Determination of resistivity tensor and Hall tensor of anisotropic conductors (Philips Res. Repts **16,** 187-195, 1961, No. 2).

The resistivity tensor of an anisotropic conductor with respect to an arbitrarily chosen rectangular coordinate system can be described by six constants. It is shown that these six constants are related to the "sheet resistivities" of six plane-parallel samples by six linear equations. The plane-parallel samples may be of arbitrary shape and cut in arbitrary but known directions. The Hall effect can most generally be described by nine constants. For the determination of these nine constants only three such samples are required, combined however with three different orientations of the magnetic induction.

H 9: K. Böke: Kapazitätsmessungen an der Grenzfläche Silicium-Elektrolyt (Z. Naturf. **15a,** 550-551, 1960, No. 5/6). (Capacitance measurements on silicon-electrolyte interfaces; in German.)

A short report of capacitance measurements on the interface between silicon and an electrolyte. These experiments form part of a fundamental investigation of the phenomena occurring at the surface of semiconductors. See also **H 10.**

H 10: H. U. Harten: The surface recombination on silicon contacting an electrolyte (Phys. Chem. Solids 14, 220-225, 1960).

A silicon disc of thickness equal to the recombination length for diffusion is immersed in an electrolyte. A voltage applied between the electrolyte and the sample is used to vary the charge density on the surface of the silicon. The rate of surface recombination and the surface photoelectric effect are measured as functions of the applied voltage. The results are in qualitative agreement with the theory, and are dependent on the oxidation state of the silicon.

H 11: G. Schulten and H. Severin: Dämpfungsarme Leitungen für Millimeterwellen (Nachr. techn. Fachber. **23,** 20-23, 1961). (Low-damping transmission lines for millimetre waves; in German.)

A brief survey of surface-wave transmission lines, which can have considerably lower attenuation for millimetre waves than the more common type of waveguide in which the wave is propagated in the interior of a hollow conductor.

H 12: H. Severin: Neuere Mikrowellenferrite und ihre Anwendungen (Nachr.techn. Fachber. **23,** 24-27, 1961). (New microwave ferrites and their uses; in German.)

A brief survey of ferrites which can be used at higher and lower frequencies in the microwave region than has been hitherto possible. A number of factors determining the upper and lower frequency limits for such applications are discussed.