

# Preliminary report on the measurement of cutting-tool temperature

***Citation for published version (APA):***

Veenstra, P. C., Bus, C., & Zweekhorst, E. T. W. (1963). *Preliminary report on the measurement of cutting-tool temperature*. (TH Eindhoven. Afd. Werktuigbouwkunde, Laboratorium voor mechanische technologie en werkplaatstechniek : WT rapporten; Vol. WT0072). Technische Hogeschool Eindhoven.

***Document status and date:***

Published: 01/01/1963

***Document Version:***

Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

***Please check the document version of this publication:***

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

***General rights***

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

[www.tue.nl/taverne](http://www.tue.nl/taverne)

***Take down policy***

If you believe that this document breaches copyright please contact us at:

[openaccess@tue.nl](mailto:openaccess@tue.nl)

providing details and we will investigate your claim.

BB 483176



**technische hogeschool eindhoven**

**laboratorium voor mechanische technologie en werkplaatstechniek**

rapport van de sectie: **Machining**

titel: **Preliminary Report on the measurement of cutting-tool temperature.**

auteur(s): **Prof.dr. P.C. Veenstra, Chr. Bus Ing.  
Ir. E.T.W. Zweekhorst.  
Technological University Eindhoven - Holland.  
Production Engineering Laboratory.**

sectieleider: **Chr. Bus Ing.**

hoogleraar: **Prof. Dr. P.C. Veenstra**

samenvatting

prognose

blz. 1 van 14 blz.

rapport nr. 0072

codering:  
M 5.P 7 a 1

trefwoord:  
cutting tool  
temp.

Temp. meting  
van draai-  
beitel

on behalf of  
"C.I.R.P."  
conference  
Cincinnati  
1963  
U.S.A.

datum:  
24-7-1963

aantal blz. 14

geschikt voor  
publicatie in:

## 1. Starting point

The aim of this investigation into the measurement of the temperature of single point cutting tools is to collect information towards a general wear-vs-temperature relation.

From the at present known and developed methods the one described by Gottwein/Herbert has been chosen.

The methods founded on measurement of radiation have not been entered due to the fact of the great difficulties in obtaining a reliable relation between the radiation measured and the surface temperature of the radiator.

The thermo-electric method appears to be a straightforward one and it is good accessible to physical analysis.

Moreover the calibration of the measurement can be performed in a direct and accurate way.

Known is of course that the Gottwein-method up to now always leads to probably far too low figures of the temperature of cutting tools.

In our opinion this is mainly caused by poor calibration techniques and perhaps by the overlooking of active thermocouples in the measuring circuit.

For this reason a considerable amount of attention has been given to the development of a calibration set-up and the discipline of measuring thermo-electric tensions.

## 2. Tentative Results

- a) The temperature obtained with the Gottwein-method is in a good approximation the average of the temperatures of the areas of contact between tool, workpiece and chip, on the conditions that both the transition resistance is throughout the same and the internal resistance of the tool is high compared with the transition resistance.

In most cases these conditions are not fulfilled which causes the measured temperature being lower than the average temperature.

b) Typical results of measurements

tool, Sandvik Coromant - throw-away bits number: 194.4-1623

carbide grade S2 (I.S.O. - P20; U.S.A. - C6)

workpiece material, steel C45 = 0,45%C; 0,25%Si; 0,65%Mn;

0,045%max. x(P+S)

machine tool, lathe A.I - DR 200, modified, number of revs:

0 - 5000/min. continuously

feeds: 0,0025-40,0 mm/rev, continuously

input power: 60 kW max.

motor: d.c., magnetic amplifier control.

depth of cut, mm	feed, mm/rev.	cutting speed m/min.	average temperature °C
2	0,13	100	745
2	0,52	100	870
2	0,13	158	820
2	0,52	158	1005
6,56	0,10	200	870
6,56	0,69	200	1055

3. Experimental Techniques.a) The measurement of temperature

The experiments have been performed with a fixed tool geometry according to the Sandvik standard toolholder type: hR 174.2-2525

- a) back rake angle =  $0^{\circ}$
- b) true rake angle =  $+ 6^{\circ}$
- c) end relief angle =  $5^{\circ}$
- d) side relief angle =  $5^{\circ}$
- e) end cutting edge angle =  $15^{\circ}$
- f) side cutting edge angle =  $15^{\circ}$
- g) nose radius =  $3/64''$
- h) no chip breaker

the toolholder has been modified according to fig. 1 on the purpose of temperature measurement.

