EUROPEAN COAL AND STEEL COMMUNITY

Community Ergonomic Research

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Technical report n° 7

JOB STRESS IN BILLET GRINDING

Source : Ergonomic Team of the Dutch iron and steel industry
Project n° 4

Author : J. VAN DER LAAN

Reference period : 1.4.1968 - 1.10.1970

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Financial assistance was provided for this study by the European Coal and Steel Community

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CECA: 781

This study was undertaken with the financial help of the European Coal and Steel Community.

It was carried out mainly in a production department of NKF STAAL N.V., Alblasserdam.

Members of the staff of the following organizations and undertakings collaborated in the study :

- N.I.P.G./M.F.I. - T.N.O. (Netherlands Institute of Preventive Medicine of the Netherlands Central Organization for Applied Science Research) under the direction of Dr F.H. BONJER;

- I.G. - T.N.O. (Hygiene Institute of the Netherlands Central Organization for Applied Science Research) at Delft under the direction of P.B. MEYER, Engineer;

- Grasso Perslucht N.V., Rotterdam;

- N.V. Slijpsteen Industrie "De Maas", Cuyk (Holland);

- NKF STAAL N.V., Alblasserdam (Holland).

Project leader : J. VAN DER LAAN (Head of Slab and Billet Rolling Division)
NKF STAAL N.V., Alblasserdam

Summary of report

The Slab and Billet Rolling Division, which also looks after billet grinding, came into service in 1965 and was extensively mechanized. In addition to sundry finishing operations on rolled semi-finished products, it is responsible among other things for the removal by grinding of surface defects. Although billets can be dressed very satisfactorily on a fixed grinding machine, the number involved was so small that purchasing such a machine was not economically justified, and the operation is carried out with a portable appliance.

As it was felt that this labour-intensive operation could be improved in a number of ways, it was decided to carry out an ergonomic study.

The billets are about 9 m long, 80 x 80 mm in section, and weigh approx. 420 kg. They are made from killed carbon steel and light-alloy steels and are later worked into wire rod. For certain applications, such as springs and high-quality nuts and bolts (e.g. for the automobile industry) exacting demands are made on the surface finish of billets and no faults are accepted.

Laps, skins and cuts are easily detected, but cracks do not come to light until the skin is removed from a rolled surface by grit blasting. Following that operation, the grinder's job is to detect any flaws and remove them with the aid of a portable grinding machine.

A study was carried out of the following aspects of grinding :

1) Safety
2) Dust concentration
3) Lighting
4) Heating in winter
5) Suitability of the grinding equipment used
6) The stress involved in grinding operations
7) The economic aspects of production

Item 1

In handling billets, i.e. rolling them down from the delivery table to the grinding bench, use was previously made of a canting iron which gave rise to a number of accidents. We then developed and put into service a new model, after which the accidents ceased. Accidents caused by bursting grinding wheels were forestalled by clearly instructing operators how they should be fitted and used.

Item 2

Dust concentration was measured and found to be excessive by the standards in force in the Netherlands. Various means of reducing this nuisance were explored but many had to be rejected as uneconomical. The remainder, i.e. wearing of dust masks, good ventilation, spreading out grinding work places over different sites, were adopted.

Item 3

Lighting was modified by fitting a double row of fluorescent tubes. This gives a level of illumination on the billet of approx. 500 lux, which was felt to be adequate. In spite of this, however, hair cracks a few tenths of a millimetre in depth remain invisible.

We came to the conclusion that grit blasting of billets gave inadequate results and therefore switched to "serpentine" grinding of billets, dispensing with grit blasting altogether. This method gives better results.

Item 4

Winter heating was provided by a brazier set up between grinding benches. Grinders used to leave their bench from time to time to warm themselves before the brazier. We erected a draught screen behind their backs, and over their heads a canopy to which were fitted the fluorescent tubes. We carried out tests with :

a) plate radiators set up against the screen
b) electrically heated air blown out below the canopy
c) hot-air cannons arranged at the sides to blow warm air below the canopy.

The hot-air cannons gave the best results. The grinder is kept warm at his work place and has therefore no cause to leave it. The screen and canopy ensure that warm air spreads over the 10 m long grinding bench.

Item 5

A study was carried out of the effectiveness of the portable grinding machine and wheels used.

It was found that the machine had to be in first-class condition and the air pressure adequate. Failure to meet these requirements is disastrous for production. The best answer appeared to be a portable grinding machine weighing approx. 5 kg and fitted with a 2 kg cup wheel, 150 mm diameter, peripheral speed 45 m/s, hardness N. Optimum grinding pressure was 8 kg.

The grinding pattern is regular and cracks are clearly visible. The combined weight of grinding machine and wheel is close to the optimum grinding pressure. This was pointed out to grinders, who had tended to apply too heavy pressure.

Item 6

The job stress to which billet grinders are exposed was determined under actual operating conditions, i.e. while grinding and handling with portable grinding machines.

We then rigged up an assembly in which hose and grinding machine were hung up and job stress was determined afresh.

In this way job stress was reduced by about 10 % but the nature of the equipment was such that grinders do not set much store by the arrangement. They feel that the slight reduction in job stress does not offset the inconvenience they feel they suffer from having to hang up the grinding machine and hose. This is also probably due to the fact that the job stress involved may be regarded as only moderate.

Item 7

The decision to switch from manual to mechanical grinding is governed mainly by the following factors :

a) The surface finish of the unground billets
b) The surface finish required on ground billets
c) The number of billets to be ground.

As there has recently come onto the market a machine which can be used for billet grinding and which costs about 90,000 Guilders, and as the number of billets to be ground is steadily mounting, the transition from manual to mechanical operation has been speeded up.

In the case studied, it was found that with an output of 25 tons of ground billets per week it would already pay to purchase an automatic grinding machine.

Conclusion

Manual grinding of billets is economically justified only if a very small quantity of billets have to be ground each week, or if the surface finish of the unground billets is already so good that only a few faults have to be removed, so that the main need is to inspect the billets and apply slight corrections. As circumstances vary from one works to another, it is difficult to quote figures.

If, however, it is decided to retain manual grinding, it appears to be essential to use simple equipment and benches and to provide satisfactory lighting and ventilation. The results of the study, which are set out in the following report, should prove both useful and informative.

Alblasserdam, 15 April 1971

REPORT OF AN ERGONOMIC STUDY OF JOB STRESS IN BILLET GRINDING

Existing situation

The steels requiring treatment in billet form are killed carbon steels and low-alloy steels.

A batch consists of 2 x 4 ingots (first and second casting plate).

More and more 4-ton ingots are being cast. Ingot moulds are only rarely used.

Ingots are not inspected for surface faults. They are not "washed" in the soaking-pit. Blooms are not flame scarfed.

Precautions are taken not to introduce any rolling defects.

Ingots are reduced to blooms 160 mm square on the cogging mill. These are in turn reduced into billets 80 mm square on 6 billet mills. All operations are carried out at a single rolling temperature. The 80 mm square billets are processed, after treatment and reheating, into wire rod 5.5 to 25 mm in diameter.

The surface of billets manufactured from the steels mentioned must be flawless before the billets are reduced to wire rod.

The following faults are found on billets :

a) isolated patches of mill scale;

b) scale trails;

c) a single crack 2 mm deep and ranging in length from 0.5 to several metres;

d) one or more cracks about 1 mm deep and usually ranging in length from 0.5 to 1 m;

e) several shallow cracks, fairly short and only a few tenths of a millimetre deep.

Faults d) and e) are those most frequently found.

All cracks run down the length of the billet. Faults do not occur systematically. Sometimes two or more sides of a billet are completely fault-free. Billets taken from the head and foot of the ingot exhibit the most faults. Wide differences in the surface quality of billets are found from batch to batch, even where the results of analysis are the same.

From among the billets obtained from one ingot one sample is taken (from the middle of the ingot), i.e. 8 billets per batch.

The results of this sampling procedure determines whether the batch is to be treated or not.

