DUTCH REPORT ON GERMAN MANUFACTURE OF SCALES ON METAL, GLASS AND CELLULOID

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B.I.O.S. MISCELLANEOUS REPORT NO. 101

GERMAN MANUFACTURE OF SCALES ON METAL, GLASS AND CELLULOID.

Visit to Leitz Optical Works, Wetzlar.

1. Personnel interviewed: Mr. Henri Dumur, Swiss director of the Leitz Works, who conducted us through the factory.

2. Machines.

Dividing machines of different makes and types are used, comprising both automatic and hand-operated machines. Their best machine was made by Heyde in Dresden.

3. Division on metal-surfaces.

The desired division is scratched in the metal surface with a diamond tipped chisel. The division is not etched or otherwise finished.

4. Division on glass; mechanical method.

a. Wax-coating

A coating of wax is applied to the surface. The wax is dissolved in benzine. The thickness of the layer is the same as the width of the line to be drawn. Thick layers are applied by spraying. Thin layers are applied by brush.

This coating is heat-treated by keeping it in an oven at 120° centigrade. Subsequently the division is ruled in the wax-layer. For divisions with very thin lines and a corresponding thin film of wax a diamond-tipped cutting tool is used.

b. Etching.

When broad lines are to be etched the etching fluid, hydrofluoric acid, is applied with a felt brush. Etching time is between 2 and 3 minutes and at the end of this period the object is very carefully washed with ordinary water.

Thinly coated glass surfaces are etched in the vapour of 75% hydrofluoric acid. The acid is kept at 40° centigrade in a lead container, and the object to be etched is exposed for a very short time, only a few seconds, to the vapours that emerge from the container. The divisions are coloured with a mixture of waterglass and zincoxide.

5. Divisions on glass. Photographic method.

A hundred to two hundredfold enlarged drawing of the desired graticule is made on dull drawing paper with normal drawing ink. To prevent distortions the drawing is glued on glass. The drawing is photographed on wet collodion plates and a negative of standard dimensions is obtained. Great care is taken to ensure an equal distribution of light over the surface of the drawing. The negative thus obtained is projected on the glass surface to be divided. This surface too is covered with an alcoholic solution of sollodion. The glass-surface is submerged in a silver-bath for two minutes, exposed, subsequently treated with high-speed developer and finally fixed. After this treatment the collodion layer is washed and strengthened.

Finally a thin piece of glass is glued on the top of the layer with Canada-balsam, small air-cells and dust particles being removed from the balsam. The whole is then ground in the desired shape. It should be noted that the collodion layer is applied with a small spray and is not centrifuged as done by Moeller in Wedel.

Visit to Albert Nestler A.G. in Lahr.

1. Personnel interviewed: Mr. Nestler Sr. and Jr., owners and directors of the plant. Mr. Nestler Jr. demonstrated the technique for making slide rules, as developed by his father. It was emphasised that the machines used were of their own design and make.

2. The top layer of the slide rules is made from celluloid. At present it is rather difficult to obtain celluloid, since the raw materials for this product, mainly camphor, came from Sackalin. Mr. Nestler claims that he has no knowledge of any existing plastic that could take the place of celluloid without a lowering of their quality standards. Astralon, for instance, is too hard to give a clearly ruled line. It is not known to us how far this aversion to plastics is due to the unadaptability of plastics to the dividing methods used at present.

3. Two rows of 15 rules are clamped on the table of a dividing machine, the longitudinal axis of the rules being parallel to the spindle of the machine. Each ruler is divided by a separate tracelet-mechanism and the 30 mechanisms are actuated by one master-shaft. A notched drum controls this shaft and the rotation of the spindle that moves the table.

4. The scribing tool does not chisel, i.e. remove material from the celluloid layer, but it presses its knife-like edge in the material, the weight of the scribing tool plus its holder providing the necessary downward force. The form of the scribing tool is conventional.

5. The two corresponding sections of a division on rule and slide are made in one operation, thus ensuring a perfect coinciding. The line, that runs parallel to the longitudinal axis of the slide-rule, along the top-edges of the shorter lines, is ruled after the division has been made.