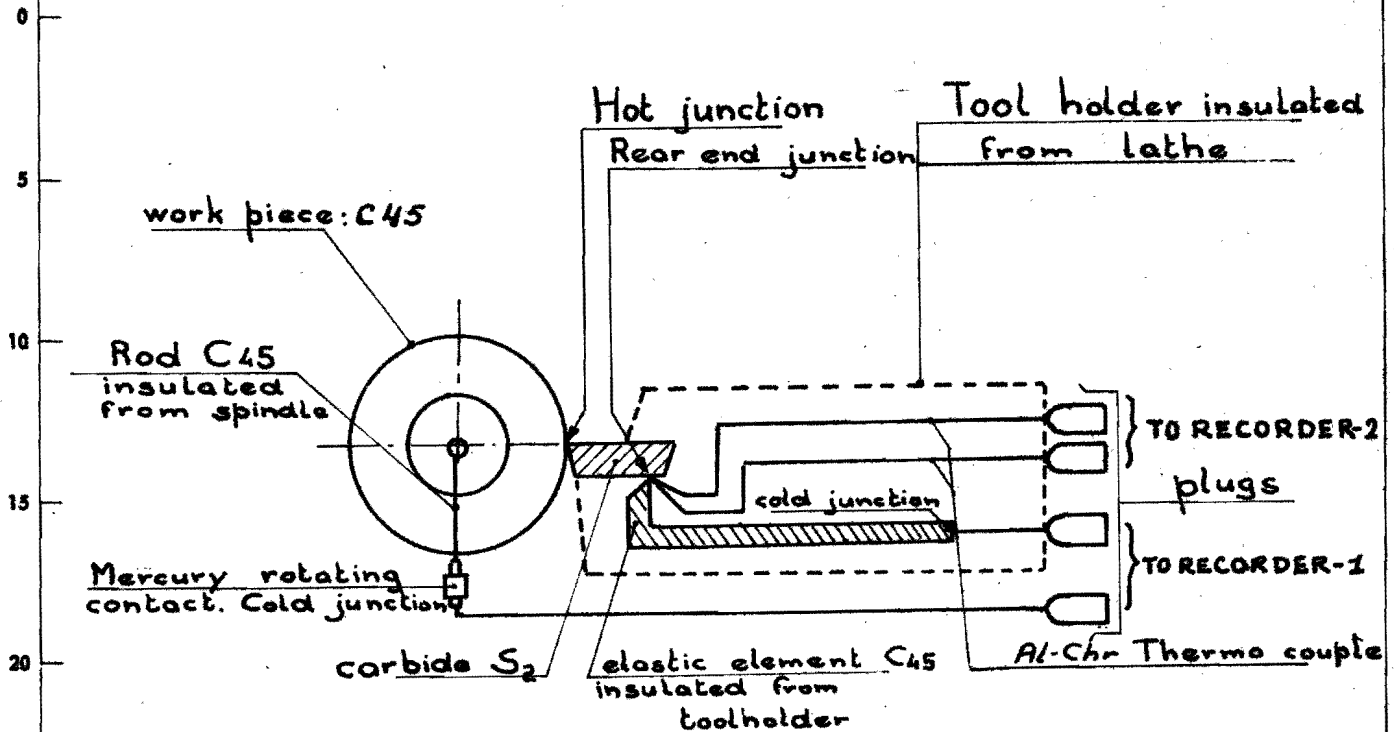


Fig 1

**SCHEMATIC DIAGRAM OF TOOLHOLDER  
MODIFIED ON PURPOSE OF TEMPERATURE MEASUREMENT**

The bit is clamped in the normal way and is forced at the rear end to an elastic element made out of the workpiece material. When the tool is in action the system represents the thermocouple: steel-carbide-steel. This thermocouple is an active one because of the difference in temperature between the cutting edge and the rear end of the bit.

The elastic element contains in its tip a Cr-Al thermocouple which allows to measure directly the temperature at the place of contact with the bit.

As shown in fig. 2 the thermo-electric tensions of both of the systems are fed into two serve recorders.

One of them (2) records the temperature of the rear end of the bit the other one (1) reads the differential voltage between the cutting edge and the rear end of the bit. Typical recordings are

shown in fig. 3.