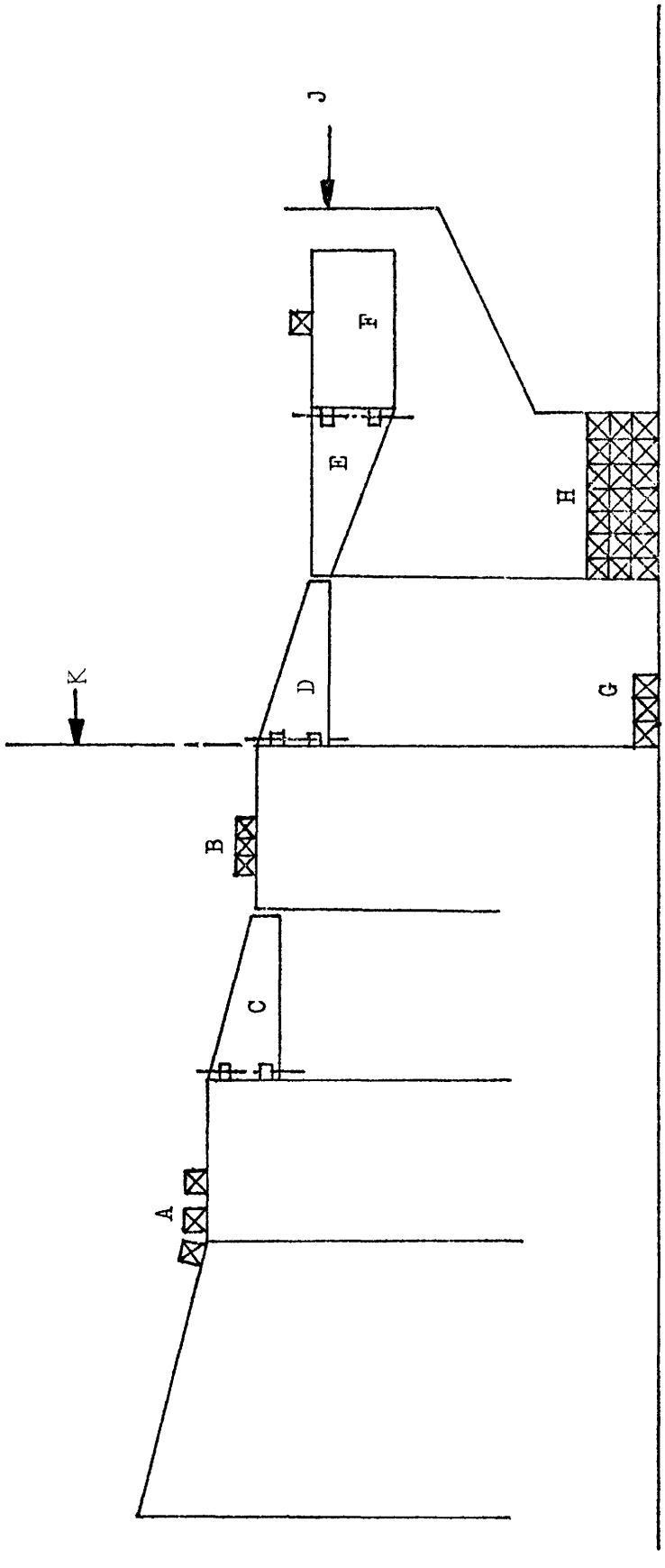


Fig. 1

See also Photos 2, 3 and 4

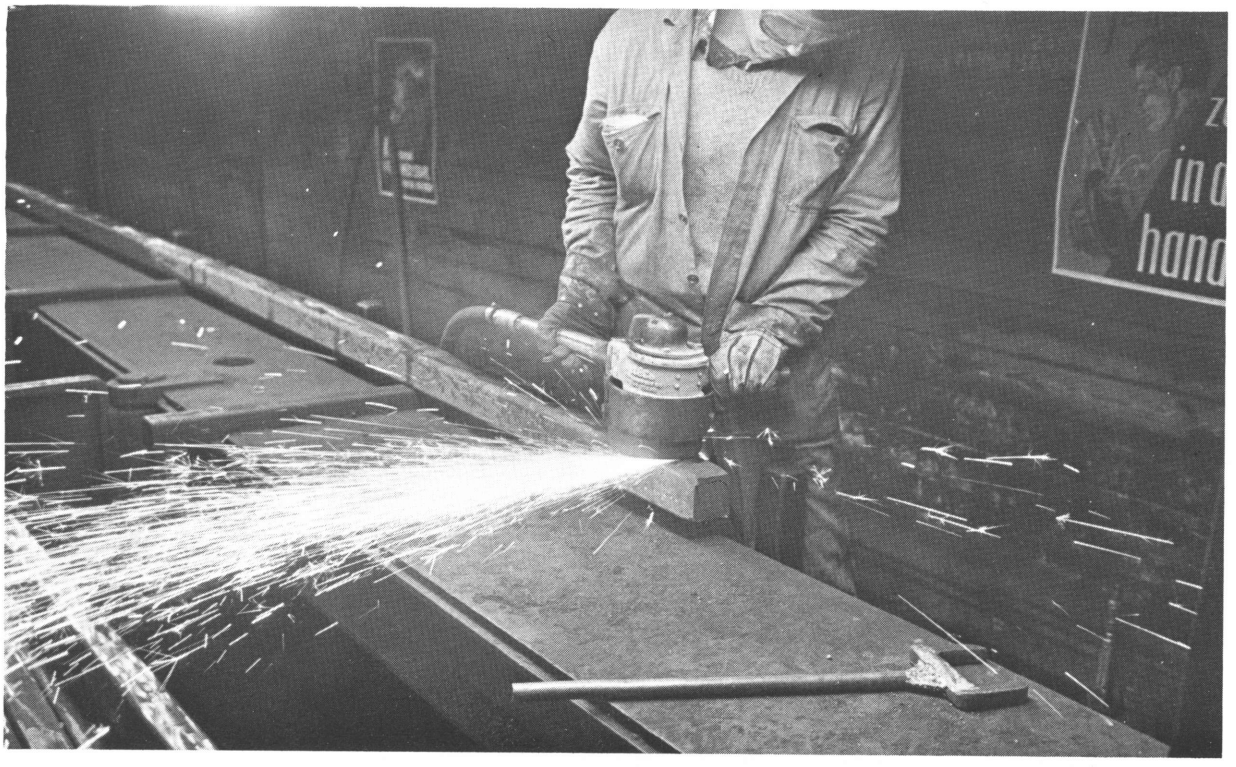


Photo 1

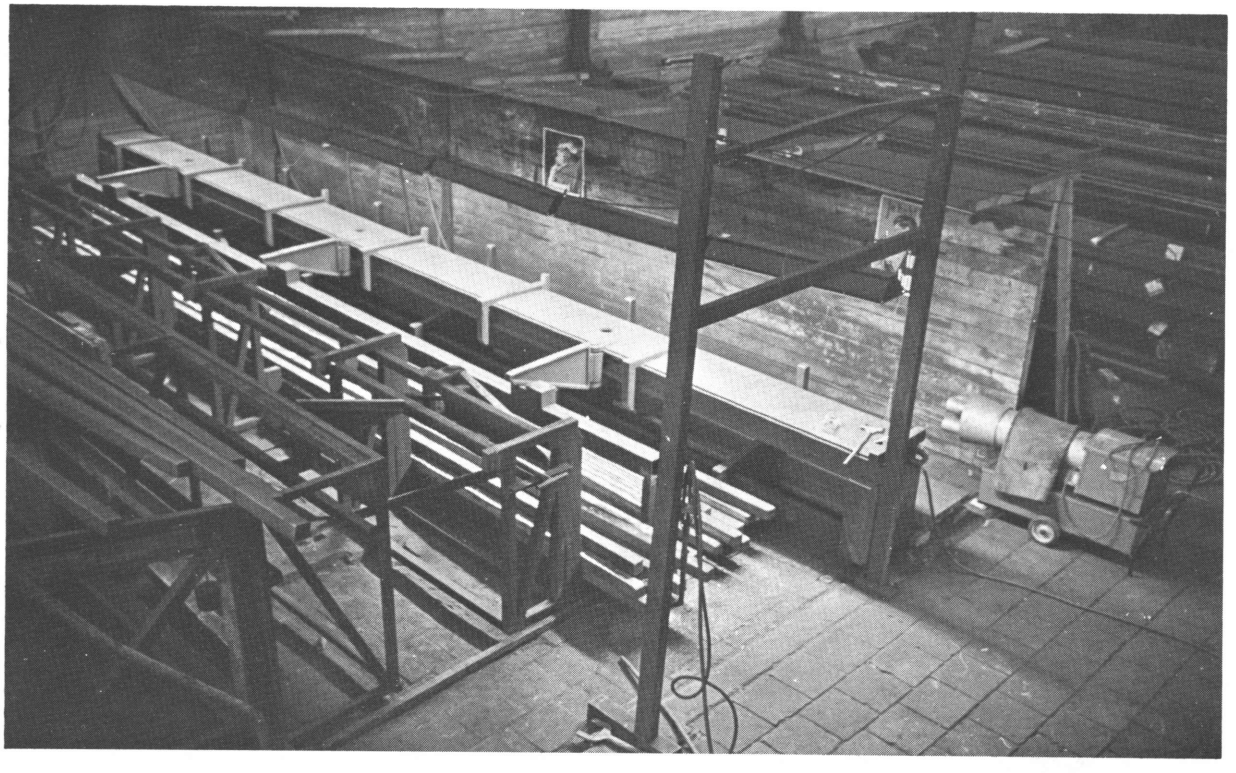


Photo 2

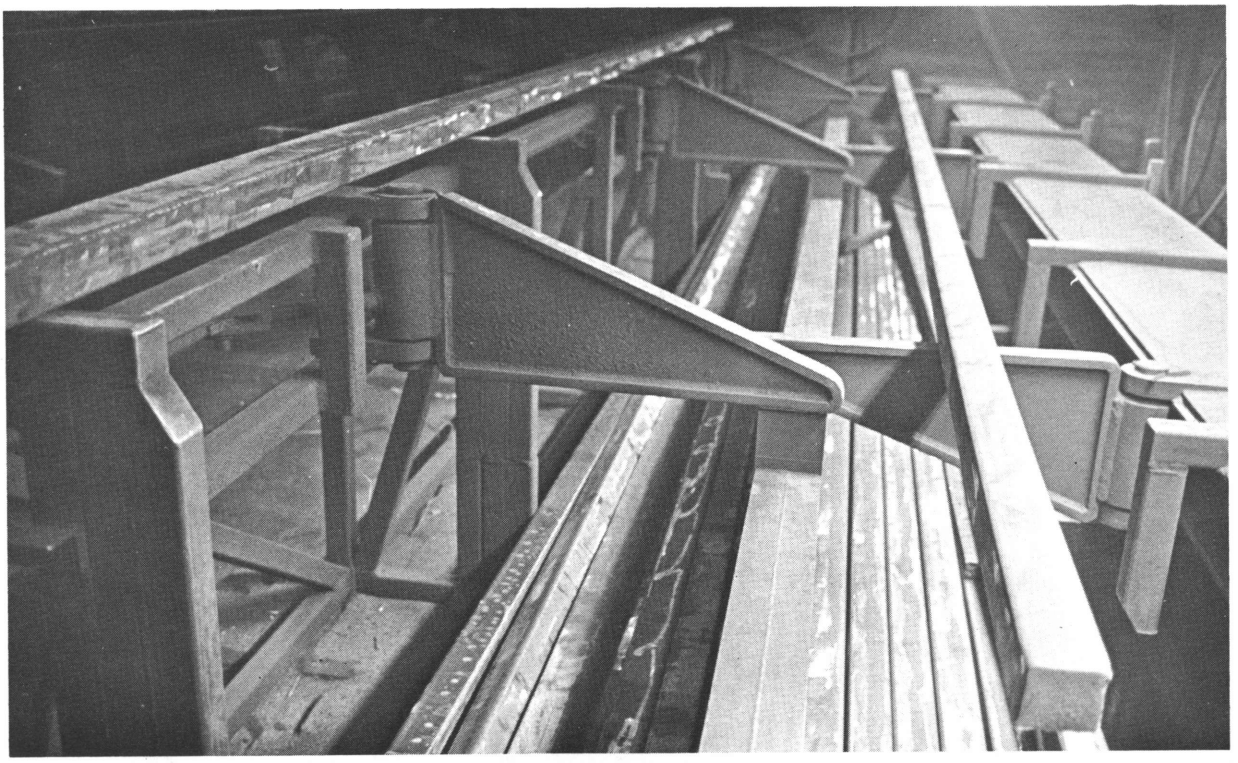


Photo 3

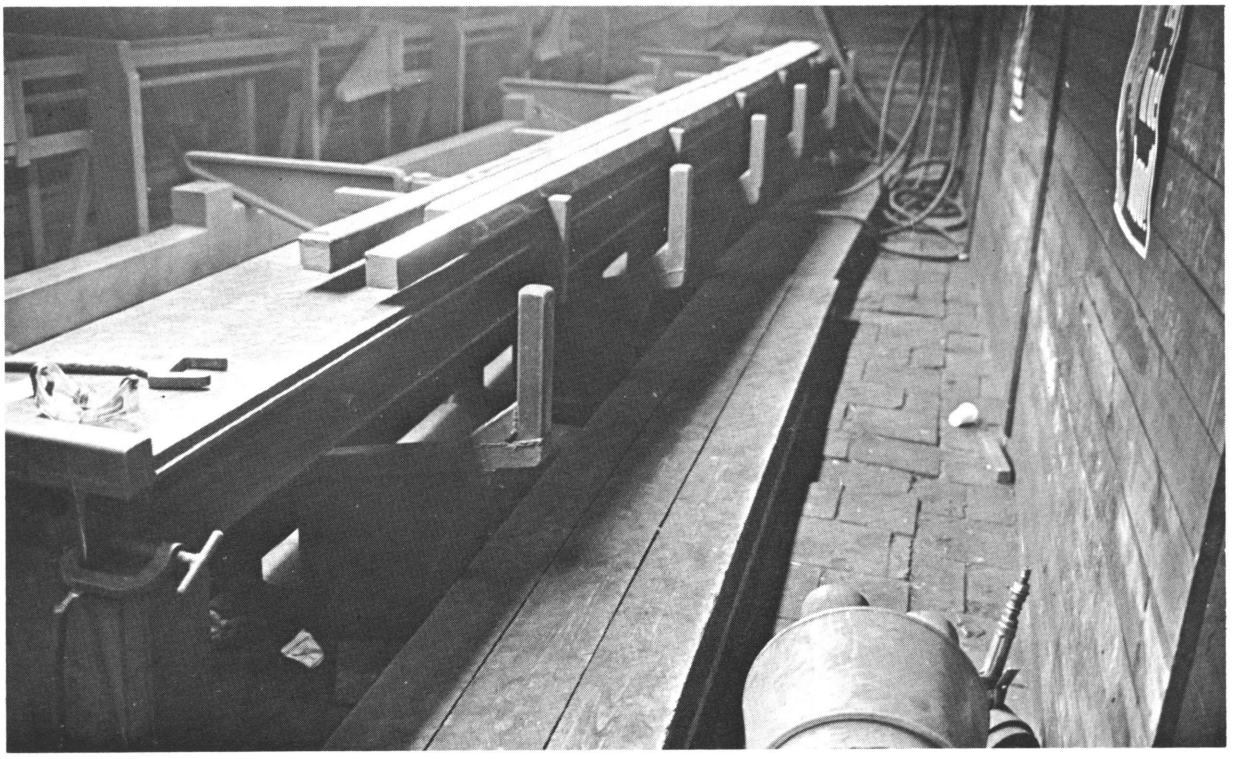


Photo 4

After grinding, 8 billets are chosen at random to check the results of the operation. They are grit-blasted to remove the skin and bring faults more clearly into view.

The billets are then ejected one by one from the grit-blasting installation onto delivery table A (Fig. 1). With the aid of a canting iron (Photo 1, foreground) 3 to 4 billets are rolled onto inspection bench B. Brackets C are turned through an angle of 90° so that the inspector can take up a position between A and B, walking alongside the billets and marking any faults in chalk (Photo 2). Billets for grinding are rolled via D and E to grinding bench F (Photo 3). Billets of too poor a quality are rolled into reject bin G after bracket D has been drawn back. Those that come up to standard are rolled via D into acceptance bin H after bracket E has been drawn back.

Billets for grinding are rolled along to F and, after grinding, fall down the inclined slope to H. Screen K protects the inspector from showers of sparks from the grinding wheels.

Work with an inspector was not a success for a number of reasons. One was that hair cracks in grit-blasted billets were not detected.

Screen K was removed. Billets are now rolled onto grinding bench F and inspected and ground by the grinding machine operator.

No billets are found to be absolutely fault-free.

Billets of too poor a quality to be ground are a rarity. By moving the grinding wheel over the billet with a snake-like movement even hair cracks can be perceived and removed. Use is made of a portable pneumatic grinding machine fitted with a cup wheel.

Posts J (Fig. 1 and Photo 4) were regarded as a hindrance (the operator had to get round them and clothing and air hose tended to catch on them) and were therefore got rid of. Stops were welded to the fore-edge of the grinding bench to prevent billets from slipping off.

They also hold the billet when it is turned over so that it is always positioned at the fore-edge of the bench before grinding.

Contrary to what is shown in Photo 4, only one billet at a time is rolled onto the grinding bench.

Once it has been ground, the billet is rolled into bin H after bracket E has been drawn back.

The weight of the pneumatic grinding machine used (about 8 kg), with the connected hose trailing on the floor, is found inconvenient, as also having to lower the machine to the floor and then pick it up again before and after canting the billet.

The first question to be answered was whether lighter equipment could be used while maintaining or even stepping up productivity.

Basic problem : Given a crack on the surface of a billet, how to remove it while taking off as little as possible of the surrounding material.

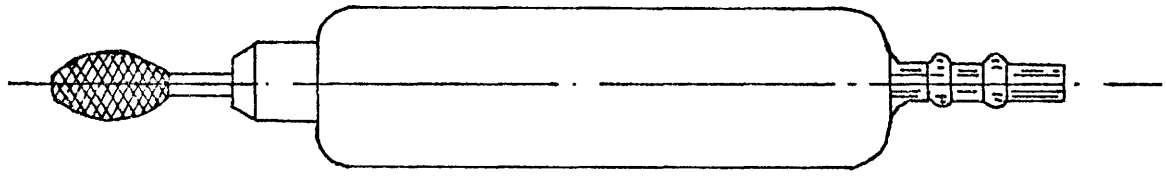


Fig. 2

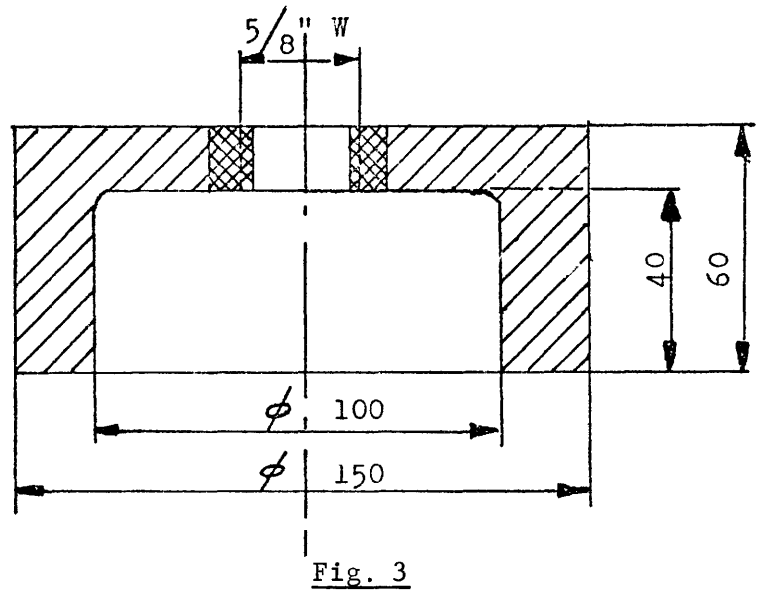


Fig. 3

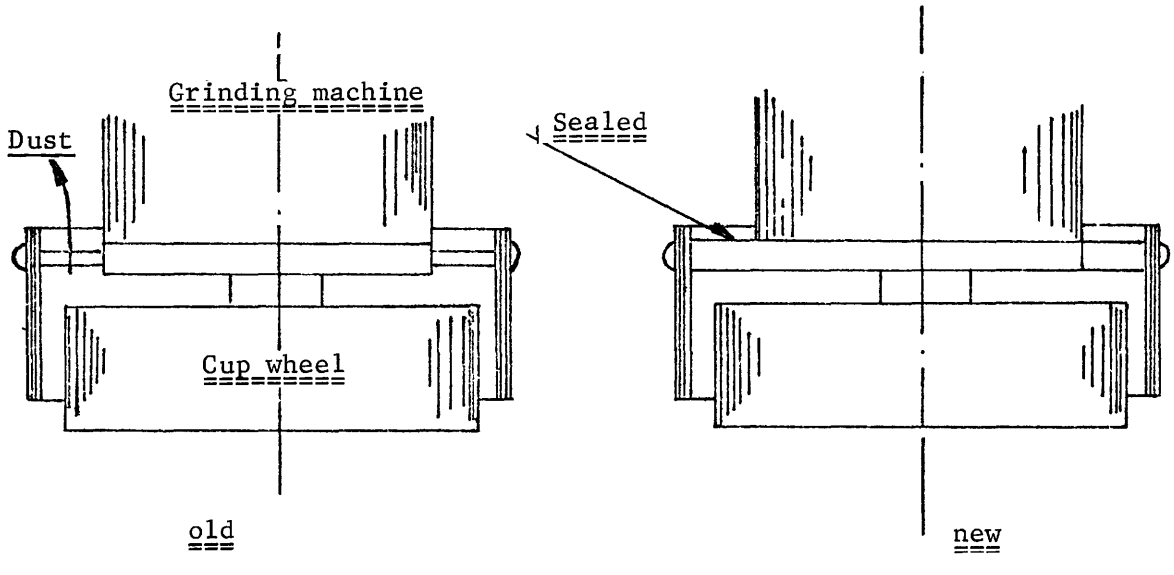


Fig. 4

Test 1

Cracks were removed with a portable pneumatic milling cutter (Fig. 2). The speed of the operation was satisfactory.

Test 2

Cracks were removed with a portable pneumatic straight grinding machine (lightweight, speed 80 m/s) fitted with a 3" diameter straight grinding wheel. Grinding was carried out across the cracks.

Results

1. Great force is needed to hold the cutter or grinding wheel exactly on the crack; this was found to be more tiring than the existing method.

2. The milled or ground surface presented such an irregular pattern that it was impossible, even after the minutest scrutiny, to see whether the crack had disappeared.

3. Any hair cracks in the vicinity of a deep crack were undetectable.

We concluded that the following secondary conditions must be satisfied :

a) The process must yield a regular surface finish on which it can be seen whether a crack has disappeared.

b) It must facilitate detection of minor flaws in the vicinity of the main fault.

c) The tool (grinding wheel or cutter) must be such that it can be held at the desired spot without excessive effort.

d) Grinding lines must not run along the direction of the crack as otherwise it cannot be seen whether this has disappeared.

On further investigation we found that the methods described under Tests 1 and 2 were not very successful and therefore abandoned them.

Test 3

Tests were carried out with an angle grinding machine and a cup wheel. This is the same type as we have always used except that the wheel diameter was 4" instead of 6" and the machine was lighter and faster, so that grinding speed remained unchanged at approx. 45 m/s. Total weight was 5 kg as against 8 kg with the machines we normally use. (The grinding wheel made an angle of about 15° with the surface of the billet).

Results

1. Greater pressure had to be applied to the grinding machine to remove (by feel) the same material per unit of time.

2. More effort was needed to keep the appliance on the desired spot.

3. The grinding pattern was satisfactory.

Test 4

A new grinding test (grinding angle approx. 15°) was carried out with an angle grinding machine fitted with a wheel (9" diameter, 8 mm thick) turning at 80 m/s.

Results

1. The grinding pattern was satisfactory.
2. The results depend closely on correct pressure. The appliance had to be raised a trifle because even a slightly heavier pressure led to discoloration of the ground surface.
3. The appliance is very difficult to keep under control.

From these tests we came to the following conclusions :

1. For any given case there must be an optimum grinding pressure.
2. The grinding machine must have a certain mass if it is to be kept at the desired spot without excessive effort.
3. The cup grinding wheel is the right choice but as it is not (yet) made for a grinding speed of 80 m/s we cannot avail ourselves of it. (We have been unable to interest any grinding wheel manufacturer in making it).

Test 5

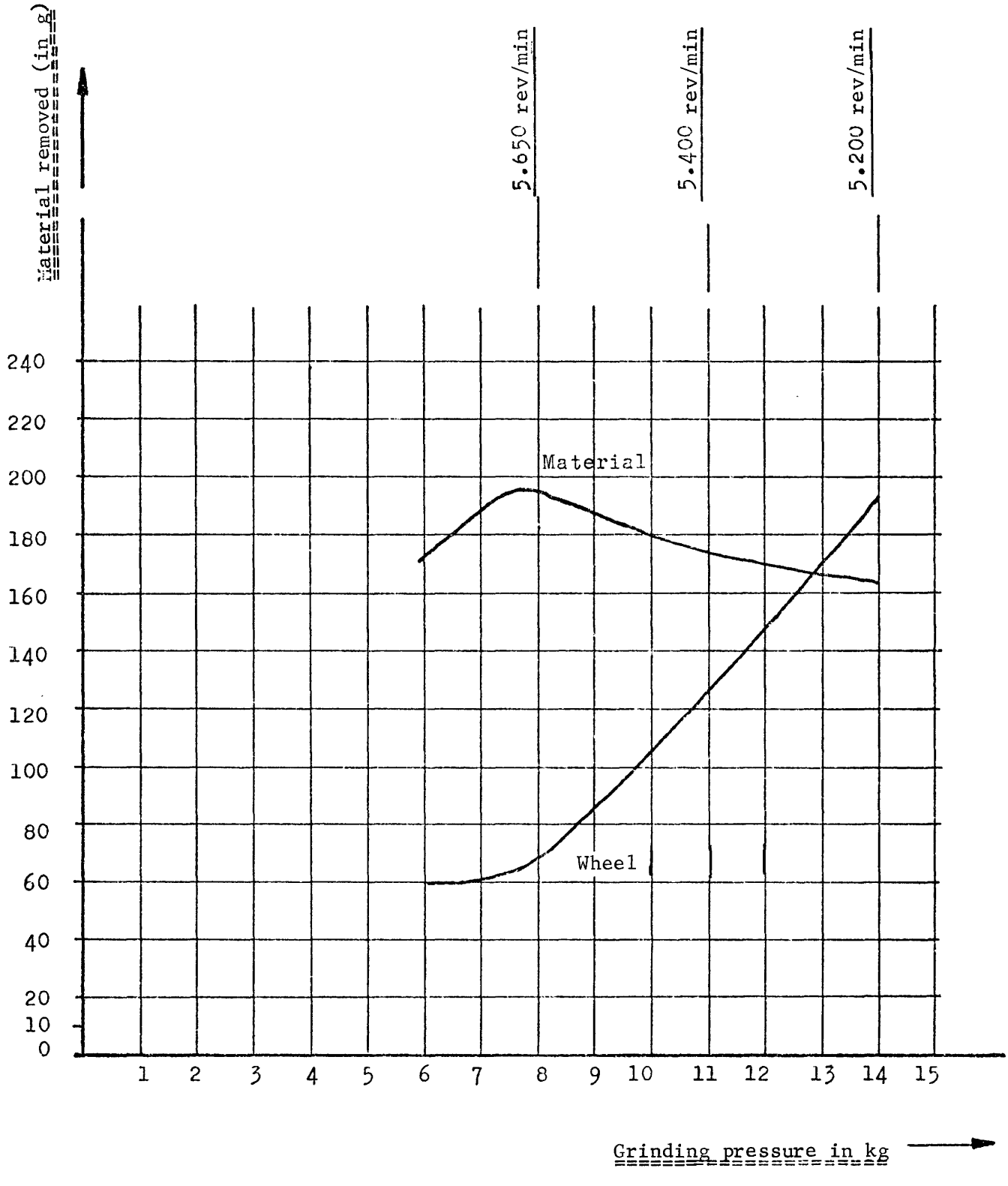
On our instructions, Grasso Perslucht N.V. of Rotterdam carried out tests to determine the optimum grinding pressure.

Description of test

A portion of billet and a new cup wheel were weighed. The portion of billet was then placed on a balance and ground for 5 minutes with the cup wheel, under a constant pressure checked by reading off the scale of the balance.

The portion of billet and cup wheel were then reweighed and the loss in weight of both was calculated.

Optimum grinding pressure on steel 60
with 150 mm diameter cup wheel



Grinding time : 5 min

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The test was repeated a number of times under the same grinding pressure, and mean values were noted down. This was done for grinding pressures of 6, 8, 11 and 14 kg. The values recorded were plotted on a diagram (optimum grinding pressure).

The spindle speed of the cup wheel was stroboscopically determined. The conclusion reached was that the optimum pressure lies between 7 and 8 kg. The combined weight of grinding machine and new wheel is approx. 7,5 kg.

In the light of this knowlege we instructed grinders to exert no pressure or only slight pressure. Like us they had thought it necessary to press down on the grinding machine in order to remove more material per unit of time. It is too early to say whether this measure will prove effective since five other factors affect wear of the wheel per unit of time.

The grinding machine of this weight has sufficient mass to enable it to be held easily in the hand; moreover, it can be steered without much effort.