6. All red lines are ruled first and then coloured, and all protuding elements are abrased together with the surplus paint. Subsequently all black lines are ruled, coloured and further treated.

Visit to Zeiss-Opton, Heidenheim near Ulm.

1. Personnel interviewed: Dr. Ramb and Dipl. Ing. W. Traut.

2. Part of the scientific and technical staff of the Carl Zeiss works has been evacuated to Heidenheim. When they tried to rebuild the works gradually, one of the main difficulties encountered originated from the very high specialisation of the technicians. As a result therof the Heidenheim-group has but general knowledge of the field covered by those, who stayed in Jena. Thus many problems can now be solved only after long and tedious work, where formerly a certain specialist was consulted. It is claimed that no specialist on graduations is in Heidenheim and that no scale-divisions are made at present

A production program has been outlined and at present a small group of trainers is working on the manufacturing of spectacle-lenses and on doing repairs on all sorts of instruments. The machine and instrument situation is not very favourable. There is no instrument for accurate measurements of length.

3. In Jena divisions were made by a normal cutting operation. For some purposes, however, a small circular saw, ∅ 30 mm, at high rotational speed was used. Swedish steel was used for this saw, but some difficulties were experienced, owing to a different rate of wear along the circumference. This was explained by the change of the angle between the saw-teeth and the directional structure of the steel along the circumference.

4. The lines are filled in with wax for colouring. This method ensures an adequate filling of the small sharp niches at the end of the lines.

Visit to Steinheil in München.

1. Personnel interviewed: Mr. Bachel and Mr. Popp.

2. The firm of Steinheil does not produce the divisions used in their optical equipment. These divisions are ordered from Moeller, Wedel. Steinheil only makes such divisions as are needed for products still in the development stage.

3. Graduations on glass; waxing.

A glass surface is carefully cleaned and covered with asphalt-lacquer of the following composition:

Asphalt	200 grammes
Colophonium	200 "
Wax (ceresine)	200 "
Turpentine	1200 "

The wax is dried under room-conditions of temperature and humidity for one or two hours. The desired scale is thereupon drawn in the wax-layer with a dividing machine. A very narrow line is obtained by using a diamond-tipped scribing tool. The downward force in the scribing chisel is estimated at 200 grammes.

4. Graduations on glass; etching.

The graduation is etched in the glass by the same process as used by Leitz and Moeller. The surface to be etched is exposed to the vapour of 40-60% hydrofluoric acid. For very narrow lines this vapour is blown on the glass from a lead or bakelite pipe. To ensure a uniform etching over the whole surface great care should be taken to free the vapour from air-pockets. Therefore the acid-container is left opened a

few minutes before the actual etching begins. The evaporating hydrofluoric acid then drives the air from the container.

Etching time is 3 seconds for a line depth of 3/100 mm. Etching time is 1 second for a line depth of 1/100 mm.

BAL-10 glass, manufactured by Schott in Jena is very suitable for etching purpose.

5. Divisions on metal-surfaces.

Since an etched line is not as deep as a drawn line, divisions on metal are very often etched and not directly scratched in the metal surface. Thus the concentration of tensions in the remaining metal is lessened, and an undesirable unevenness of the lines can be prevented, e.g. when divisions are made on the tapered ends of micrometer drums.

6. No divisions are made by optical methods. Dr. Johannes Heidenhain, c.o. Fa. Apparatebau RAIN in Rain am Lech is considered to be top man in this field. Dr. Heidenhain has been on the staff of Moeller in Wedel.

7. It was mentioned that in order to avoid formation of small vapour-bulbs in coatings on glass surfaces ion-bombarding of the surface before coating is recommended. No theoretical explanation offered thus far has been found entirely satisfactory.

Visit to J.D. Moeller, Wedel near Hamburg.

1. Team was met by Mr. Betz and escorted by Mr. Fellsman, who is in charge of the graticule-department and by Mr. Krasner, the general technical manager. The former is the successor of Mr. Seliger.