Test 6

At our request, a comparative study was made to enable us to choose the right grinding wheel for different qualities of steel. The following wheels were tested :

- Masolite Normaal Bakelite 24 L 5 Wheel No. 1
- Masolite Normaal Bakelite 24 N 5 Wheel No. 2
- Masolite Normaal Bakelite 16/20 N 5 Wheel No. 4
- Masolite Normaal Bakelite 24 O 5 Wheel No. 3
- Masolite Normaal Bakelite 16/20 O 5 Wheel No. 5

These wheels were tried out on the following billet samples :

- Billet sample No. 1, quality Cq 45
- Billet sample No. 2, quality Cq 15
- Billet sample No. 3, quality Cq 35 Cr
- Billet sample No. 4, quality St 90
- Billet sample No. 5, quality 67 Si Cr 5.

Quality

	Cq 45	Cq 15	Cq 35 Cr	St 90	67 Si Cr 5
			Guide analysis in %		
C	0.46-0.50	0.12-0.18	0.35-0.39	0.76-0.80	0.64-0.70
Mn	0.60-0.80	0.25-0.50	0.55-0.70	0.55-0.70	0.40-0.60
P max	0.030	0.030	0.040	0.025	0.025
S max	0.040	0.040	0.040	0.040	0.035
Si	0.15-0.30	0.15-0.35	0.15-0.35	0.15-0.30	1.15-1.45
Cr			0.15-0.25		0.40-0.60

The grinding wheel measured

180 x 35/26.5 x 15.9.

Grinding pressure was 12 kg.

The whole constituted a mechanical assembly in which grinding pressure and spindle speed were kept constant.

The results are shown in the diagram "Behaviour of 5 grinding wheels with respect to different qualities of billet".

The ratio $\frac{\text{material removed from billet in g/min}}{\text{wheel wear in g/min}}$ (Q factor) gives values deviating from those found in determining optimum grinding pressure. This is probably due to :

a) the larger grinding wheel
b) the constant spindle speed
c) the constant and higher grinding pressure.

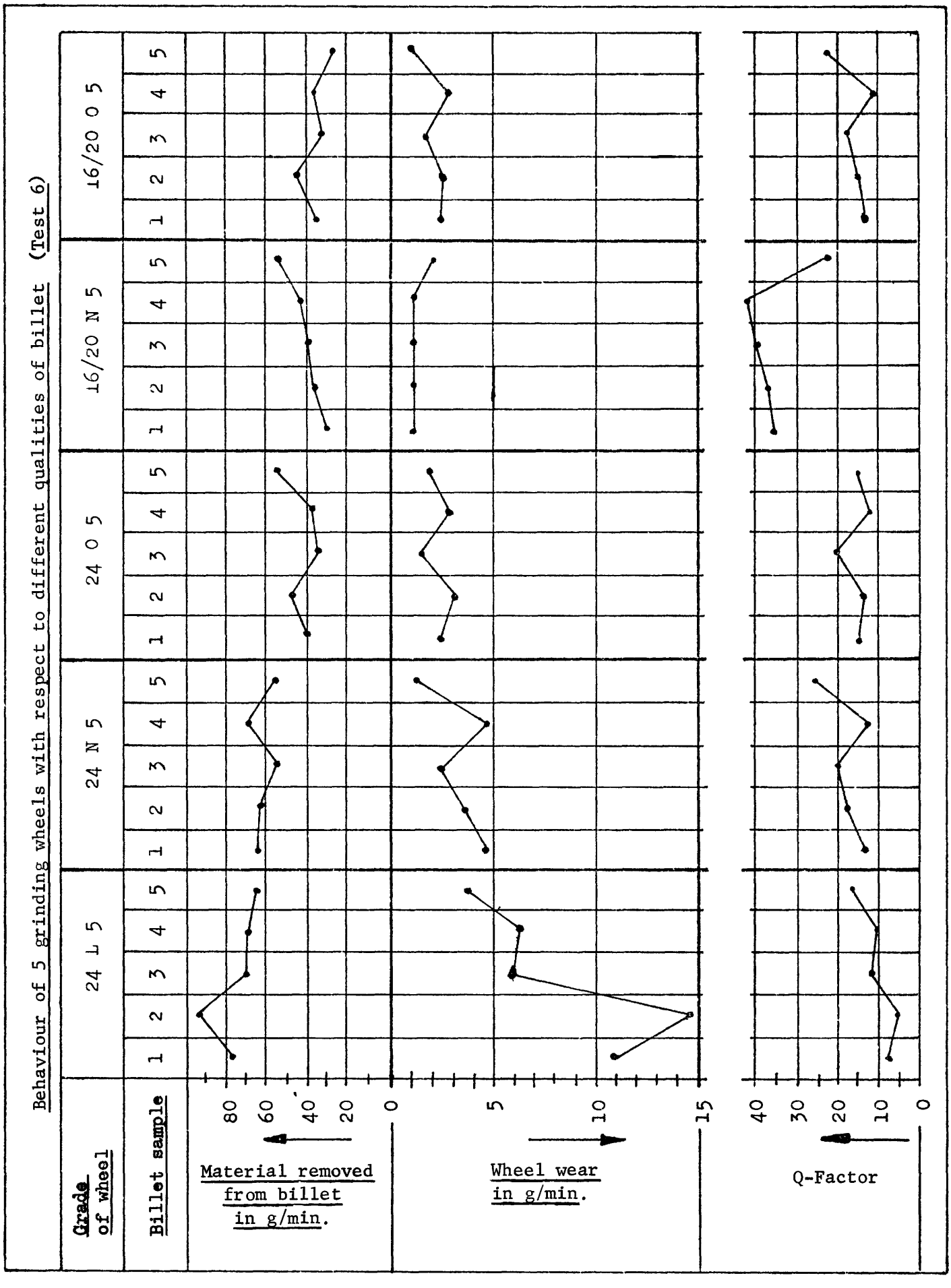
The weight of 5 new cup wheels was found to be 10,600 g and that of 5 worn cup wheels 5,900 g. In other words, weight loss was 940 g per wheel. The diagram "Optimum grinding pressure" shows that at a pressure of about 8 kg the wheel lost weight at 65 g per 5 minutes, or 13 g/min. A weight reduction of 940 g thus corresponds to a grinding time of $\frac{940}{13}$ = 72 minutes.

In practice, with a quantity of several hundred tons of billets to be ground, it was found that grinding one ton of billets required 4 man-hours and 2 cup wheels, i.e. 120 man-minutes per wheel. Of these 120 minutes, 72 were spent in grinding, the remainder in inspection, materials handling, attending to personal needs, etc.

At a price per man-hour of 13 Guilders, 72 man-hours cost 15.60 Guilders. A wheel costs 10 Guilders.

It follows that "material removed from billet in g/min" rates higher than wheel wear.

The diagram "Behaviour of 5 grinding wheels with respect to different qualities of billet" calls for the following comments :


Behaviour of 5 grinding wheels with respect to different qualities of billet (Test 6)
Grade of wheel
Billet sample
24 L 5
24 N 5
24 O 5
16/20 N 5
16/20 O 5
1 2 3 4 5
Material removed from billet in g/min.
80 60 40 20 0
Wheel wear in g/min.
15 10 5
Q-Factor
40 30 20 10 0

Wheels of hardness O are too hard for portable grinding machines and have a tendency to "waltz". From the production planning point of view we prefer one grade of wheel for all types of billet. Grade 24 L 5 is to be avoided because of the unfavourable Q-factor for Cq 45 and Cq 15 steels.

There remain therefore grades 24 N 5 and 16/20 N 5. As we are always working under capacity, our choice fell on grade 24 N 5. Although it wears more rapidly, it cuts down on grinding time. Specification : normal corundum, grain size 24, hardness N, structure 5, Bakelite-bonded. For dimensions, see Fig. 3.

Test 7

The grinding machines used were on average some six years old. We arranged for Grasso Perslucht to compare them for performance with a new model, the Grasso S66/60. In both cases the maximum speed is 6000 rev/min.

Results

Grinding machine type	Grasso S66/60	Old model
Max. power	3.85 CV*	2.48 CV
Weight without wheel	5.2 kg	7.0 kg
Speed at max. power	5250 rev/min	4000 rev/min
Speed at identical power	5700 rev/min	4000 rev/min
Air consumption at 2.48 CV	2.25 m^3/min	2.9 m^3/min
Air consumption, when idling	0.85 m3/min	1.82 m^3/min
Air consumption per CV at max. power	0.64 m^3	1.15 m^3

* Cheval vapeur, equivalent to 75 kg m/s or 1.986 h.p.

The maximum power of the Grasso model lies between 5000 and 5500 rev/min.

As labour costs are many times higher than the cost of a grinding machine, a maximum performance model gives the most economical results.

We decided to purchase new grinding machines, and in future the economical service life will take precedence over the technical.

As intense use is made of the grinding machine, a number of their drawbacks came to light in the course of the investigation :

1. The hard-plated stator has a life of only a few weeks. The manufacturer is now making it from quenched steel, prolonging its useful life to 2 months.

2. The bolts with which the protective cap is fixed to the base plate still snapped at times. Moreover, grinding dust reached the operator's face via the gap between the wheel and cap. The base plate was then enlarged and the gap sealed so as to prevent dust escaping, and the protective cap was reinforced (Fig. 4).

Test 8

Problem

To work out a design that would eliminate the inconvenience caused by the hose trailing on the ground and enable the operator to dispose easily of the grinding machine when he has to handle the billet.

Theoretical solution

1. Hang up hose in such a way that it readily follows movements carried out during grinding operations.

2. Suspend the grinding machine from a wire, hoisting it upwards when not in use. The wire must not drag on the appliance during grinding.

Practical set-up

The hose was suspended from a rail (Photo 5) on fittings that slide so smoothly as to cause no hindrance. The grinding machine was suspended by a length of wire from an air cylinder fixed to a crab travelling along a beam (Photo 5). Later it was found that the entire assembly could be attached to a single runner if the rail was slightly strengthened (Photo 6).

The air cylinder operates as follows. If the intake to the grinding machine is cut off, the intake to the underside of the cylinder opens and the grinding machine is hoisted upwards.

If the intake to the grinding machine is opened, air flows to the upper part of the cylinder and the grinding machine is lowered. Both operations are automatic (see Photos 6 and 7).

Photo 8 shows the slack in the suspension wire. In Photo 9 the grinding machine hangs freely in space while the operator handles the billet.

As we did not know whether all this equipment would function as we expected, and as some secondary drawbacks might be encountered, we decided to rig up an unsophisticated apparatus. This primitive

assembly is shown in Photos 5 to 9. As no such drawbacks were met with, we settled on a final canopy assembly with some changes in a number of technical details.

In the meantime this canopy has been installed.

As grinding machines tend to freeze up during the winter months under the influence of air expansion, ample air ducts fitted with condensation traps were provided and anti-freeze added to the lubricant (which enters the air duct automatically).

Working with suspended grinding machines did not turn out to be a particular success. The grinding shop housed three grinding benches over one of which the machines were suspended.

Whenever there was a shortage of grinders it was always that bench that was deserted. On enquiry we were told that the drawing power of the grinding machines in question was less than that ot the others. We then fitted larger diameter air ducts and connections. Air pressure was then measured by means of a manometer applied to the grinding machine intake. Readings were found to be the same at all benches. The grinders were then given a free choice of bench and once again preferred the old situation.

Operators complained of the trouble involved in unhooking the grinding machine once or twice an hour, disconnecting the high-speed coupling of the small control hose, and uncoupling the air hose before fitting a new wheel and then repeating the process in reverse.