The Moeller firm mass-produces graticules in glass, and three methods are used:

1. Photochemical method,
2. Mechanical method,
3. A combination of photochemical and mechanical methods.

About the same degree of accuracy is obtained by any of the three methods and an excellent product is obtained. Technical details of the three methods will be briefly discussed in the following paragraphs.

2. A 10 to 4000-fold enlarged drawing of the scale to be manufactured is very carefully made on dull white paper. A normal tracing pen and dull drawing ink are used for this purpose. This paper is glued on glass with Arabic glue, so as to prevent distortions of the drawing that might otherwise result from a change in the moisture content of the paper.

A photo of the graticule in its proper dimension is obtained in two steps. The drawing is illuminated by 4 carbon-arc lamps, ensuring an equal division of light over the whole drawing. The negative thus obtained on a glass plate, is illuminated by a carbon-arc lamp and a second negative is obtained. This second negative is used to make the graticules. The photochemical method whereby the graticules are made has been described in great detail by Eder in his "Handbuch der Photographie".

The method may be summarized as follows:

a. A glass plate is coated very thinly with albumen and dried.
b. In a dark room the collodion is poured over the surface thus prepared and a layer of uniform thickness is obtained by centrifuging.
c. The wet collodion layer is sensibilized in a tray by running the sensibilizer over the glass plate 7 times.
d. A little tannin is poured over the sensibilized layer.
e. The plate is exposed.
f. The plate is developed physically and fixed by pouring first the developer and then the fixer over the plate.
g. The plate is dried.

The negative obtained in the first step-down, is kept as master negative. It has a standard size. Any number of smaller second-stage negatives can be obtained from this master-negative.

It is customary to make a number of prints of the graticule in one glass plate in the second photographic stage. When the prints have been chemically treated they can be separated by applying a thick coating of collodion and drying it.

The resulting layer is cut into blocks and these blocks are loosened from the glass plate with distilled water. The blocks are then laid on small glass plates. The collodion

is thereupon dissolved, but the remaining graticule is protected by a thin piece of glass, glued with Canada balsam. The grain size obtained should lie under 1 μ. Many samples were shown. The graticules may vary in length from a few millimeters, used in objective micrometers for microscopes, to 40 centimeters used for balances.

Sometimes the graticule is burned in the glass in an oven at a temperature at 800° centigrade.

3. Mechanical method.

Scale divisions in metal and glass are made on very accurate machines, made by Heyde, Dresden. Steel chisels are used for working metal surfaces, diamond-tipped chisels for working glass. The glass is thinly coated with wax before the lines are drawn and is afterwards lightly etched with hydrofluoric vapour. This is done to avoid undesirable tensions in the glass around the edges of the lines. The diamonds are bought from Winter und Sohn, Hamburg.

The lines are about 3 μ wide. The manufacturers initials and the nominal denotations are scribed with the mechanical-chemical method.

The graticule, used for counting red blood corpuscules under a microscope, is made by this method.

4. Mechanical-chemical method.

The glass surface is coated with a layer of bees-wax and on a dividing machine lines are drawn in this layer with a steel chisel, and the object is subsequently etched. For very narrow lines hydrofluoric vapour is used; for the wider lines liquid hydrofluoric acid is used. A solution of hydrofluoric acid is kept under a funnel at about 40 degrees centigrade. A little amount of this fluid is taken out of the container with a lead spoon and spread over the surface to be etched. The vapour, used for etching very narrow lines, is obtained by applying a little air pressure to the container; a stream of hydrofluoric vapour will leave through a small tube.

5. Lines are coloured black with printers ink. The dried ink is burnt in the glass by keeping the object in an oven at 200° centigrade for 30 minutes.

Visit to E. Leybolds Nachfolger, Berg Neustadt.

1. Personnel interviewed: Mr. Meckenstock.

2. The Cologne plant of this firm has been severely damaged by Allied air-raids, and has been evacuated partly to Berg Neustadt, partly to St. Andreasberg. In the latter plant mercury vapour pumps are made; the former plant produces "kapselpumpen" and demonstrating equipment for high schools. The necessary scale divisions were not made by Leybold, but were ordered from specialists. Pressure guage scales are printed. The mechanism of the pressure-guage is adjustable and is set to the correct ratio at the inspection stage. Precision scales for pressure-guages are drawn by hand, using a few calibration points. A cheap and fast method for the manufacturing of scales for a great many purposes is found by using transfers.

3. The firm has no dividing machines. They informed us that good machines are obtained from G. Heyde, Dresden or G. Kempten, Kempten, (Allgäu).

Visit to the Faber-Castell factory, Geroldsgrün.

1. Personnel interviewed: Mr. Liebrandt and Mr. Tegtmeyer, who showed us round the factory, though with noticeable reluctance.

2. Manufacture of rules.

The making of ordinary woodon rules with or without celluloid toplayer was shown.

a. The ruling of the lines.

In a room with temperature control divisions are made in the mechanically finished rules. For this purpose five dividing machines of conventional type, each dividing 6 to 8 rules simultaneously, are used. The rules are clamped in slots of the table of the machine, thus ensuring a quick way of mounting and loosening of the pieces. The older machines have a tracelet-mechanism with pivot-points for all movements, but in the modern machines the tracelet-mechanism can move over a bed in a horizontal plane. The scribing tool is clamped in its holder by a screw, and the holder

has a blunt extension that controls the depth of the lines. The movements of the tracelet are governed by two shafts with adjustable notches.

The actual cutting is the same as described earlier (see visit to Nestler plant).

b. The writing of the numbers.

The numbers are pressed in the rules in one operation. The die is held at a certain temperature in the press, the latter having a die-holder with an electrical heating circuit. The temperature depends on the material to be worked, and varies from 40° for wood to 120°C for celluloid. The maker of the die has to allow for the thermal expansion under actual operating conditions.

c. Finishing the product.

The lines are coloured black with a mixture of asphalt, soot and turpentine, that is applied with a piece of felt, mounted on a wooden stick. The rules are finally treated with abrasive paper, polished and varnished.

3. Production of slide rules.

a. General.

The manufacture of slide rules differs from the manufacture of rules in the way the lines are made. The non-linear division of the slide rule is stamped in the celluloid layer in the same way as the numbers are stamped in the rules. In a second stamping operation the numbers are pressed and the rule is finished by colouring lines and numbers, abrasing, polishing and varnishing.

b. The manufacture of the die.

The construction of the die makes it possible to press all the lines on one surface of the slide rule in one operation. For this purpose the die consists of a number of strips, exceeding the maximum length of the division to be made by some centimeters. The strips are about 5 cm high and

the width is the same as the length of the longest line to be made. A circular saw, clamped between two circular plates with a diameter only slightly smaller than that of the saw, is mounted in a dividing machine. This tool cuts slots in one of the narrow sides of the strip. The slots are located where the lines of the division should come. The forward movement of the circular saw between two cuttings is hand controlled. Small knives are inserted in these slots, the length of the knives being determined by the length of the line they should make. The knives are cut to proper length from a steel band, that has been sharpened in one side on a very normal grinder. The band is about 4 mm wide and the knives protrude about 1 mm from the die. The knives are firmly fastened by "stamping" the material between the knives with a small hand chisel.

A die is built up by clamping the strips together, if necessary interspacing them with blank strips. It takes a long time and a good deal of skill to make such a die but as thousands of rules can be made with one die, die manufacturing time per rule is short.

A copper-base alloy is used for the dies and great care should be taken to obtain the correct dimensions at the actual working temperature.

The rule is laid on a table in the press. This table can be tilted, making it possible to press the division on the slanted sides of the slide - rule.

The rule is held in its proper place relative to the table and the die by pressing the rule in a slot against a small block.

4. The wood machining operations are completely mechanised, Fit finishing of the slides in the rules, however, is a hand operation.

Visit to Carl Mahr, Esslingen.

1. Personnel interviewed: Mr. Kustin, sales manager and Mr. Schmidt, foreman of the dividing section.

2. Method used for dividing.

The graduations, made by Carl Mahr, are mechanically ruled in varnish and are subsequently etched.