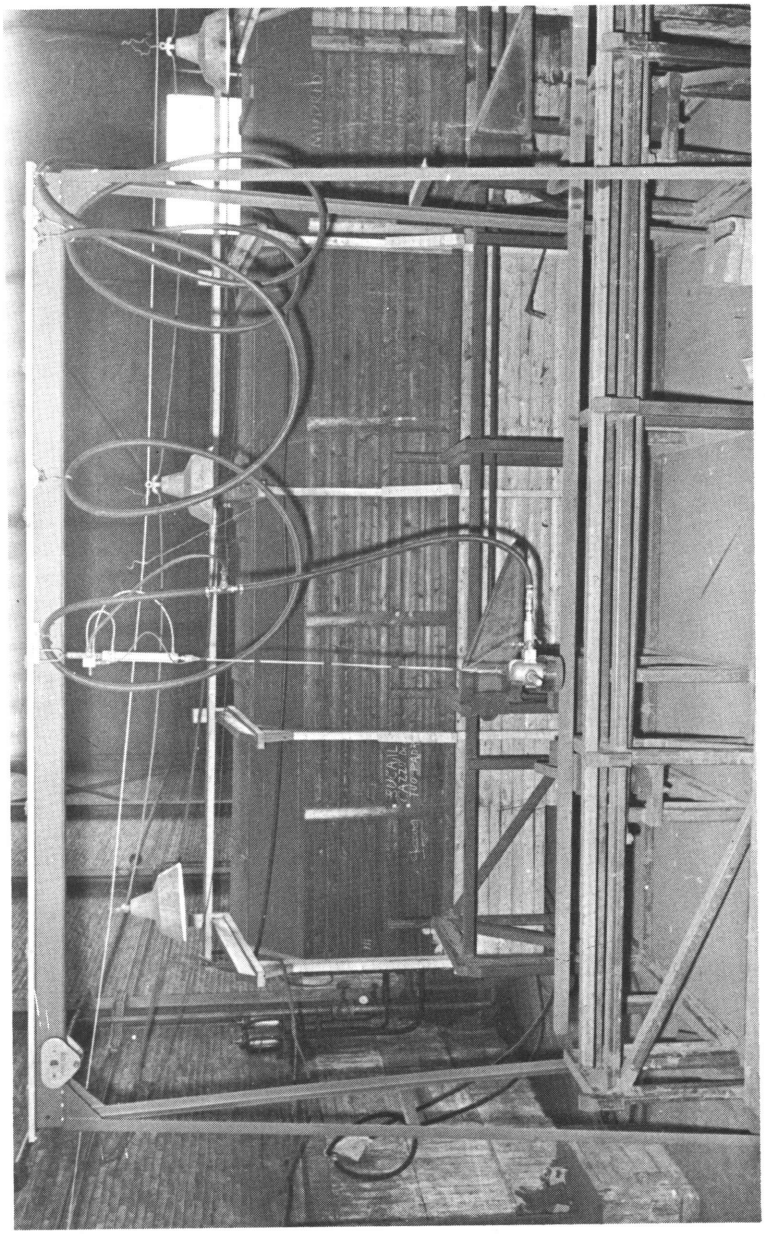


Photo 5

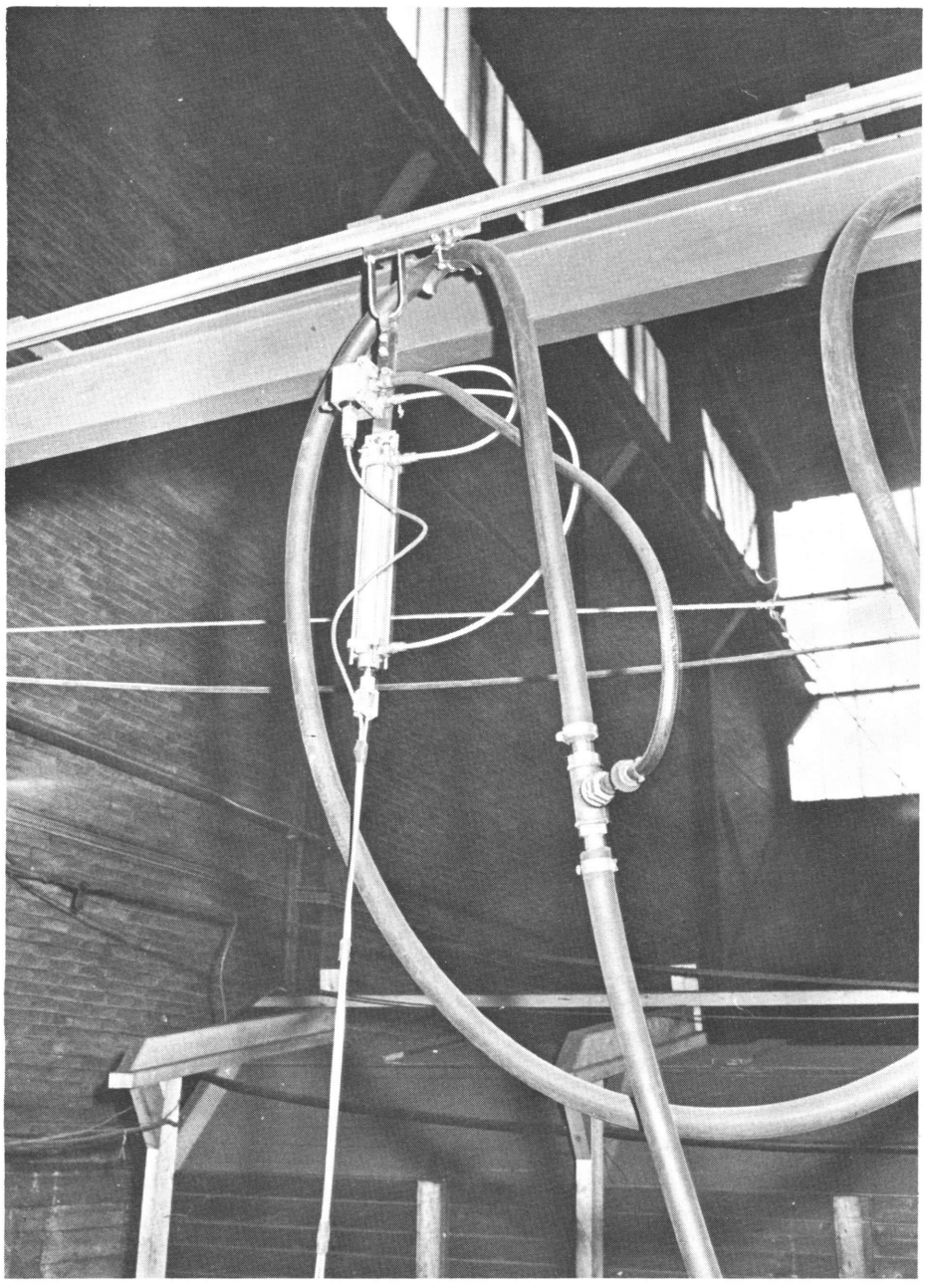


Photo 6

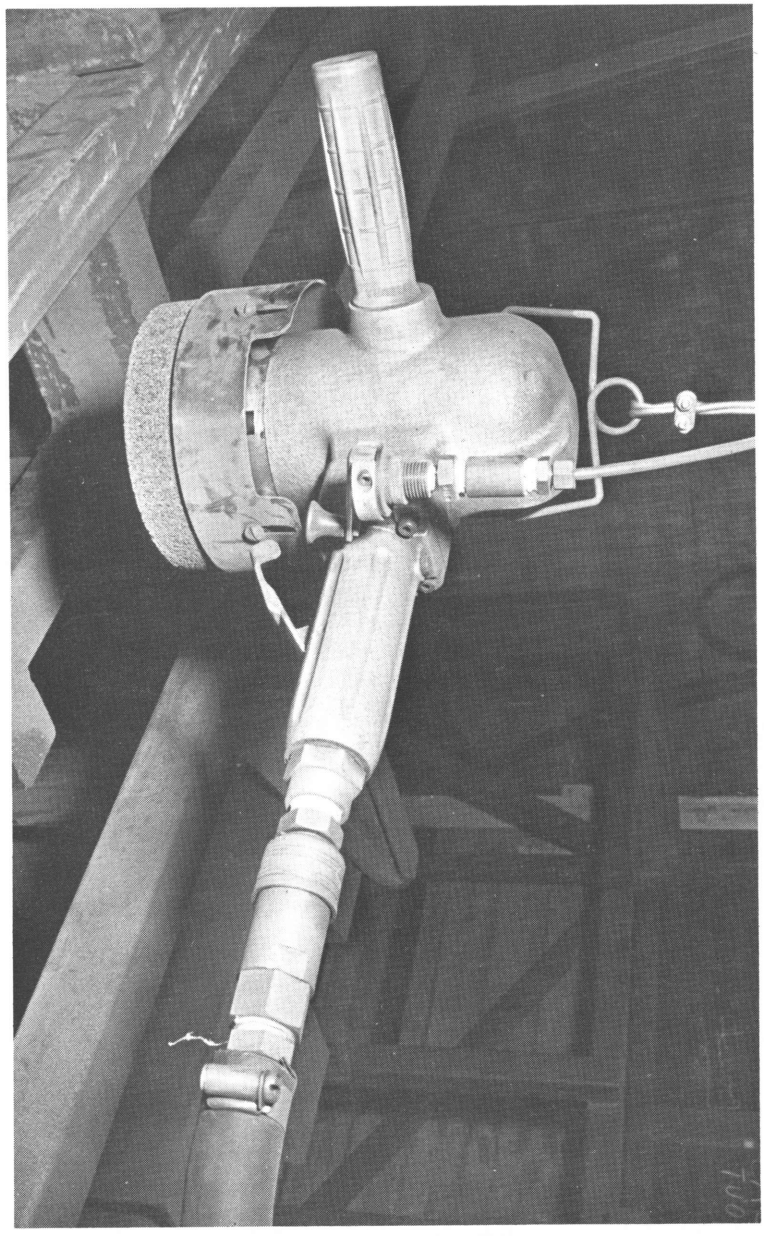


Photo 7

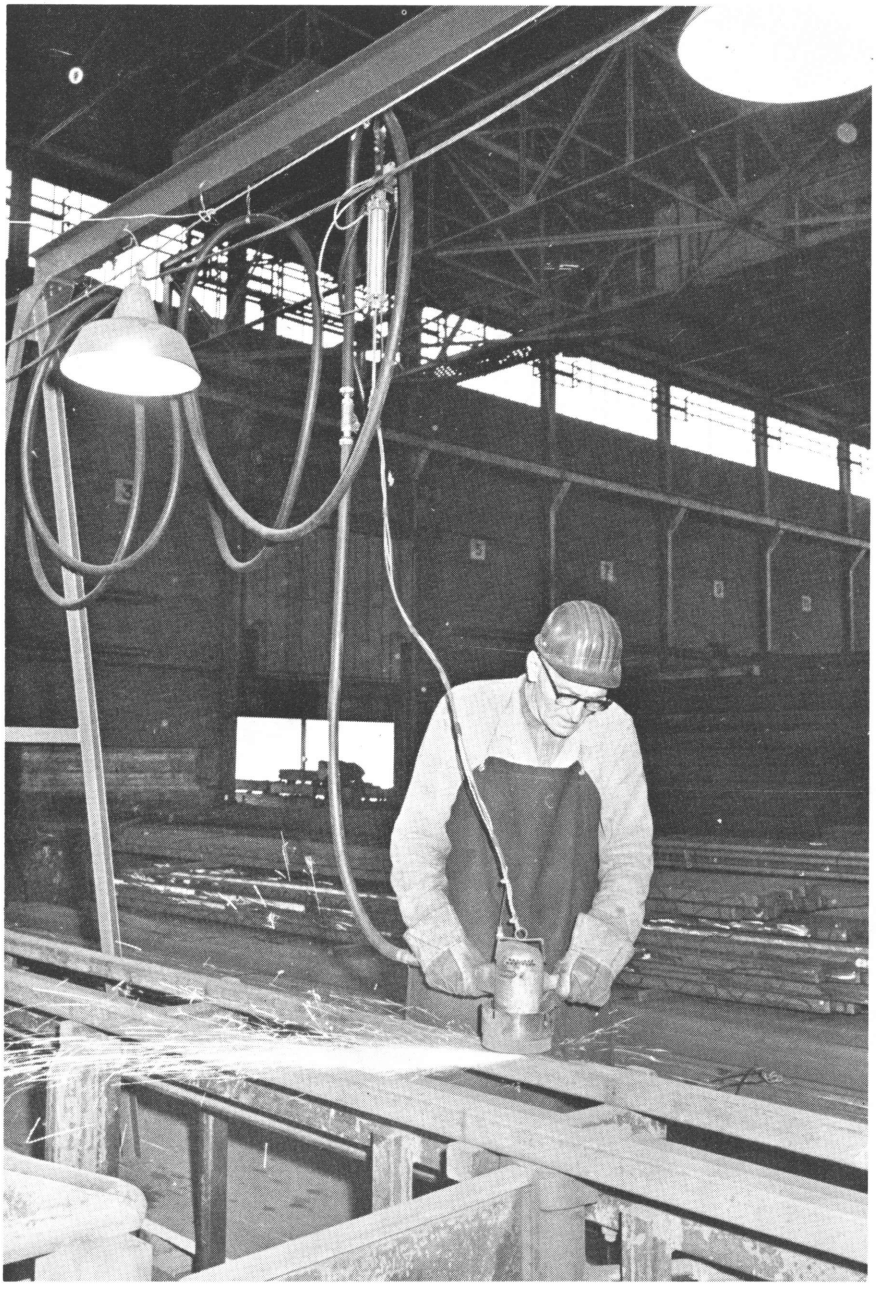


Photo 8

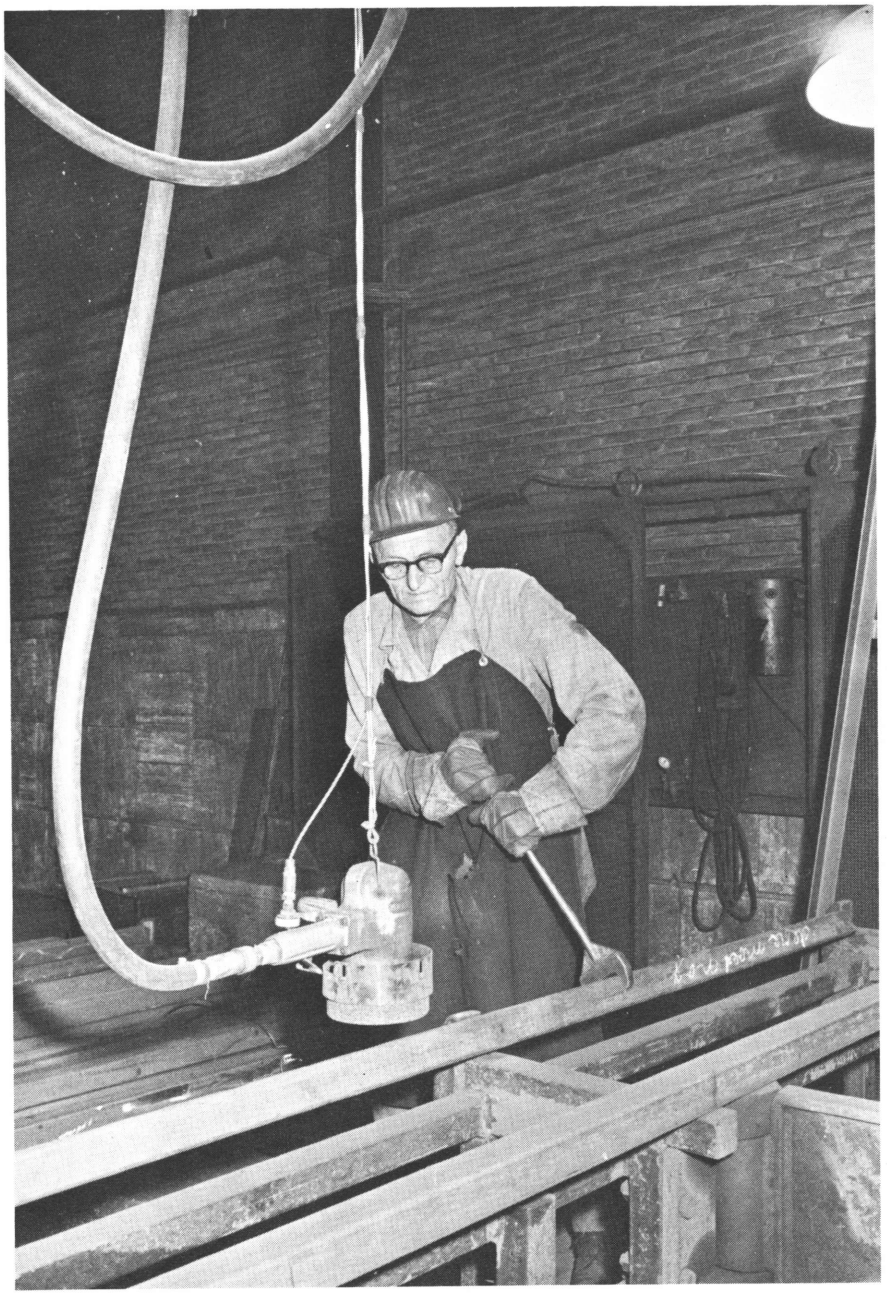


Photo 9

We did not adopt this working method for the following reasons :

a) It seems likely that the job stress on billet grinders is not very high, and the reduction in this brought about by hanging up the grinding machine is too slight to reconcile operators to making the effort once or twice an hour. This was borne out by measurements.

b) The introduction of any innovation runs up against psychological resistance.

c) The installation of a canopy and the suspension of hoses and grinding machines involves considerable expenditure, i.e. approx. 13,000 Guilders per bench. We did not consider this justified as in the old situation grinders did not complain of fatigue. Furthermore, output did not rise in the new situation.

Grinders would like to see the following requirements met :

- adequate air pressure (preferably as high as possible);
- grinding machines in sound technical condition;
- good heating in winter;
- good ventilation in summer.

Test 9

Both in the old and in the new situation the metabolism and cardiac frequency of grinders were determined during work. The "Nederlands Instituut voor Preventieve Geneeskunde TNO" (Netherlands Institute of Preventive Medicine of the Netherlands Central Organization for Applied Science Research) carried out this study. Its report is reproduced in full in the following pages.

REPORT ON AN OCCUPATIONAL PHYSIOLOGY STUDY CARRIED OUT ON BILLET GRINDERS

at NKF STAAL N.V., Alblasserdam on 16 December 1969
within the framework of

COMMUNITY ERGONOMICS RESEARCH

Object of the study

To determine the influence of a number of ergonomic improvements in working methods on the job stress involved in billet grinding.

Introduction

In June 1968 a preliminary study was made of the job stress involved in grinding billets with pneumatic grinding machines. This showed that the work entailed a calorie consumption of 4 - 6 kcal/min. The work therefore rated as moderately hard. A number of changes in working methods and working environment were then thought up and put into effect. The study here reported on is confined to aspects that might be expected to influence the physical stress attendant on actual grinding (Fig. 1). This arises from hanging up the compressed-air hose and the automatic hoisting of grinding machines when not in use, so as to avoid the need to lay them down and lift them off the ground (Fig. 2).

Study programme

The programme of measurements was designed to ensure that one and the same experimental subject had to use, for two consecutive periods of about 20 minutes each, the new and the old accessories, the grinding machine and grinding job being kept as nearly constant as possible. Four subjects differing in physique and age took part

in the tests. For organizational reasons the same sequence was followed in each case. Had the study been planned on a wider scale, it would have been better to alternate between the old and the new working method.

The criterion chosen for measuring job stress was oxygen consumption, which was measured continuously with the portable apparatus developed by NIPG-TNO (Netherlands Institute of Preventive Medicine of the Netherlands Central Organization for Applied Science Research) (*).

Electrical signals, giving the volume of air inhaled and the difference in oxygen content of air inhaled and exhaled, were transmitted through a cable, together with the electrical changes during contraction of the muscle of the heart, to a recording unit set up in the shop concerned. The signals, which were recorded on magnetic tape, were then automatically reproduced in the laboratory with the aid of a multi-channel recorder. Simultaneously, the regular activities involved in grinding were recorded by means of a keyboard, so that a study could be made of the relationship between oxygen consumption, cardiac frequency and the activities in question.

During each test, air was collected for a few minutes as it issued from the automatic apparatus so that it could be calibrated volumetrically and by conventional gas-analysis (Fig. 3).

(*) BLEEKER, J. and M. HOOGENDOORN (1969) : Draagbare apparatuur voor het continu meten van het zuurstofverbruik tijdens het verrichten van arbeid.
Polytechn. T. (Procestechn.) 24 (1969) 19-23.

BLEEKER, J. and M. HOOGENDOORN (1969) : A portable apparatus for continuous measurement of oxygen consumption during work.
Acta physiol. pharmacol. neerl. 15 (1969) 30.

BONJER, F.H. (1969) : Application of a portable apparatus for continuous registration of oxygen intake.
Acta physiol. pharmacol. neerl. 15 (1969) 32.