The lacquer coating has the same appearance as coatings used elsewhere for the same purpose and the necessary chemicals can be purchased from any good firm. The lacquer is applied by brush and dries quickly at room-temperature, changing into a rather tough mass. Lines are ruled by a scribing tool, mounted in a dividing machine or in a pantograph; the first method gives a very neat and accurate division; the latter method has the advantage of higher production speed. The lacquer-layer is lightly dusted with powdered chalk and the etching liquid is applied by brush. To ensure an equal spread and good penetration into sharp corners the brush is moved through the etching fluid during the etching. This takes 6 minutes. The excess liquid is then washed away, the varnish is dissolved and the scale is ready.

The numbers on slide and micrometer calipers are drawn with a pantograph in the lacquer coating and they are etched together with the lines. A complication sets in when chromium plated parts are to be etched, since chromium is not affected by the nitric acid used as etching fluid. Therefore the following method is used: The lines and the numbers are drawn in the lacquer coating and the pieces are put in a bath of ammonium chloride containing some nitric acid.

Direct current, the direction of which is contrary to the one used in electro-plating, is applied, and dissolves the chromium at the exposed places. The result is that at these places the steel surface is no longer protected by the chromium and will be etched by the nitric acid from the bath.

3. Accurate slide-calipers with 1/20 or 1/50 vernier are made one by one in a linear graduating machine of normal type. The tracelet is not pushed, but drawn through the lacquer coating. The scribing tool, a sharpened cylindrical pin, diameter 2 mm, is soldered into a more massive shaft, and this shaft is clamped in the tool-holder. The estimated downward pressure is 100 grammes.

Carl Mahr manufactures only the accurate type of slide-calipers. They are inclined to believe that inaccurate slide-calipers are mass-produced on linear-dividing machines, operating several tracelet-mechanisms simultaneously.

Visit to the Hommel-works, Mannheim-Käfertal.

1. Personnel interviewed: Mr. Schnitler, assistant-director and Dipl. Ing. H. Schmidt, technical manager.

2. Manufacture of precision-rules.

At present the only divisions made are those on H-shaped rules of the well-known internationally adopted standard type, made from non-hardened steel. The measuring surface of these rules is nickel-plated and coincides with the neutral plane of the body.

The divisions are made by a linear dividing machine, equipped with a normal tracelet mechanism. The traverse of the table, that carries the rule to be graduated, is not derived from a rotating spindle, but from a master scale, with a known correction, mounted on the same table. The table is moved forward until a line of the master scale is in the middle of the field of view of a measuring microscope, that is mounted firmly on the bed of the dividing machine. The tracelet mechanism is thereupon actuated and rules a line. By repeating this operation a very accurate copy can be obtained from a master scale.

When a very narrow line is desired, a diamond-tipped cutting tool having a 90° angle in a plane, perpendicular to the direction of the movement, is used. The lines thus obtained have a width of 2 μ. A sample, made for demonstration purposes, was shown, where one centimeter had been graduated in millimeters, one millimeter had been subdivided in 0.1 millimeters, and finally one of the 0.1 mm intervals had again been divided in 10 equal parts.

3. Manufacture of slide-calipers.

Formerly slide-calipers were produced. The graduations were ruled in varnish on a normal linear dividing machine and subsequently etched with corodol. These calipers were not mass-produced.

The etching process was demonstrated in the slip-gauge department where it is used for inscribing, the numerical denotations and the manufacturers initials on the slip-gauges, that have passed all stages of mechanical finishing and inspection.

To avoid damage to the lapped surfaces from remaining droplets of etching fluid, every piece is cleansed with a thin but powerful jet of water, cross section 1 mm.

4. The firm has adequate facilities for the production of precision scales. Their two dividing machines stand in an air-conditioned room in the basement of the factory. This room also contains two Zeiss interferometers, using cadmium light for the inspection of slip-gauges. For the surface quality the well-known apparatus designed by Bush and by Schmalz are used.