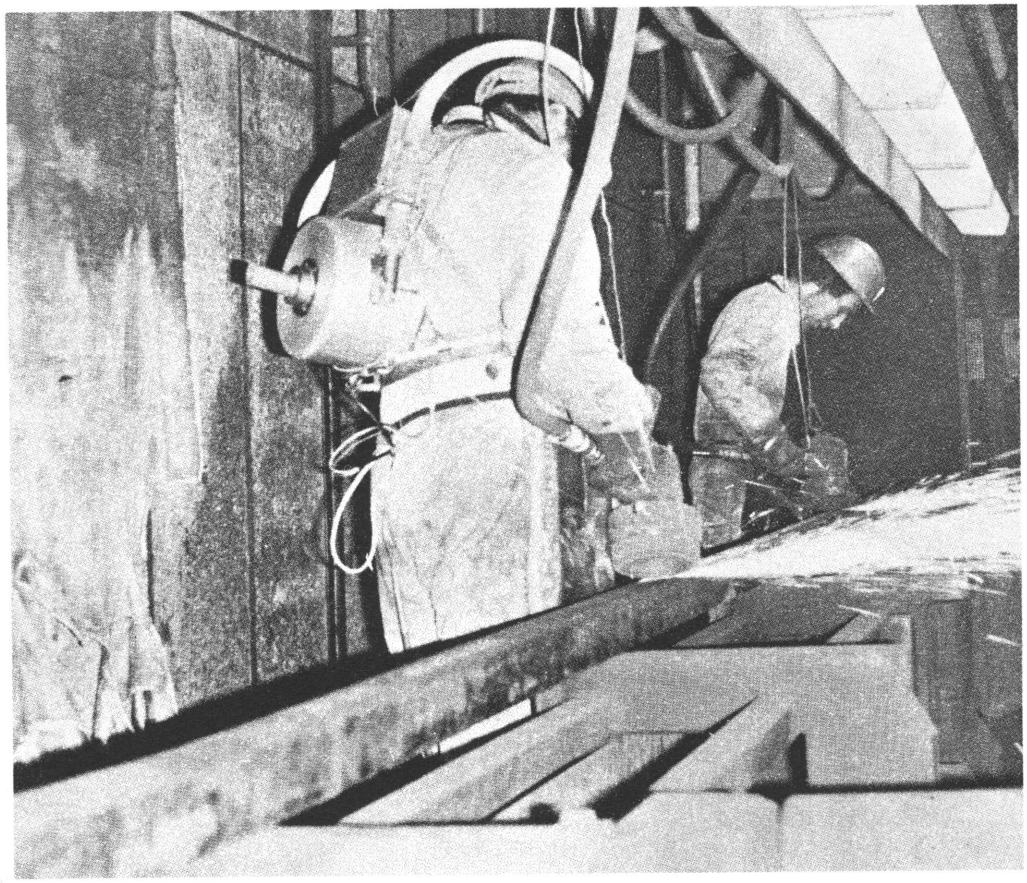


Fig. 1

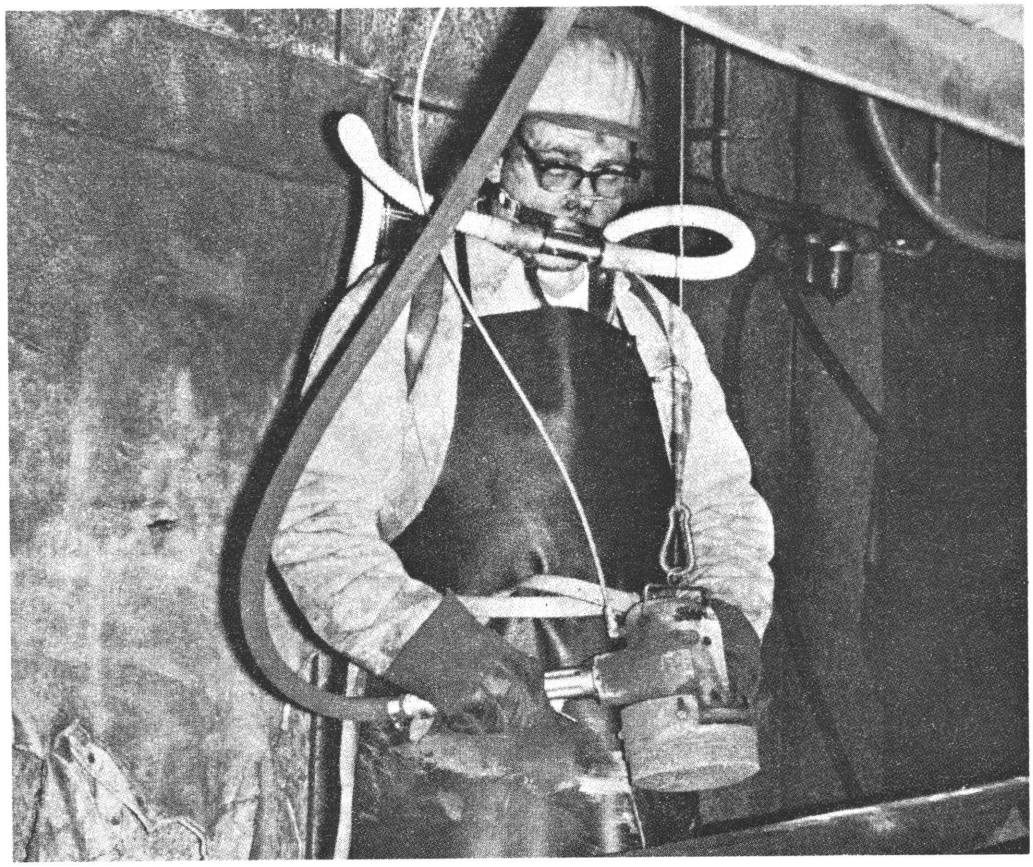


Fig. 2

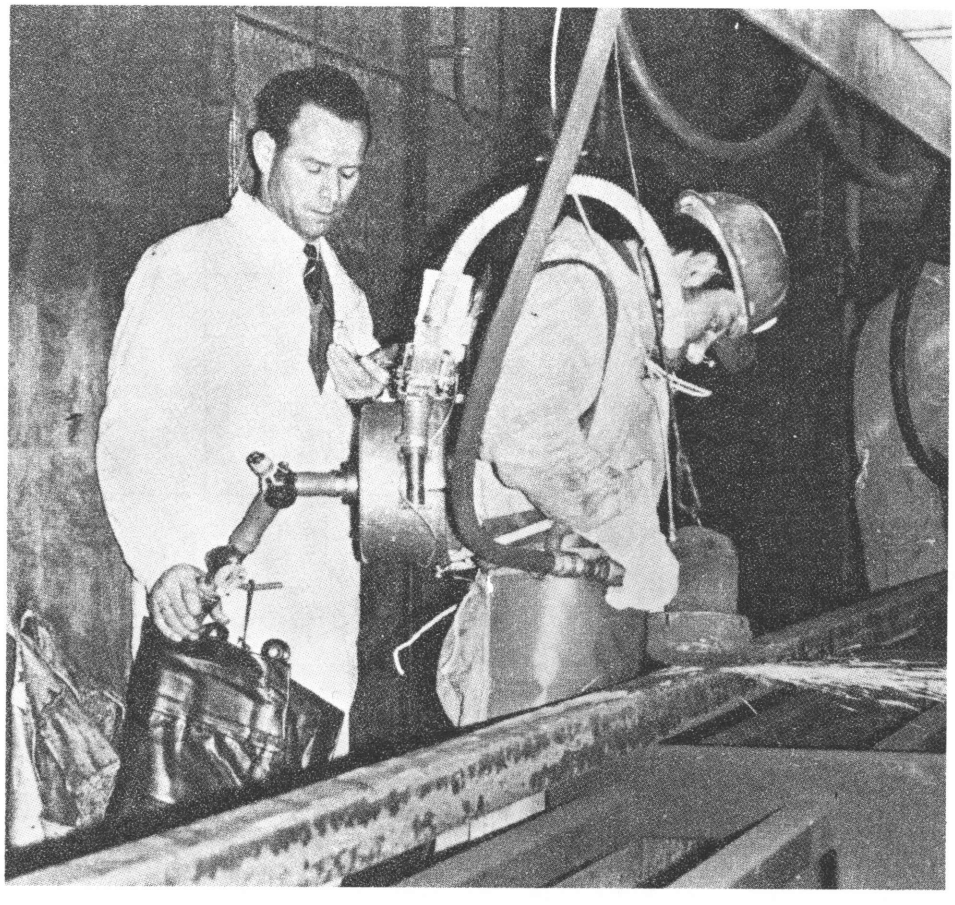


Fig. 3

The tests were performed at an air temperature around 4°, at which the apparatus at first did not function satisfactorily. The difficulties were overcome by introducing artificial heating.

Results

The following data concerning experimental subjects are of significance in judging the results :

Initials	Date of birth	Height in m	Weight in kg
C.V.	7.7.27	1.80	67-68
C.J.L.	27.5.34	1.96	110
W.K.	14.4.49	1.73	70
T.J.M. de G.	18.7.46	1.95	118

A distinction was made between the following activities :

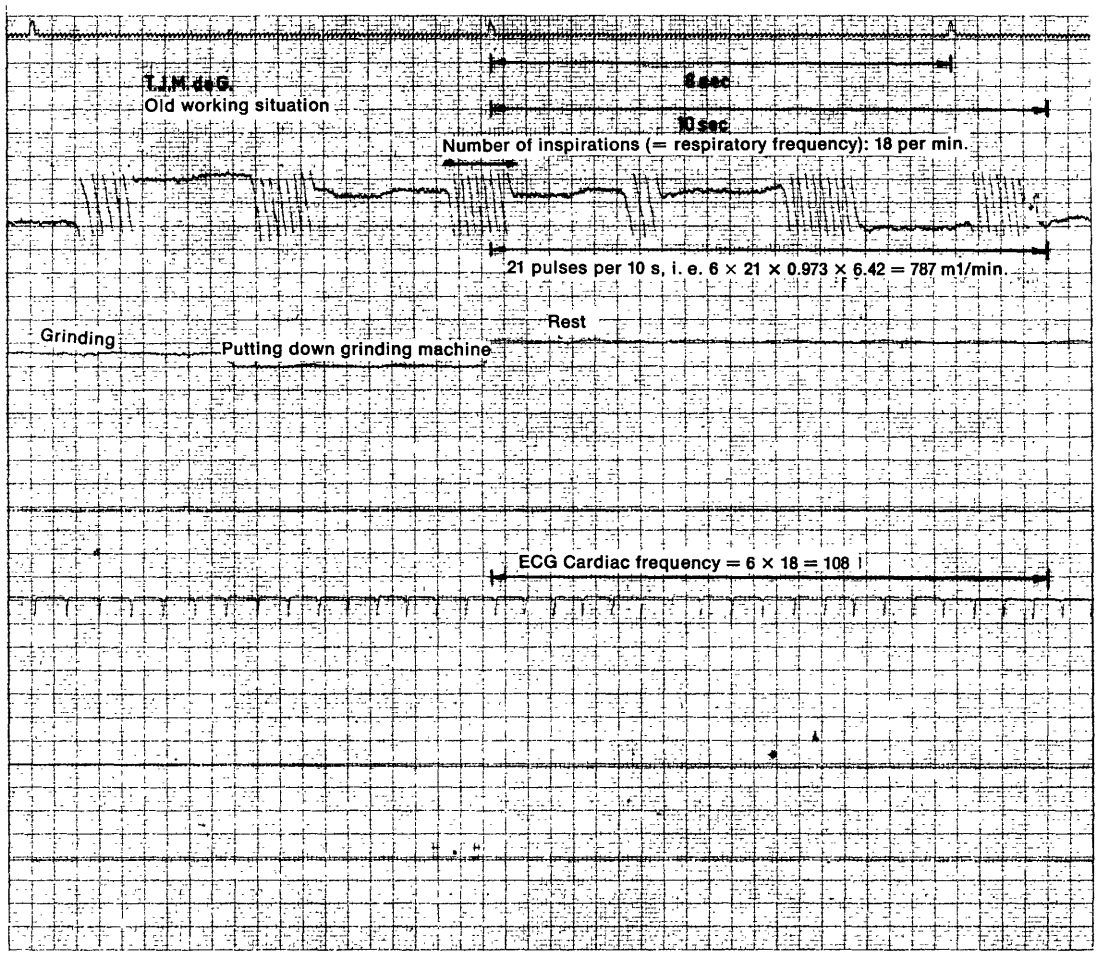
1. rest - zero level
2. grinding
3. putting down the grinding machine
4. lifting up the grinding machine
5. canting the billet
6. inspecting the billet
7. rolling billet down
8. positioning the new billet
9. changing the grinding machine
10. connecting/disconnecting the calibration bag

An example of recording is given below (Fig. 4), showing time base, recording of oxygen inhaled, nature of the activities, and electrocardiogram. From this can be obtained the respiratory frequency, oxygen consumption and cardiac frequency corresponding to the various activities. Each pulse group corresponds to an inhalation. The number of pulses per group or per unit of time is a measure of oxygen consumption. To compensate the influence of temperature and atmospheric pressure, a correction factor was applied - in the present case 0.973. The calibration factor, i.e. that by which the number of pulses per minute must be multiplied to give oxygen consumption per minute, is obtained through the calibration carried out for each test with a Douglas bag, and amounted in this test to 6.42 ml O_2 per pulse.

The nature of the activities is given by the level of the corresponding line. Cardiac frequency is determined by the number of QRS groups in the electrogardiogram per unit of time.

The speed at which the paper travels makes it difficult to obtain an overall picture of the effect of the various activities on the functions mentioned. This is why oxygen consumption for large parts of the test was plotted against a time base six times smaller, i.e. an average of 10 seconds (Fig. 5).

Fig. 4


T.J.M. de G.
Old working situation
8 sec
10 sec
Number of inspirations (= respiratory frequency): 18 per min.
21 pulses per 10 s, i. e. 6 × 21 × 0.973 × 6.42 = 787 ml/min.
Rest
Grinding
Putting down grinding machine
ECG Cardiac frequency = 6 × 18 = 108

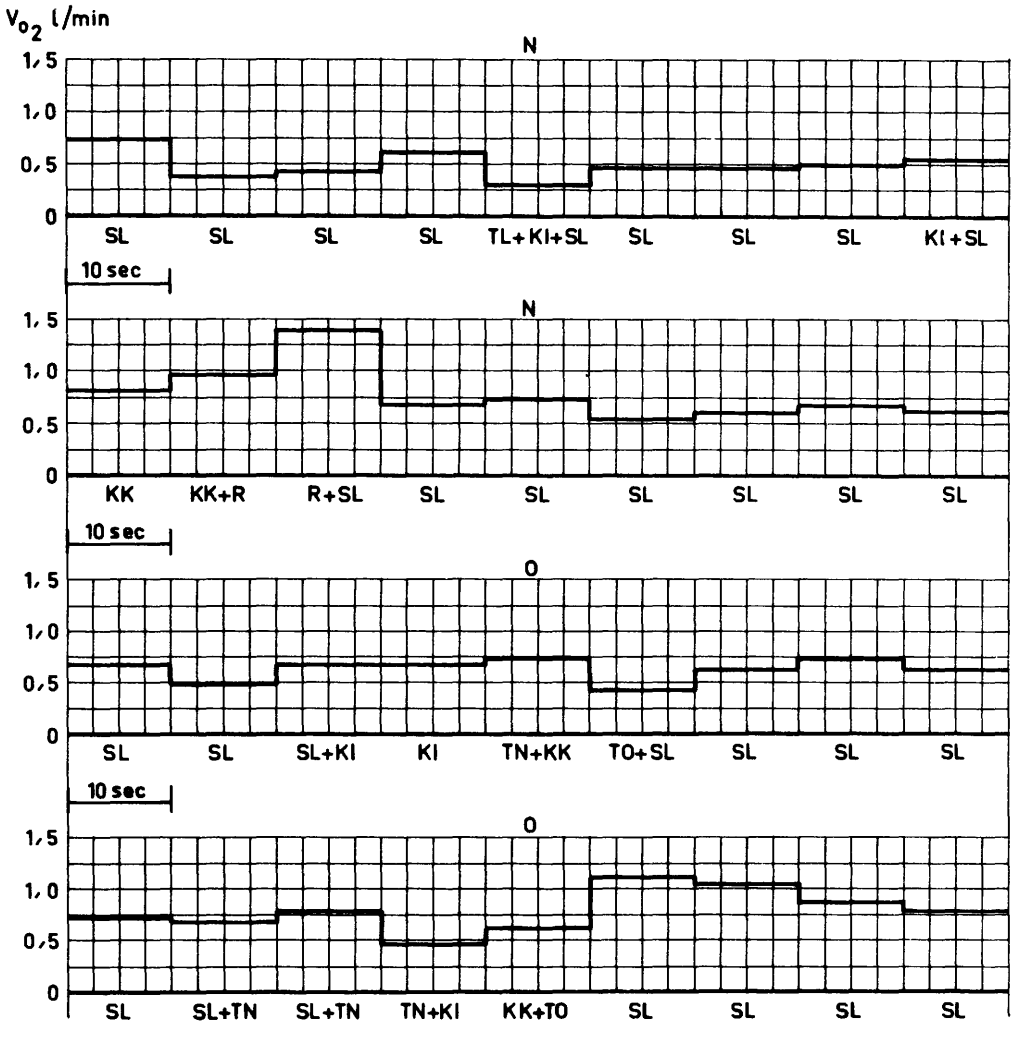

V_{O_2} l/min
N
1,5
1,0
0,5
0
SL SL SL SL TL+KI+SL SL SL SL KI+SL
10 sec
N
1,5
1,0
0,5
0
KK KK+R R+SL SL SL SL SL SL SL
10 sec
O
1,5
1,0
0,5
0
SL SL SL+KI KI TN+KK TO+SL SL SL SL
10 sec
O
1,5
1,0
0,5
0
SL SL+TN SL+TN TN+KI KK+TO SL SL SL SL

Fig. 5

In addition, mean values were calculated for each test during calibration and during a second period. These values of oxygen consumption and cardiac frequency are shown in the table below.

Test subject	New situation V_{o2} l/min.	HR	Old situation V_{o2} l/min.	HR
C.V.	0.773 *) 0.660 *)	112	0.755 0.633	109
C.J.L.	1.179 1.175	99	1.333 1.258	101
W.K.	0.646 0.630	105	0.690 0.739	109
T.J.M. de G.	0.686 0.708	112	0.718 0.820	112

*) Difficulties with mask (leaks) and mouthpiece (loose bit)

Discussion of results

Examination of mean oxygen consumption shows that it is in general lower with the new working method. Only the values recorded during the first test conflict with this rule. During that test, however, the activity of the subject was interrupted a number of times while changes were made to the apparatus.

First the face mask was replaced by a mouthpiece because of leaks in the region of the cheekbones. Then excessive pressure on the bit had to be remedied by rearranging the mouthpiece. Secondly, it was found that the subject C.J.L. consumed far more oxygen than his three colleagues. This applies both to the values obtained by the conventional (calibration) method and to those obtained with the continuous measurement apparatus. The close agreement between the volumes measured and gaseous composition makes errors in these measurements highly unlikely. Since time too was measured by two independent methods and yielded the same result, an explanation is difficult to find. It can hardly be assumed that this subject was so much less competent or worked so much harder than his colleagues. This is made all the less plausible by the fact that his cardiac frequency is slower than that of any of the others.

The significance of the observed differences in oxygen consumption can be demonstrated more clearly by a diagram than in numerical values (Fig. 6).

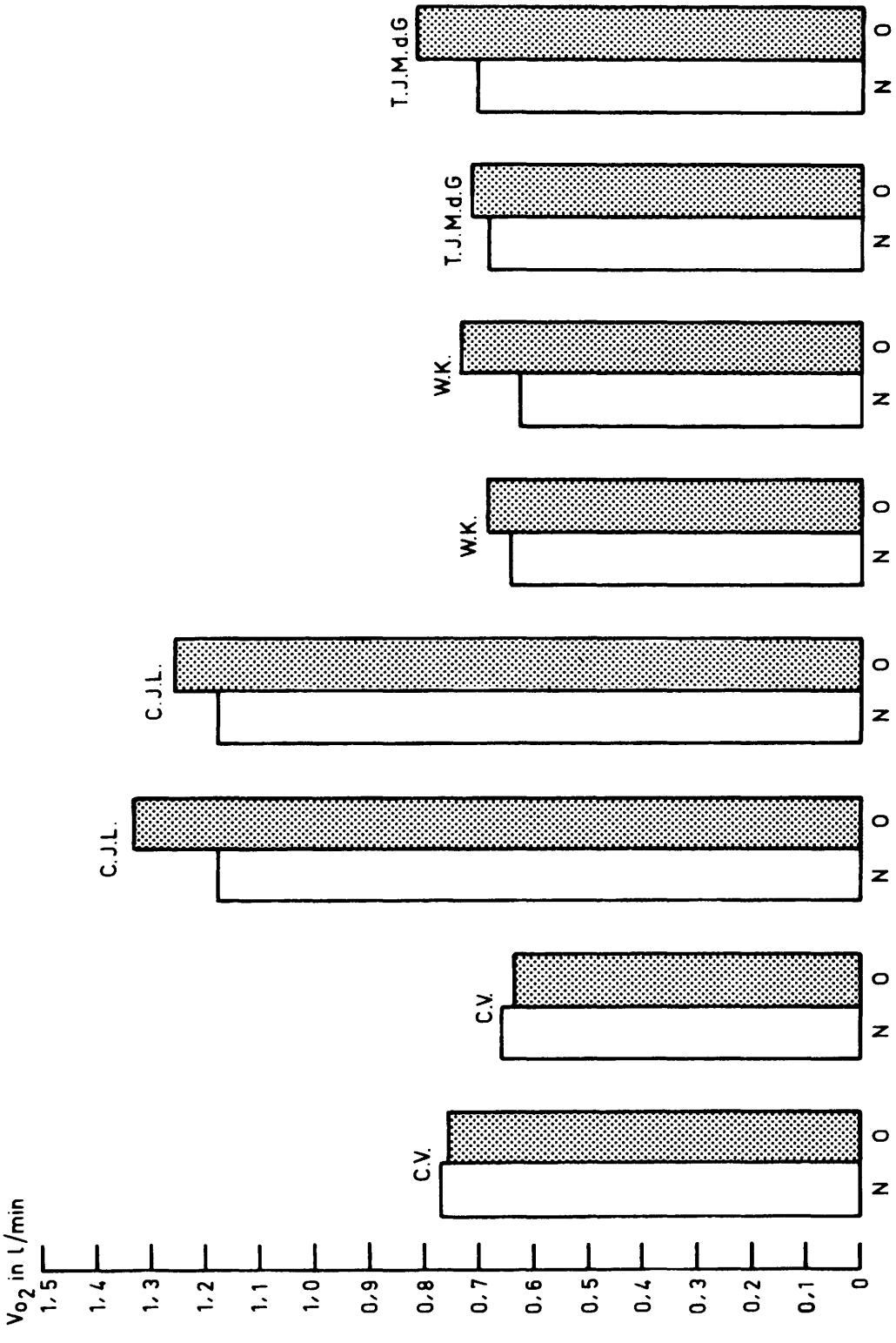

V_{O_2} in l/min
1,5
1,4
1,3
1,2
1,1
1,0
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
C.V.
C.V.
C.J.L.
C.J.L.
W.K.
W.K.
T.J.M.d.G
T.J.M.d.G
N
O

Fig. 6

Except for the first test, comparable values differ by about 10 %. This indicates a real reduction in the physical stress entailed by the job, permitting a longer spell of grinding at a stretch for the same expenditure of effort. Moreover, beacuse the operator no longer stoops and rises with the grinding machine, or stumbles or trips over the air hose, the work becomes more acceptable to a larger number of workers.

Dr. F.H. BONJER

Leiden, 16 February 1970

Test 10

The Instituut voor Gezondheidstechniek TNO (Netherlands Institute of Preventive Medicine of the Netherlands Central Organization for Applied Science Research) took measurements, in the old situation, of the concentration of dust caused by grinding operations. Its report is reproduced in full below.

STUDY OF DUST CONCENTRATION AT THE WORKPLACES OF BILLET GRINDERS

carried out at NKF STAAL N.V., Alblasserdam on 6 June 1968

Introduction

At the request of Mr BONJER of Nederlands Instituut voor Praeventieve Geneeskunde (Netherlands Institute of Preventive Medicine) in Leiden, and with the approval and collaboration of NKF STAAL N.V., Alblasserdam, a number of measurements were taken on 6 June 1968 during the grinding of billets. The request was made in connection with a study of the industrial medicine aspects of billet grinding, as it was felt desirable to ascertain the "dust stress" to which grinders were exposed. Once the working conditions have been improved, it is possible that these dust measurements will be repeated.

Equipment and working methods

The billet grinding shop is housed at the end of a large billet storage hall measuring approx. 120 x 25 m and 15 m high (see diagram). The billets, steel bars approx. 9 m long and a maximum of 8 x 8 cm in section, are manufactured by the rolling of ingots. With an eye to subsequent processing, it is necessary to grind off any hair cracks performed by three grinders per billet (Fig. 1). Billets are first

passed through a grit-blasting machine and then conveyed by the transport system to the workplaces of grinders, who turn them over with the aid of a sort of giant spanner.

Measurements

In order to take samples of the breathing zone of the grinders, a cable was extended at our request below the canopy from which apparatus could be suspended (Figs. 1 and 2 and diagram in Fig. 3). This consisted of two HTPs (*) (battery operated) for determining numerical concentration and two "GROMOZ" (**) suction filters for gravimetric analysis of concentration (see our paper : "Description of dust measurement apparatus of Instituut voor Gezondheidstechniek T.N.O.".

With filters fitted as best as possible at nose level, operators are followed during grinding operations (measuring points 1 and 2). It should be noted that the suction rate of the "GROMOZ", which is described under 2.2b in the paper referred to, is now kept constant at approx. 90 cm/s. The unit cuts off automatically when fouling of the filters prevents this rate from being maintained. Two of the three grinders were also equipped with personal sampling devices. One of these consisted of a (Dräger) filter holder attached to a

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(*) HTP = Hamilton thermal precipitator (see page 60, sec. 3.2)

(**) GROMOZ = grootmonsterzuiger (high volume sample aspirator)

lapel of the overalls and connected through a long hose to a small fixed pump. The sampling device was worn morning and afternoon by the man in the central aisle (see Annex 1, measuring point 5, pump box B). The other device consisted of a filter holder and a small portable pump (make : UNICO). This was carried in the morning by the grinder working in the middle (measuring point 2) and in the afternoon by the one close to the wall (measuring point 1). The capacity of these pumps is only 2 to 2.5 l/min.; the sunction rate of the UNICO pump is 3.7 cm/s at a 2.5 l/min. capacity, and that of the other device (Dräger filter holder) 10.6 cm/s for the same throughput.

Further space measurements were taken at measuring points 3 (on the grit-blaster platform) and 4 (at the pillar by the wall) with a "GROMOZ" unit and a programmed HTP. The latter is connected to a lighting supply which is turned on for 2 1/2 minutes and off for 7 1/2 minutes by means of a programmed switch.

In all, 29 measurements were taken, 16 with the HTPs, 9 with the "GROMOZ" units and 4 with the personal sampling devices. The results are shown in Annex 1. Annex 2 gives the results of filter-based measurements in percentages.

Discussion

To get a clearer picture of the measurements, we drew up Tables 1 and 2 in the light of the data shown in Annex 1. These tables give respectively the results obtained with the HTPs and with the filters, broken down by time and place.

Time	Measuring point			
	1. grinder by wall	2. grinder in the middle	3. on platform	4. by pillar
11.20-12.15	5400	6100	3000	3400
12.35-13.00	3800	2800		
14.45-15.35	9100	5500	5000	11000
15.45-16.20	7900	6800		
16.30-17.05	6900	4000		
17.10-17.25	3700	2800		
Average per measuring point	6100	4700	4000	7200

Table 1 - Number of particles stable at red heat per ml air, obtained with HTPs

Time	Measuring point									
	1. Grinder by wall			2. Grinder in middle			3. On platform		4. By pillar	
	Pers. sampl. device Tot.dust mg/m3	Suction filter on cable		(*) Pers. sampl. device Tot.dust <5 µm mg/m3	Suction filter on cable		Tot.dust mg/m3	Dust <5 µm mg/m3	Tot.dust mg/m3	Dust <5 µm mg/m3
		Tot.dust mg/m3	Dust 5<µm mg/m3		Tot.dust mg/m3	Dust <5 µm mg/m3				
11.20-13.00		3.3	0.4	7.7	6.5	0.6	0.5		2.5	
				9.0	2.6			0.2		
14.40-17.25	10.3	3.1	0.3				1.5		6.8	0.5
				12.1						
17.15-17.22	9.2									

(*) Sampled at point 5 (grinder in central aisle). Measurement unsuccessful.

Table 2 - Dust in mg/m^3 air obtained with "GROMOZ" units and personal sampling devices

Table 1 shows that both morning and afternoon the number of particles stable at red heat at points 1 and 2 decreases with time. Moreover, the impression gained is that the general dust level in the afternoon is slightly higher than in the morning.

The measurements made with the personal sampling devices give a measure of dust concentration in the vicinity of the grinder's nose and mouth. The samples collected with the "GROMOZ" units served to give an idea of the gravimetric concentration of 5 µm dust and to carry out an analysis of this dust fragment (see Annex 2).

In order to assess the concentrations found, we can compare them with the maximum permissible concentration laid down by the Netherlands Labour Inspectorate. This is calculated as follows. The permissible number of particles per ml air is

$$\frac{20{,}000}{\%\ SiO_2 + 5}\ .$$

The percentage total of SiO_2 is given in column H of Annex 2. The maximum permissible concentration can now be worked out by approximation to be $\frac{20{,}000}{3+5} = 2{,}500$ particles per ml. The values shown in Table 1 are all higher. Annex 1 shows that the quantity of manganese (5 µm fraction) is very low, that concentrations of aluminium are also not high, and that the concentration of iron at the grinding bench can reach 3.3 mg Fe/m^3, i.e. 4.7 mg Fe_2O_3/m^3. According to the list drawn up by the American Conference of Governmental Hygienist, the maximum permissible concentration is 5 mg/m^3 for manganese and 15 mg/m^3 for iron oxide fumes. According to PATTY, however, there have always been advocates of lowering the maximum permissible concentration of iron oxide fumes to 5 or 10 mg/m^3. PATTY also states that the maximum permissible concentration of aluminium can be set at 15 mg/m^3. The concentrations

measured for these components lie below the maximum permissible concentration.

Annex 2 can tell us something about the "iron dust/grinding wheel dust" ratio in the air. The mean percentage of aluminium at points 1 and 2 is 9.7 % and probably stems from the grinding wheel, which is made almost entirely of electro-corundum Al_2O_3. Calculated on Al_2O_3, this gives 18.3 % of the dust collected. The mean iron content at these measuring points is 55.5 %. The grinding wheel/ground steel ratio would thus be about 1 : 3 in the dust trapped on the filters. Dust concentration at point 3 is higher in the afternoon than in the morning. This is probably because in the morning the large sliding door in the hall extension is left open for a time. At point 4, too, dust concentration is higher in the afternoon, although this point is nog exposed so directly to air movements as point 3. The activity of the "fresh" afternoon shift was also greater than that of the morning shift, for which measurements were taken towards the end of the work period.

To sum up, it may be said, in the light of the criteria applied by the Netherlands Labour Inspectorate, that a risk of silicosis exists. Other dust components such as iron, aluminium and manganese oxides present no danger.

Instituut voor Gezondheidstechniek TNO
Internal Air Department
(W.C. DUBA)

Seen by :
Head of Department
(P.B. MEYER, Engineer)
TNO
24.9.1968
JK

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Dust concentration and composition as a function of time and place

Measuring point	Determination No.	Date and time	No. particles stable at red heat per ml air	mg dust per m3 air tot. <5 µm[1]		ug per m3 air (<5 µm)[1] Fe	Al	Mn	ug tot. SiO_2 <5 µm per m3 air	Remarks
		6-6-1968								
1. Near grinder by wall	HTP 7.4	11.24-12.15	5400							Coffee break at 12.15 h
	8	12.33-13.00	3800							
	10	14.42-15.33	9100							
	12	15.47-16.23	7900							
	14	16.30-17.05	6900							
	16	17.10-17.29	3700							
	Gromoz D 61	11.24-12.58		3.3	0.4(2)	1450	250	8	14	Grinder following cable
	62	14.42-17.14		3.1	0.3(2)	1380	270	8	14	
	63	17.15-17.22		9.2						Closer to grinder's head
2. Near grinder in middle	HTP 6.3	11.19-12.15	6100							Coffee break at 12.15 h
	7	17.36-12.58	2800							
	9	14.43-15.35	5500							
	11	15.47-16.23	6800							Coffee break from 16.05 to 16.20 h
	13	16.31-17.05	4000							
	15	17.13-17.28	2800							
	Gromoz C 41	11.18-12.58		6.5	0.6(2)	3300	530	17	14	With suction filter, cable following grinder
	42	14.43-17.25		2.6						
3. On platform	HTP 5.2	11.18-13.02	3000							Programmed 16.30 h : t - 16.5[A]C
	6	14.48-17.22	5000							12.40 h : 13.05 h
	Gromoz B 21	11.18-13.01		0.5	0.2(3)	410	97	3	10	Grit-blasting machine working; sliding door open 80 cm till 12.50 h. Air draught towards interior, door closed
	22	14.48-17.23		1.5						
4. By pillar	HTP 4.1	11.18-13.07	3400							
	5	14.47-17.20	11000							Programmed
	Gromoz A 1	11.19-13.05		2.5						
	2	14.35-17.20		6.8	0.5(3)	3700	680	11	10	
5. Grinder in central aisle	Pump box B K (94	11.25-12.57		7.7						
	K (95	14.44-16.06		9.0						
	K (96	16.24-17.29		12.1						
6. Grinder in middle by wall	Unico	11.25-12.19 / 14.41-17.27		10.3						Sampling during 16.05-16.20 h break

1) The 5 µm limit is based on the sedimentation rate of quartz (s.g. 2.65) in water.

2) The " <5 µm" fraction contains both 14.6 % Fe and 1.6 % Al, giving on average for these 3 filters 56 µg Fe/m3 and 6 µg Al/m3.

3) The " <5 µm" fraction contains both 13.4 % Fe and 1.3 % Al, giving on average for these 3 filters 36 µg Fe/m3 and 3 µg Al/m3.

Measuring point and date	Filter No.	A mg dust per m3 air	B Air sampled in m3	C Tot. dust per filter in mg	For fraction > 5 µm there is[1] D % Fe	E % Al	F % Mn	G % < 5 µm (s.g. 2.65) of tot. dust[1]	For fraction < 5 µm there is[1] H % tot. SiO_2	J % tot. Fe	K % tot. Al
6-6-1968											
1. Grinder by wall	63	9,2	5,3	48,6							
	61	3,3	78	257,4	52,9	9,1	0,3	12,6			
	62	3,1	128	400,6	54,1	10,5	0,3	10,3	3,2	14,6	1,6
2. Grinder in the middle	41	6,5	76	491,9	59,5	9,4	0,3	9,4			
	42	2,6	136	359,1				.			
	Unico	10,3	0,55	5,7							
3. On platform	21	0,5	87	47,6	48,2	11,3	0,3	15,1	3,0	13,4	1,3
	22	1,5	129	188,8							
4. By pillar	2	6,8	144	983,7	60,4	11,0	0,3	6,7			
	1	2,5	91	227,0				.			
5. Grinder in central aisle	K094	7,7	0,163	1,258							
	K 095	9,0	0,207	1,862							
	K 096	12,1	0,230	2,781							

1) The 5 um limit is based on the sedimentation rate of quartz globules (s.g. 2.65) in water.

. Determination not successful.

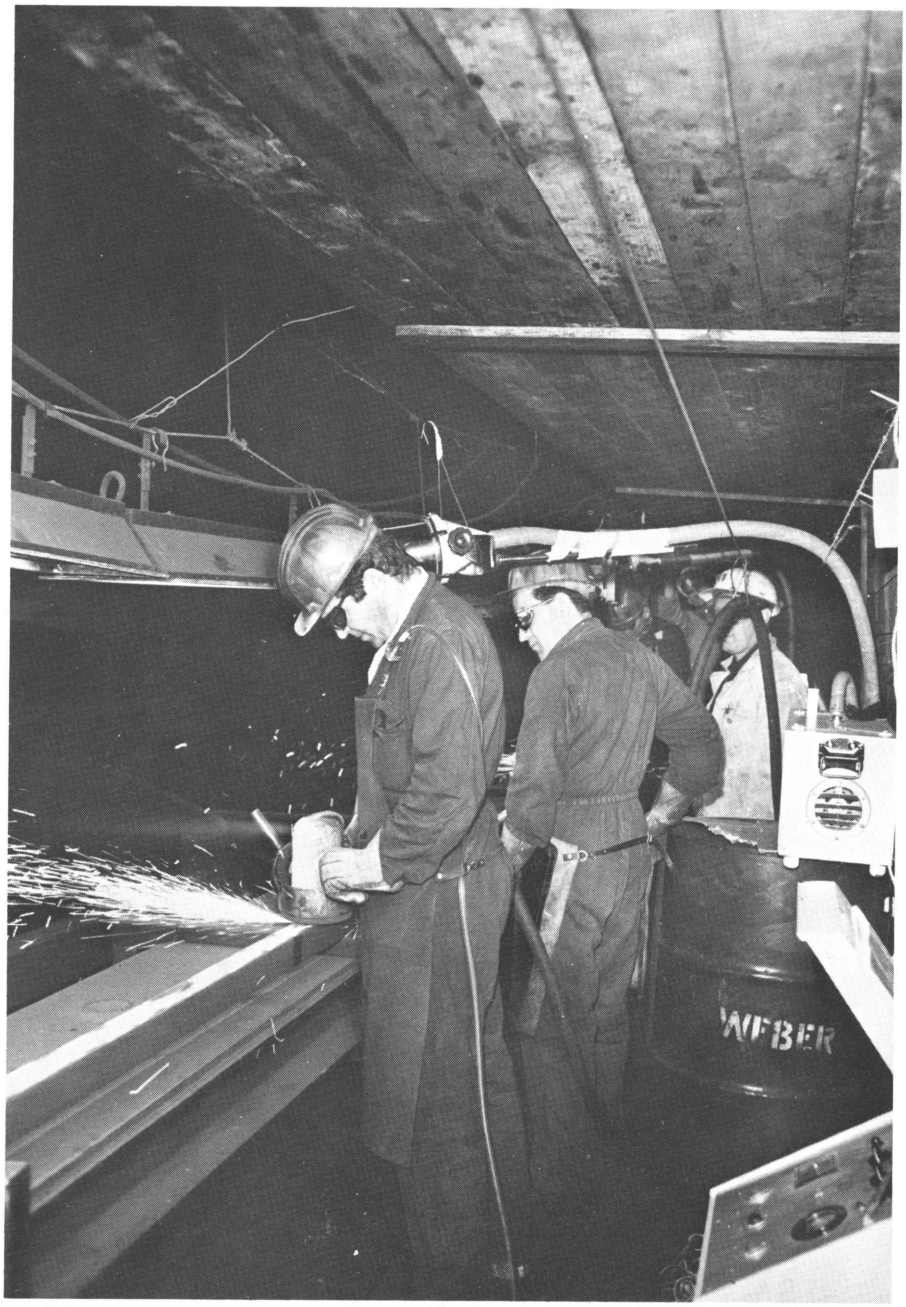


Fig. 1

Dust measurement during billet grinding

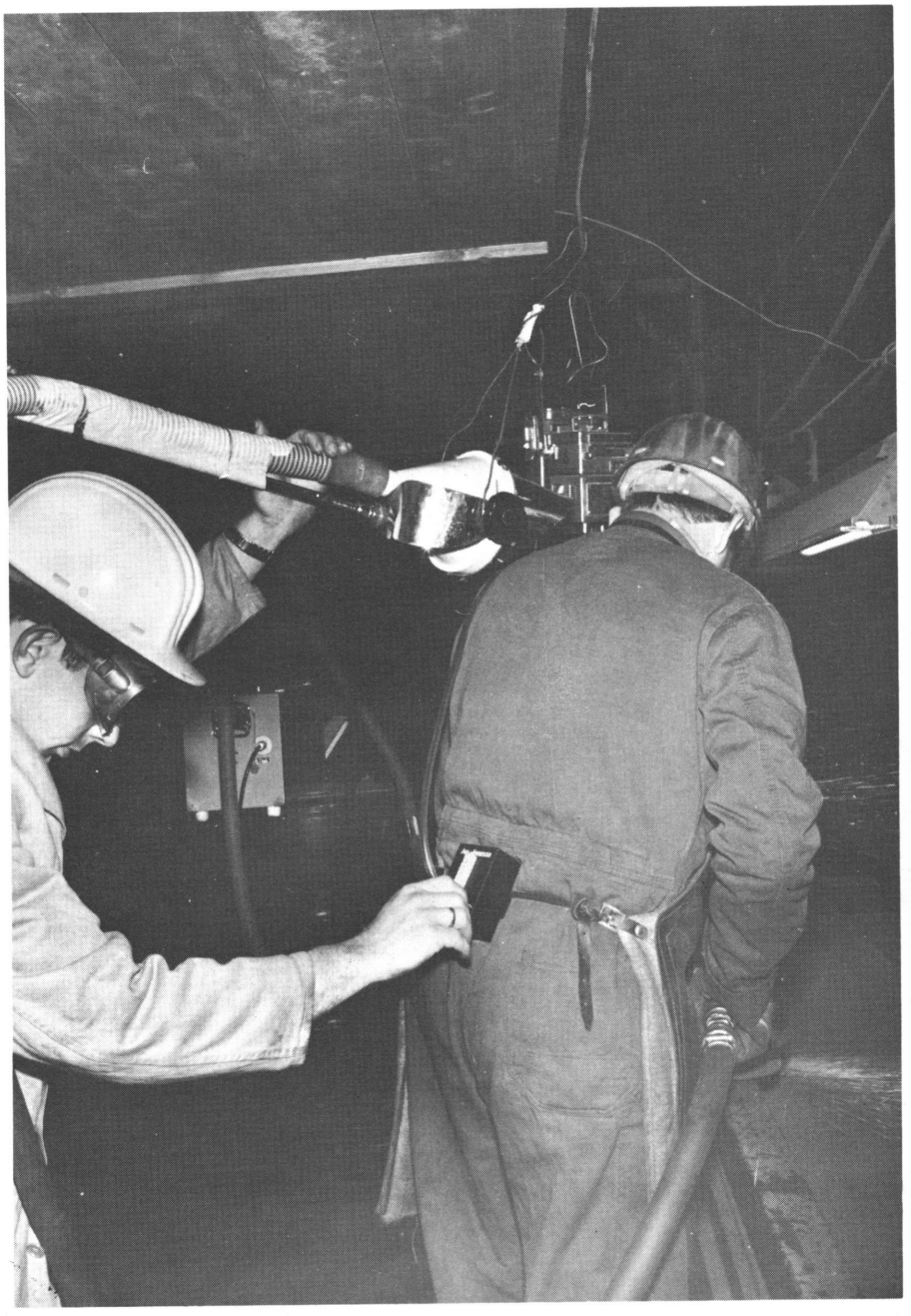


Fig. 2

Positioning of personal sampling device; the method of suspending the "gromoz" unit can also be clearly seen