It may be mentioned here, that the measuring surfaces of the Hommel slip-gauges have a higher finish than the gauges of Carl Zeiss. Zeiss claims that they do not finish the measuring surfaces too highly, so as to avoid damage from cold-welding when the two surfaces are in too close contact. Hommel claims that this theory is only uphold by Zeiss because they cannot finish their surfaces as well as Hommel can, and Hommel points out that the contact between two protruding spots on not too highly finished surfaces will be much closer than the contact between two highly finished surfaces, and that therefore the danger of cold-weld-damage is smaller the higher the degree of finishing.

Visit to ABA-Werke, Aschaffenburg.

1. Personnel interviewed: Mr. Otto and Mr. Kaspari, Sales manager.

The ABA-works have been put on the reparations list, i.e. they are eligible for having their machines removed so that these may serve as payment to Allied countries. As a result hereof little initiative is displayed in repairing machines, tools and buildings, that suffered badly through bombing and evacuation. Therefore no dividing machine could be shown in operation, but a verbal account of the methods used by ABA and others was given.

2. Brief outline of some methods for the manufacture of scale divisions.

a. ABA used to dip the slide caliper, that was to be divided, in a bath of liquified lacquer, withdrawing same mechanically at constant speed. Thus a good lacquer coating of uniform thickness was obtained. Lines were ruled in this layer on a Deckel dividing machine. This machine is equipped

with two tracelet mechanisms and it can handle two pieces at a time. A rod with a sharpened wheel was used as scribing tool. Etching was done with "Corodol".

The etching fluid, known as "Corodol" has been developed during the war under the sponsor-ship of the German Air Ministry (Reichsluftfahrtministerium). The chemical formula was kept secret and all Germans interviewed claimed no knowledge on this point. It was generally presumed that allied investigators had found the formula by now.

b. The graduation is rolled into the piece with a steel cylinder. The piece has a traverse motion, not the roll. The main-axis of the roll is perpendicular to the division to be made. This method was demonstrated. A micrometer drum was divided. The results obtained were not very good.

c. The graduation is scratched directly into the metal with a pantograph. This method was demonstrated. A 1/100-millimeter division was made on a micrometer drum.

d. A round of flat rubber stamp stamps the lacquer on the metal surface, leaving the sites of the lines uncovered. The piece is then ready for etching. Some difficulty is experienced, mainly resulting from the distortion of the rubber stamp, when pressure is applied.

e. Common roller-tapes have graduations printed on metal.

f. A photographic reproduction of a divided glass-plate is made in a sensitive layer on the metal surface. Subsequently the surface is etched, with suitable chemicals. Specialist in this field is Dr. Heidenhain. He has also invented a method to make the divisions on the drum of a micrometer-caliper by letting the light fall along the axis of the hollow drum on a mirror of conical shape.

g. It is advisable to adjust the traverse of the carriage with slip-gauges when making accurate divisions on a dividing machine.

Note: Mr. Otto told us that a little factory near Aschaffenburg used optical methods for mass production of slide-calipers. We could not inspect this plant for lack of the necessary clearances from the Allied authorities.

Visit to Reich, Aschaffenburg.

1. Personnel interviewed: Mr. Reich, director and Mr. Schubert. The factory has been completely destroyed by direct hits during air raids. A few rooms have since been repaired and some work is being done. The main line of production is slide-calipers but the finished product, samples of which were shown, is not very good, the lines being coarse and unevenly spaced.

2. All graduations for slide-calipers are made by the etching method, as described previously. The asphalt-lacquer is applied to the surface of the slide-caliper by brush and dries for one half-hour. Lines are drawn in this coating by a dividing machine. Two slide-calipers are clamped on the same table, and they are in turn divided by the same tracelet mechanism. When the lines have been drawn, the necessary numbers are cut in the wax-layer with a pantograph and subsequently etched with a mixture of nitric and sulphuric acid. Sometimes the numbers are burnt in the metal with a pantograph, having an electric sparking device instead of the normal milling device.

3. It is planned to produce these calipers by a photographic method. The piece is to be covered with a light-sensitive coating and a graduated glass plate and is then exposed, treated chemically and etched. No research work is done in this field, but all necessary equipment: glass plates, light sensitive chemicals, etching fluid and so on, is purchased from: Jozef Rieder, A. Schoesser, KOLN-BRAUNSFELD.