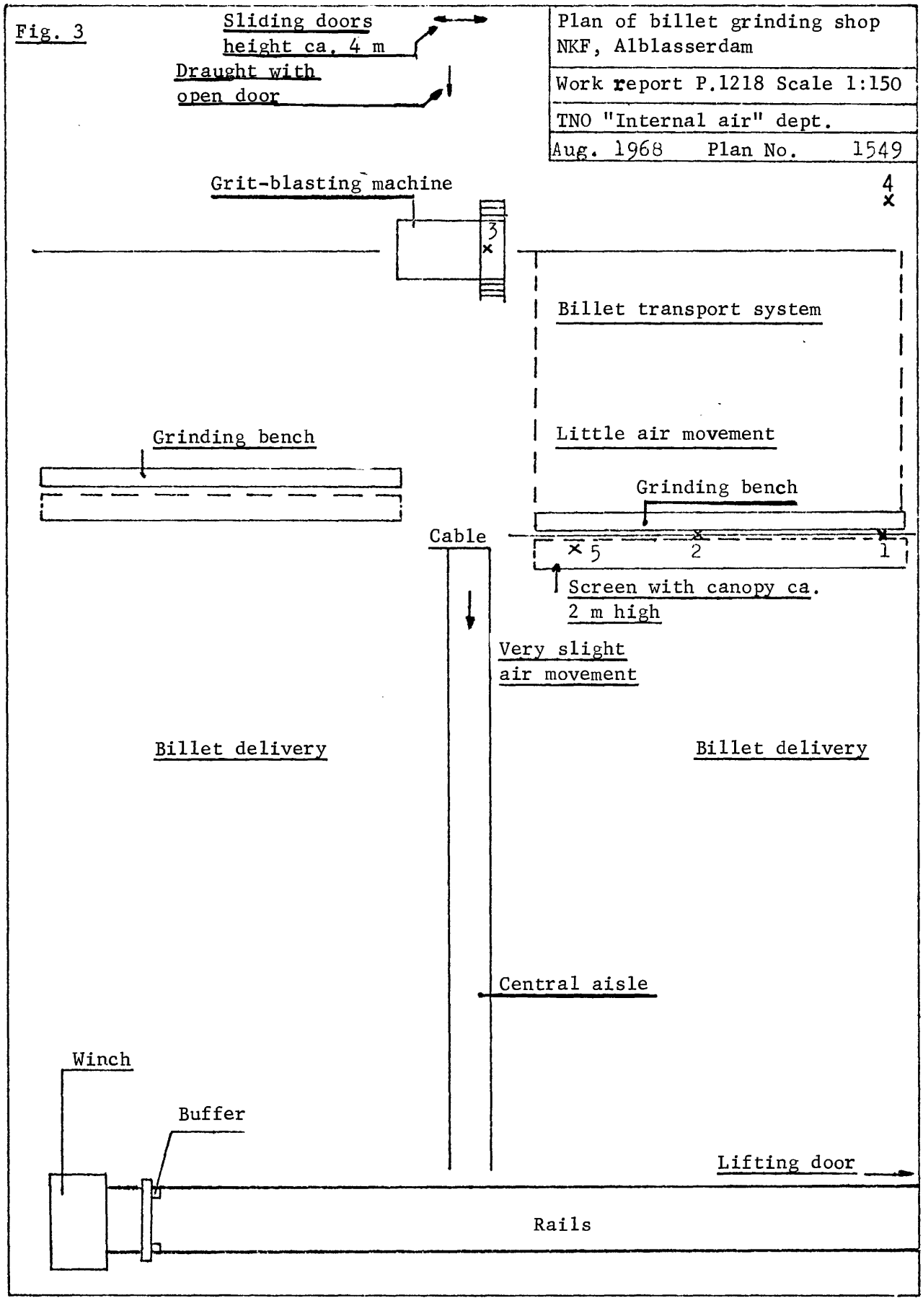


Fig. 3
Sliding doors
height ca. 4 m
Draught with
open door
Plan of billet grinding shop
NKF, Alblasserdam
Work report P.1218 Scale 1:150
TNO "Internal air" dept.
Aug. 1968 Plan No. 1549
Grit-blasting machine
4
3
Billet transport system
Little air movement
Grinding bench
Grinding bench
Cable
5
2
1
Screen with canopy ca.
2 m high
Very slight
air movement
Billet delivery
Billet delivery
Central aisle
Winch
Buffer
Lifting door
Rails

1005/72 e - RCE

DESCRIPTION OF THE DUST MEASUREMENT APPARATUS OF INSTITUUT VOOR GEZONDHEIDSTECHNIEK, T.N.O.

1. Introduction

Dust content is usually indicated by the number of particles per cm^3 air (p/cm^3) or by the weight of particles in mg per m^3 air (mg/m^3). In practice, dust particles always exhibit wide variations in size. In a given volume of air, fine particles are always more numerous than coarser particles. Often 80 to 95 % of particles are less than 1 µm (1 µm = 10^{-6} m = 0.001 mm) while the number of particles $>$ 5 µm makes up only a small percentage of the total number. However, the total weight of the particles is chiefly determined by these few coarse particles : one 5 µm particle weighs as much as 125 1 µm particles or as 1000 0.5 µm particles. The number of dust particles in a given volume of air can thus be regarded as a measure of the content of fine particles ($<$ 5 µm) and the weight as a measure of the content of coarse particles.

It should be noted that only particles less than 5 µm in size can penetrate to the air sacs of the lung (alveoli), and that only quartz particles $<$ 5 µm can cause silicosis.

2. Determination of weight of dust

2.1. Filter apparatus

By means of a pump, air is sucked in through a filter at a rate of 2.5 to 3 m^3 per hour, the volume of air drawn in being read off a gas meter. Use is made of a paper filter (Schleicher & Schüll, Blauband, No. 589^3) or of a soluble filter (Mikrosorban, Delbag) 9 to 9.5 cm in diameter.

On a paper filter, the total quantity of dust collected can be determined by weighing the filter, before and after use, until a constant weight is obtained. This method, however, is rather inaccurate, if only because of the hygroscopic properties of the paper (errors range from 0.5 to 1.0 mg). Much greater accuracy can be attained in measuring the part of the dust that is stable at red heat by reducing the dust, together with the filter, to ashes.

When use is made of a Mikrosorban filter, this is dissolved, after use, in benzene. The dust is separated out by centrifuging and weighed, and can then be examined by different methods (e.g. granulometric distribution, chemical composition). This method is impracticable if the dust itself dissolves, wholly or partly, in benzene.

The weight of dust determined by these methods is in fact a measure of coarse particles (up to a maximum of about 80 µm).

2.2. Filter apparatus for a large volume of air

In many cases it is desirable to determine the composition of the tiniest fraction of dust particles (5 µm). In order still to obtain 5 to 10 mg of this fraction (needed for X ray analysis, e.g. of quartz, far larger air samples have to be taken, i.e. 40 to 60 m^3 per hour. Two types of apparatus are used for the purpose :

a) the high volume air sampler (Hivas), an American product;

b) the "gromoz" unit (grootmonsterzuiger = high volume sample aspirator) developed and manufactured in our works.

These devices are powered by vacuum cleaner motors. As these motors are highly sensitive to pressure, air displacement falls sharply as filter resistance increases. Both units are fitted with 16 cm diameter Mikrosorban filters.

Air intake is determined :

a) in the case of the Hivas unit by regular readings off a small built-on flowmeter. By means of a calibration chart, air displacement can be determined from these readings. Total air intake is determined with the aid of a separate chart for each measurement;

b) in the case of the "gromoz" unit by an integrating measurement obtained by counting the revolution of a sort of impeller.

During sampling, dust settles on the filter with the result that resistance increases and the rate of intake falls. If the quantity of fine dust is large, the filter soon becomes choked; in other words, its resistance becomes so high that it has to be changed. If necessary, two or more filters may be examined simultaneously.

As pointed out, these units are used if the fine fraction of dust has to be isolated; this is particularly the case in determining quartz-containing dust to establish wether a risk of silicosis exists. Both units may also be used with satisfactory results in spaces where the dust content is very low.

3. Determination of number of dust particles

3.1. Thermal precipitator (TP)

With this apparatus, a small volume of air (25, 50 or sometimes 100 cm^3) is slowly drawn in (50 cm^3 in 10 minutes) along a heated metallic wire inserted in a crevice between two cold walls.

Air is displaced by means of water aspirators. Thermal action leads to precipitation of dust particles on the cold walls, more specifically on two cover glasses fitted there. Two "dust trails" are obtained in this way; the number of particles contained on them is then counted under the microscope. Because of the low suction rate and the way the apparatus is designed, particles larger than 8 µm are scarcely drawn in. The apparatus is a standard instrument for determining the number of dust particles per cm^3 of air and provides a satisfactory measure of the content of fine dust.

The number of detectable particles closely depends on the circumstances under which counting is carried out (magnification, illumination, contrast between particles and background). The count is usually taken against a dark field - magnification approx. 500 x, dry system. Other counting methods, such as sometimes used in other countries, may give totally different (generally far lower) values.

To get some idea of the composition of the dust, the cover glasses and the dust deposited on them are heated to around 325° to

to eliminate organic material. The number of particles is then determined anew. The number remaining are classified as "after ashing" or as "stable at red heat", and the original number as "before ashing" or "total".

In many cases, particles "stable at red heat" are treated, after counting, with hydrochloric acid 1 : 1 at approx. 70° C. During this treatment many salts and oxides dissolve. Quartz particles are left, but also some highly heated oxides (e.g. Fe_2O_3) and a few silicates. The number of particles remaining is recorded as "acid-resisting".

The "percentage ratio of acid-resisting particles to particles stable at red heat" is given by :

$$\frac{\text{number of acid-resisting particles}}{\text{number of particles stable at red heat}} \times 100\ \%.$$

3.2. Hamilton thermal precipitator (HTP)

This apparatus, known also in England as a long running thermal precipitator, operates on the same principle, with the difference that it draws in air at a rate of 2 cm^3/min. for a period of 1 to 8 hours maximum. In addition, the hot wire is built into a side wall, so that only a single dust trail is obtained on a single glass, and the unit is designed in such a way that slightly coarser particles, deposited by precipitation before reaching the wire, are also sucked in. The time the apparatus has been operating is registered automatically. A sort of "breathing" pump serves to transport the air.

Chemical analysis of the grinding wheel showed that it contributed nothing towards the SiO_2 content of the dust. As the silicon content of the steel is too low to account for this percentage, it is not clear to us where it comes from.

Quite clearly, however, dust concentration was excessive. With a view to reducing the nuisance this causes to grinders, the following measures were considered :

1. Fitting extractor fans to the external wall of the grinding shop. Calculation showed, however, that this would give rise to other drawbacks such as draughts and counteracting heating in winter.

2. The provision of dust extraction facilities on each grinding wheel. This was also rejected as it would mean fitting a hood and a sunction hose to the wheel, unduly hampering the grinder's movements.

3. Tests were carried out with an air helmet such as worn by astronauts. Fresh air was fed to the helmet but the results were unsatisfactory. The helmet itself is excellent but the wearing of it, and the fact that it prevents operators from smoking or chatting with their fellows ruled it out. To this may be added the fact that grinders do not consider the dust to be a disadvantage. Nor do they want, as they put it, to "look like proper freaks".

4. Consideration was then given to extending the canopy both at the sides and at the front. Whatever happened there had to be

at the front a gap approx. 30 cm high through which billets could be rolled to the grinding bench. Such an arrangement would lead to outside air (warmed in winter) being blown into the cabin. This in turn would create in the gap at the front an outflow of air (rate 0.3 m/s). The advantage would have been that dust would be extracted from the cabin and at the same time the heating problem would be solved. We dropped the scheme, however, because it was felt (i) that the grinders would feel shut off in a sealed cabin and (ii) that the expenditure of 11,000 Guilders entailed was not economically justified.

5. To reduce dust concentration in a single area, grinding benches were spread out over a number of sites. Owing, however, to a rise in production, we were unable to carry this idea into effect.

6. Grinders were recommended to wear a simple dust-mask over nose and mouth. This advice was followed, but not for long by some of the men. The chief risk lies in breathing in dust over a prolonged period. As these workers are not bound by contract to NKF STAAL S.A., labour turnover is very high. The average length of stay with the company is about three months. As it had been decided for other reasons to go over to mechanical grinding and, in the near future, to confine manual grinding to inspection activities which entail far less discharge of dust, nu further steps were taken to combat the dust nuisance.

Test 11

Heating had previously been provided by a brazier which also served to defreeze the grinding machines. Grinders spent a great deal of time warming themselves before the brazier. The braziers were replaced by hot-air cannons burning domestic fuel (Photo 10).

After some time, a number of grinders began complaining of headache. We then switched over to fuel oil for a trial period and the complaints ceased.

During this trial period one or two barrels of domestic fuel were inadvertently delivered in place of oil. The complaints were presumably partly subjective and partly justified and/or partly due to some other factors. An attempt to heat the area below the canopy with electric plate radiators was not a success. The installed capacity was too low and yielded a temperature rise of only 2° C. This type of electrical heating is unsuitable.

Photo 10

Test 12

The following steps were taken to improve safety. Not-authorized practices were observed when grinding wheels were mounted (omission of locknut, fitting a ring behind the wheel to prolong its life).

As a result some wheels burst or spun off their spindles. At the moment only one operator per shift is authorized, after suitable instruction, to fit on wheels.

The type of spectacles worn by grinders is not important. What does matter is that they sould be worn. No eye injuries occur. The spectacles mostly used are those with a normal mounting fitted with blinkers at the sides.

Billets are handled with the help of a canting iron (Fig.5). When the billet has to be rolled from the delivery table to the grinding bench, the sloping brackets are a source of danger. Billets start to roll spontaneously. If the grinder does not withdraw the iron in time it is borne along by the billet. There is a consequent danger to fingers and hands; on one occasion the handle of the iron actually penetrated the flesh of an operator's foot.

After experimenting with self-closing pincers in tubular form, we finally adopted the design shown in Fig. 6. The handle can be pulled in only one direction. Directly the billet starts to roll, it frees itself from the iron by the shorter jaw. Since this canting iron was introduced no more

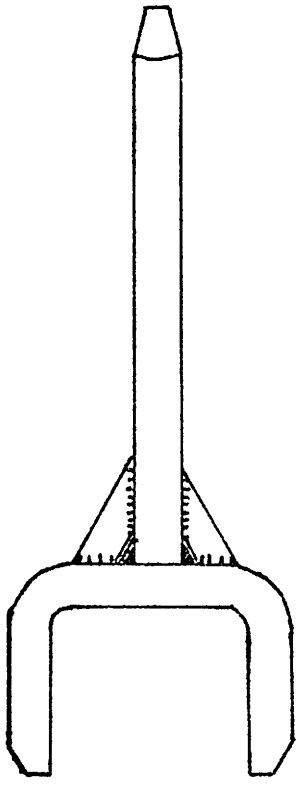


Fig. 5

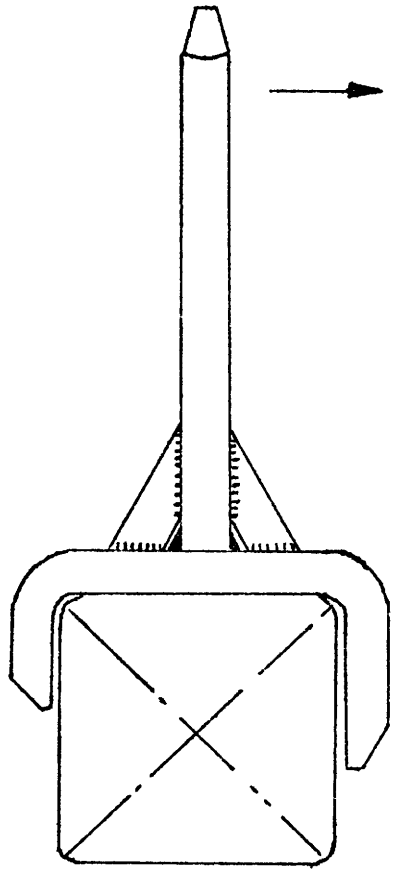


Fig. 6

accidents have occurred in tilting billets over. As the play between the jaws of the iron and the billet must be neither too much nor too little, both jaws have a hard coat welded onto their inside faces and are then made to measure (Photo 11).

Test 13

Illumination of billet grinding bench

Experience has shown that cracks on the surface of ground billets are easiest to detect when the eye is situated in the field of reflection of a light source whose rays are cast back by the surface of the billet. Punctiform and linear light sources (incandescent lamps and fluorescent tubes not fitted with a diffusor) give an irregular pattern of reflection and are therefore unsuitable.

The ideal would be to arrange the largest possible light source emitting diffused rays in such a way that the grinder's eye can sweep over a wide area without straying beyond the field of reflection.

With the space available, the arrangement closest to the ideal is one using a series of broad light-fittings comprising fluorescent tubes complete with diffusors, arranged so that the angle formed with the vertical by the line "light fitting-billet" measures about 10°. Trials with various fluorescent tubes showed that the fluorescent light corresponding to Philips shade 57 (daylight special) is the most easy on the eye. The light output was again insufficient. Dust adheres readily to plastic diffusors, reducing luminance still further. For these reasons and with a view to standardization, a double row of fluorescent tubes, shade

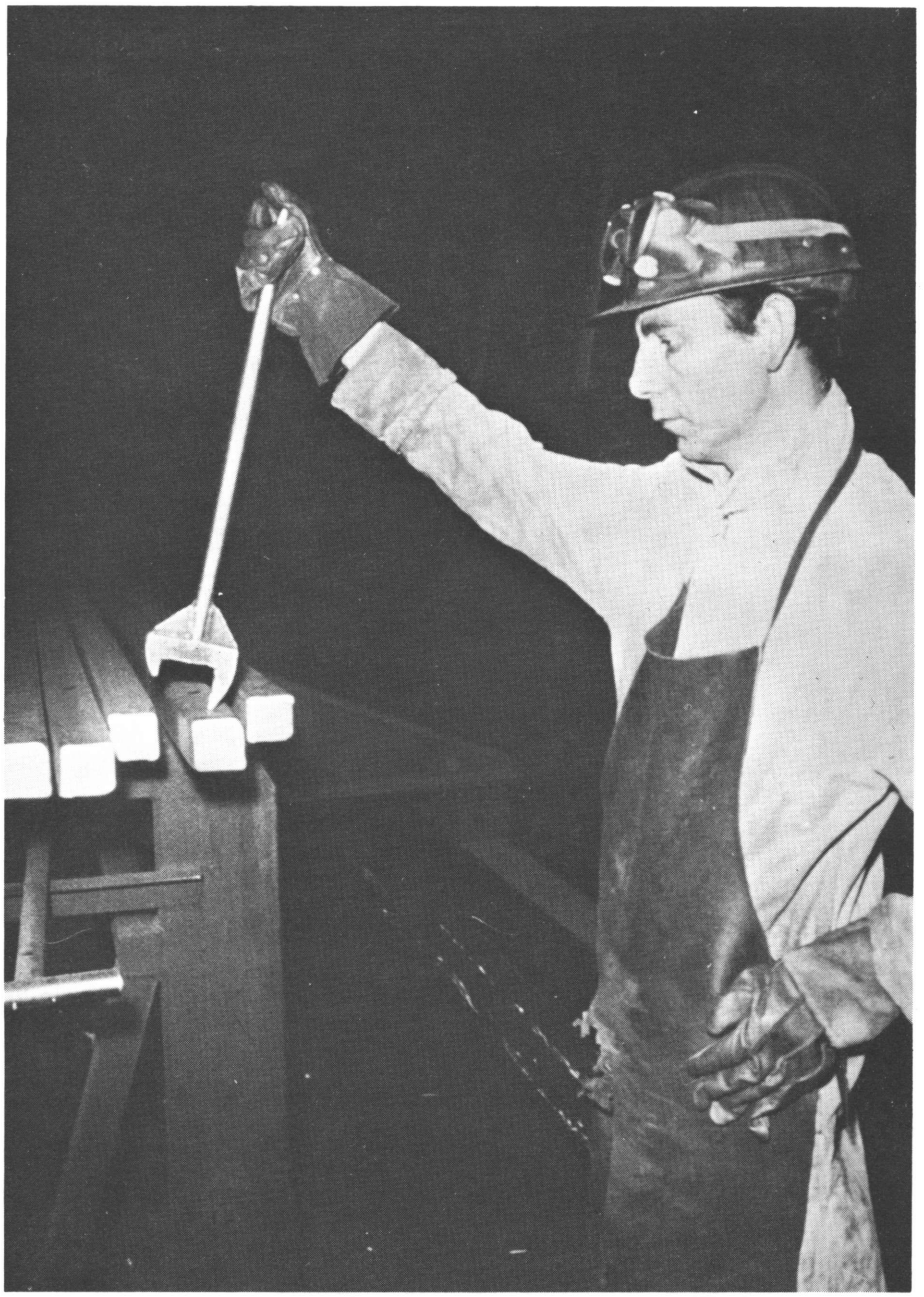
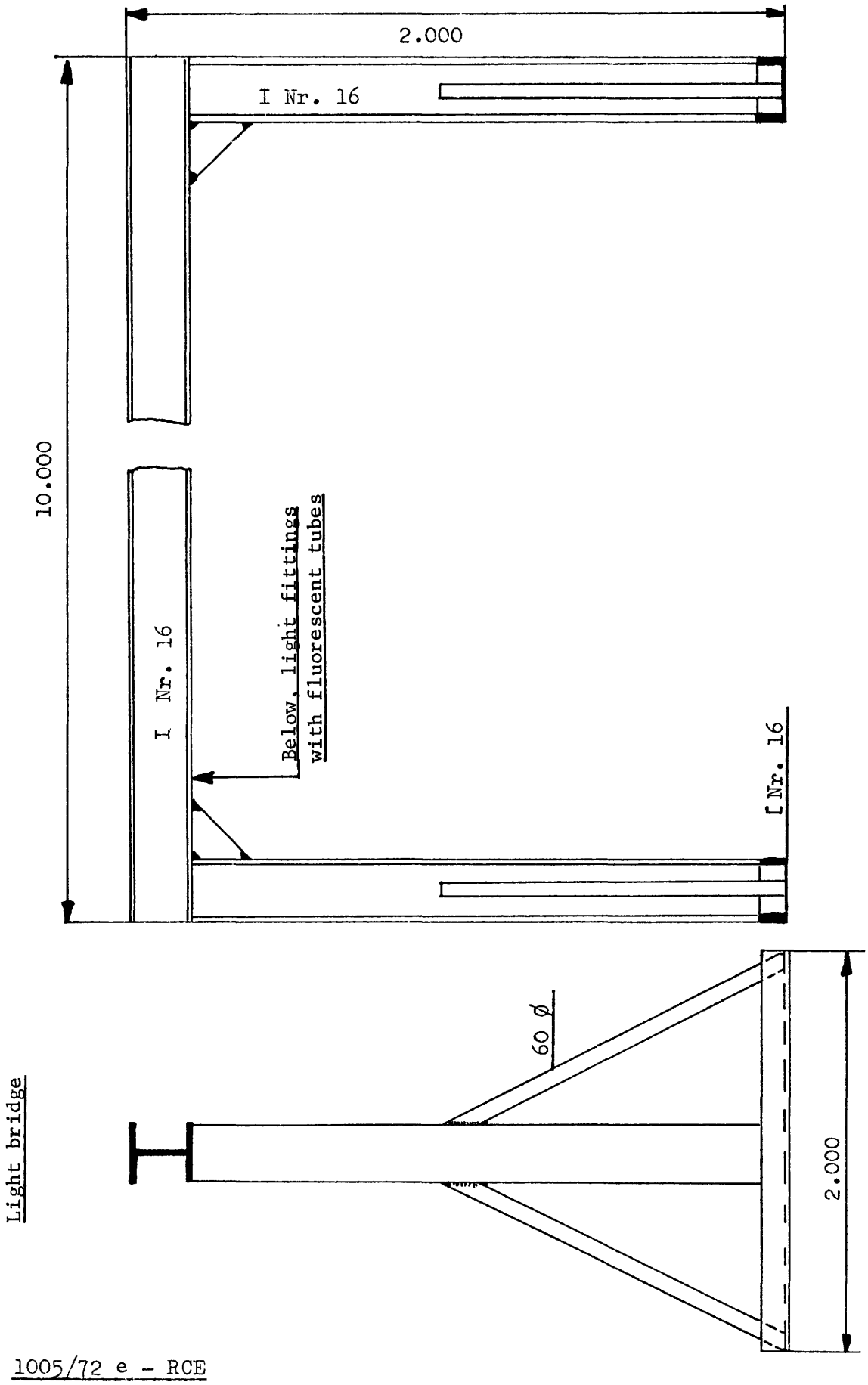


Photo 11



Light bridge

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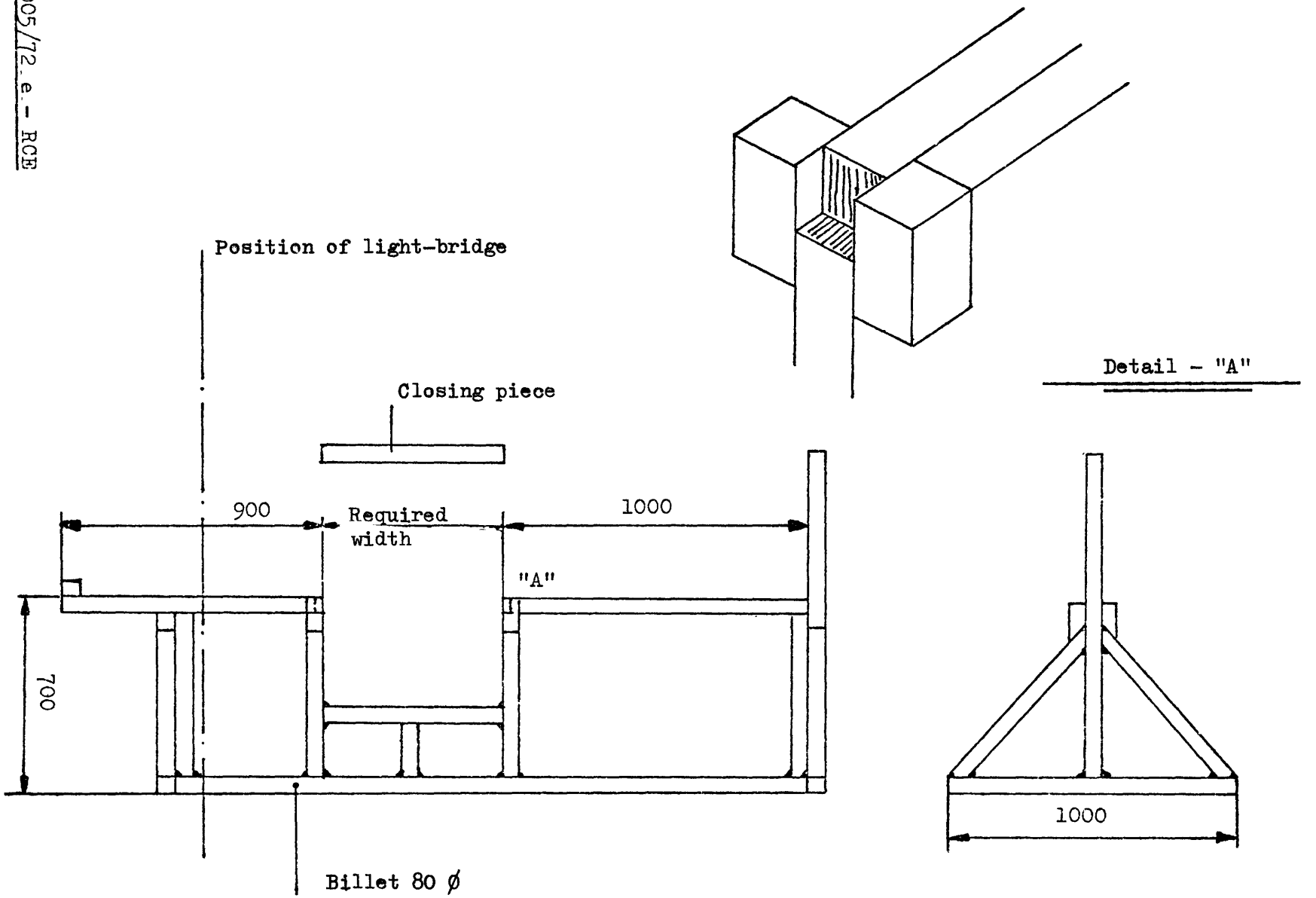
Grinding supports



33 (normal white), without diffusors, was fitted over the entire length of the billet. This gave an illumination of approx. 500 lux on the billet surface (as compared with 100 lux in the rest of the hall). This was considered sufficient, even for the older operators.

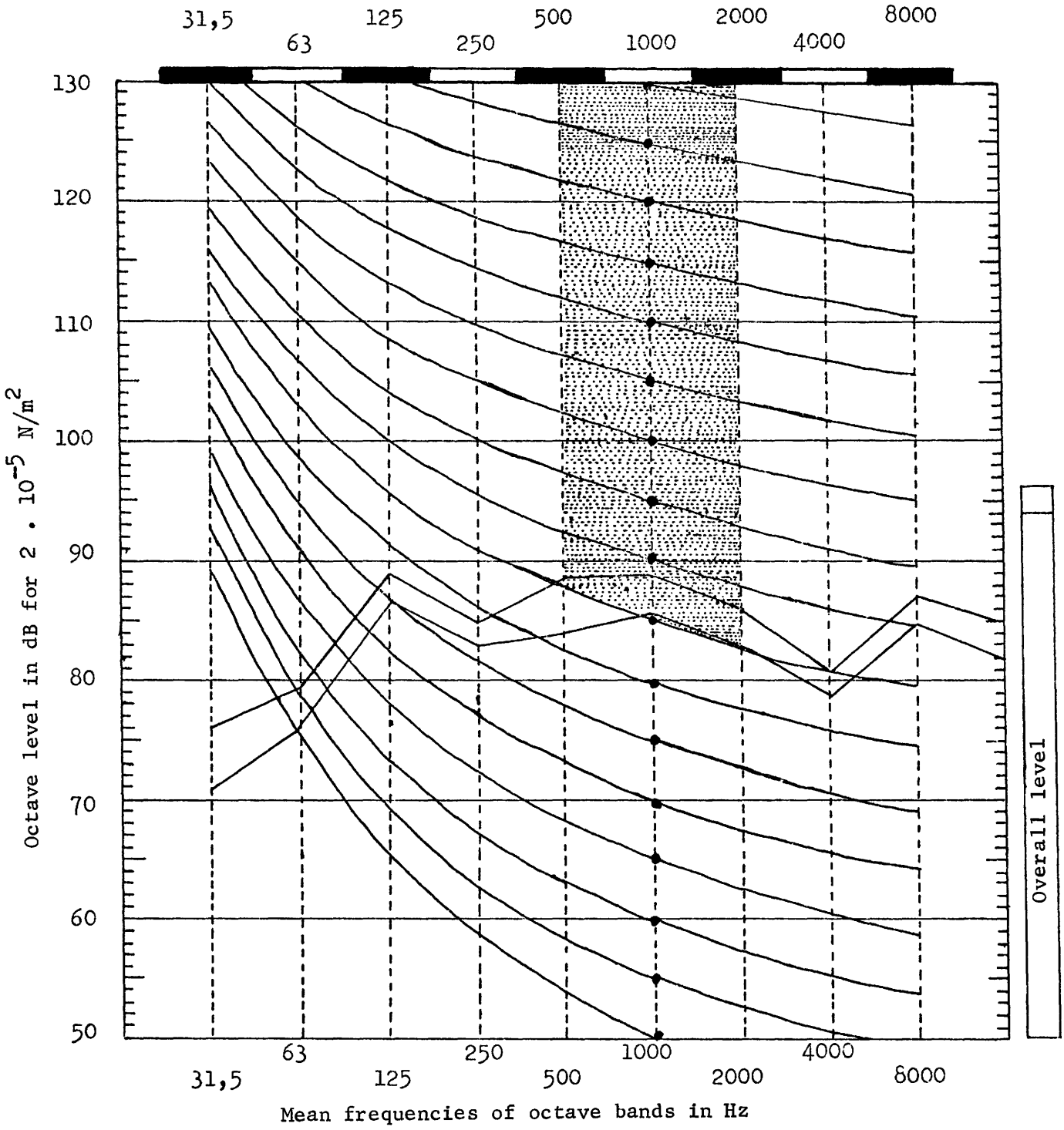
Test 14

To limit the nuisance caused by the noise of grinding operations and the outflow of air, the canopy was made out of "Heraklith" wood-wool boards. The insertion of a metal sponge at the grinding machine outlet had the damping effect desired but lowered the capacity of the machine to an inadmissible extent.

Noise abatement measurements were carried out by T.N.O. The noise level analyser was held at ear level and aimed at the grinding machine from a distance of 0.7 to 0.5 m. The measurements, both in the old and in the new situation (with grinding machines suspended), covered different machines of the same make (without metal sponge) so that slight differences in sound pressure may occur. Differences due to the existence of the sound-absorbent wall cannot be expected with this new measuring arrangement because direct noise is here clearly dominant. To measure the influence of the wall a far more sophisticated set-up would be needed.

The results are given in diagrams and in a table. Both in the old and in the new situation there appears to be a risk of loss of hearing, so that some means should be sought of reducing noise at source. This also proved impossible (see above). We should therefore switch to the wearing of earplugs by those working in the vicinity of grinding machines throughout a shift. People who have been doing this work for several years should be given regular audiometric checks.

Billet grinding
Old situation
Two grinding machines



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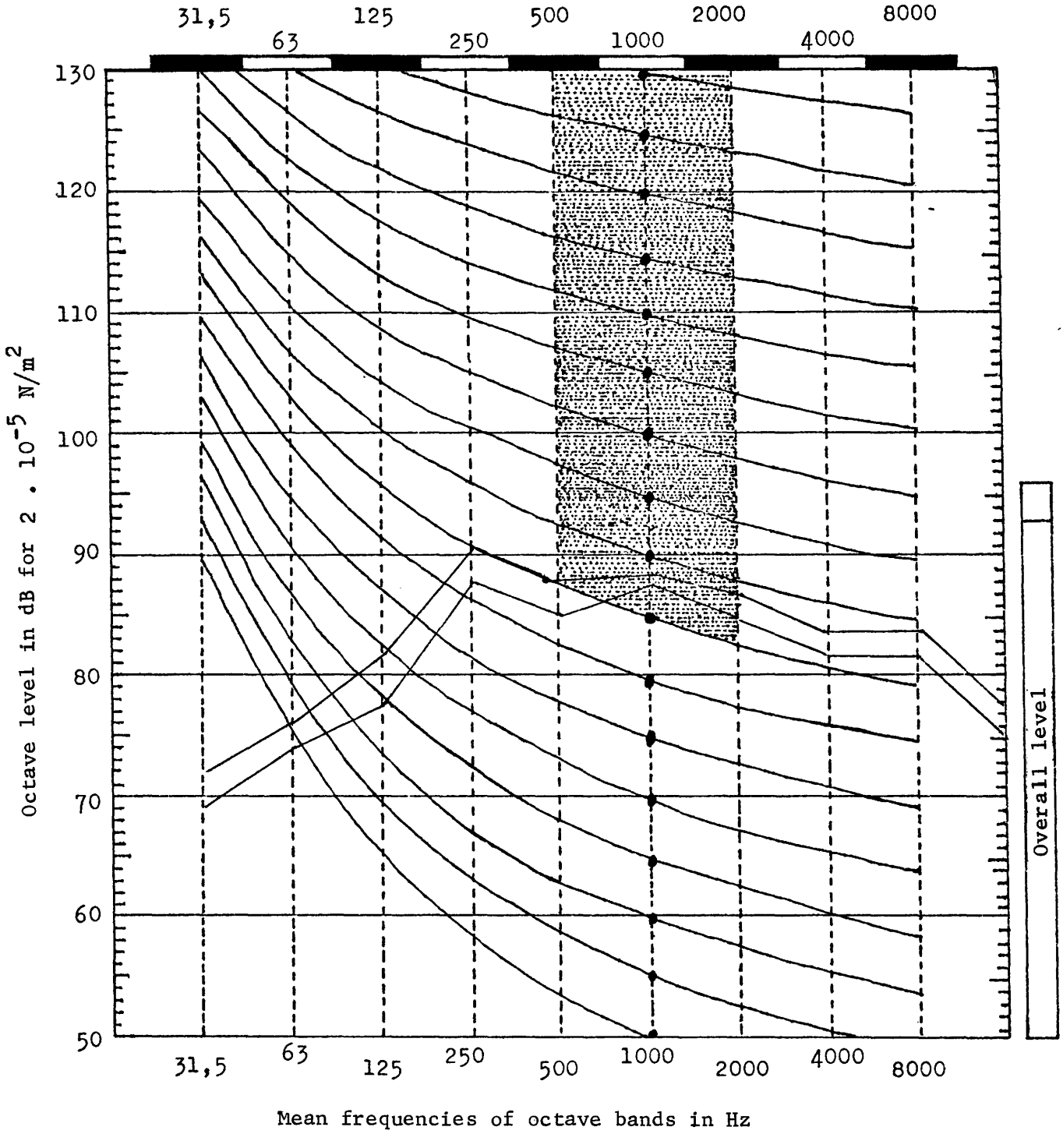
Curves drawn up in accordance with
ISO/TC 43, 314 (1963) recommendation

Billet grinding
New situation
Two grinding machines



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