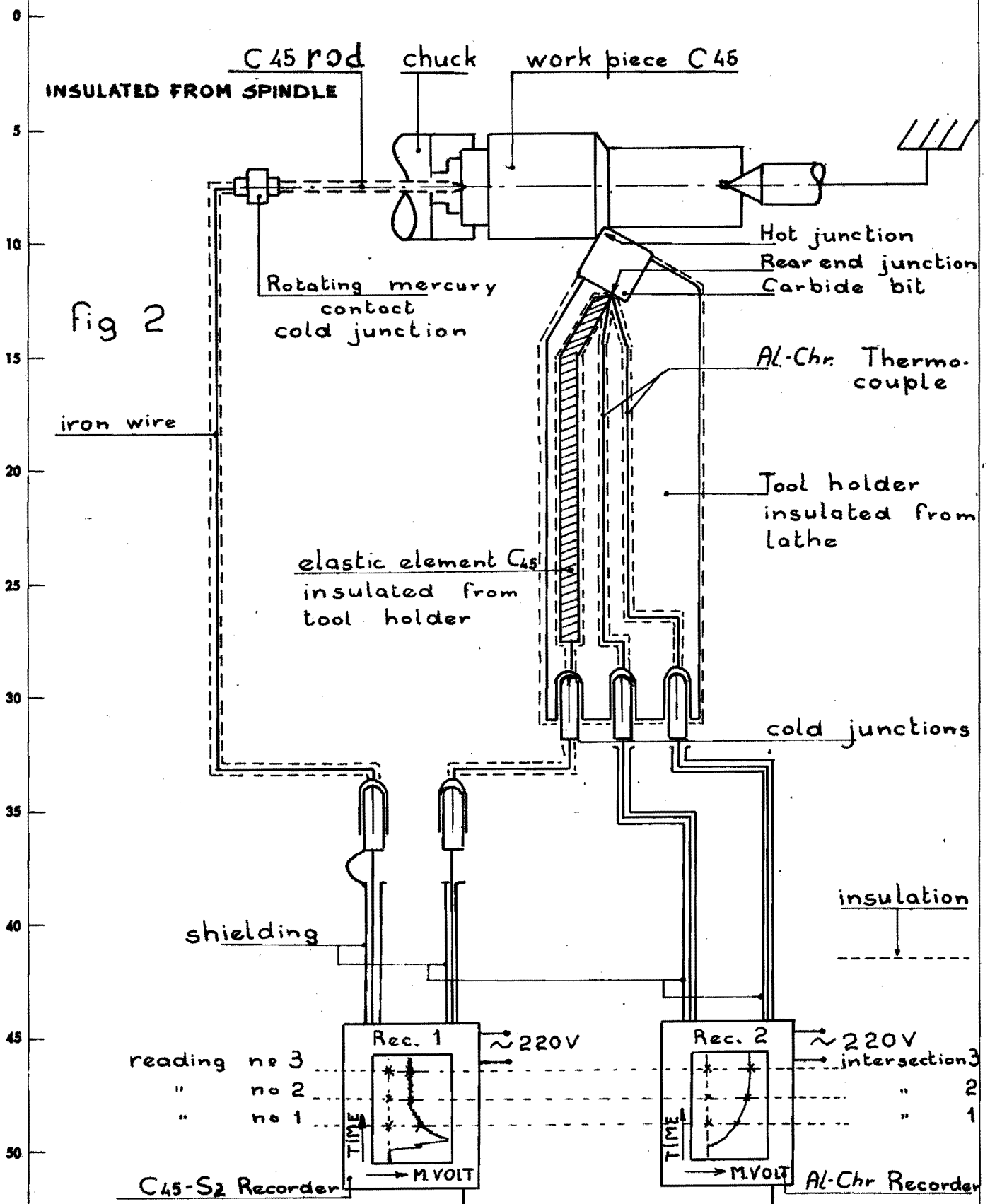


fig 3

**SCHEMATIC DIAGRAM OF TEMPERATURE MEASUREMENT**

Assuming a calibration curve is available with respect to the temperature vs. thermo-electric tension for this particular combination of carbide and steel, it is possible to determine the cutting-edge temperature from the recordings obtained. The principle of the method is shown in fig. 4.

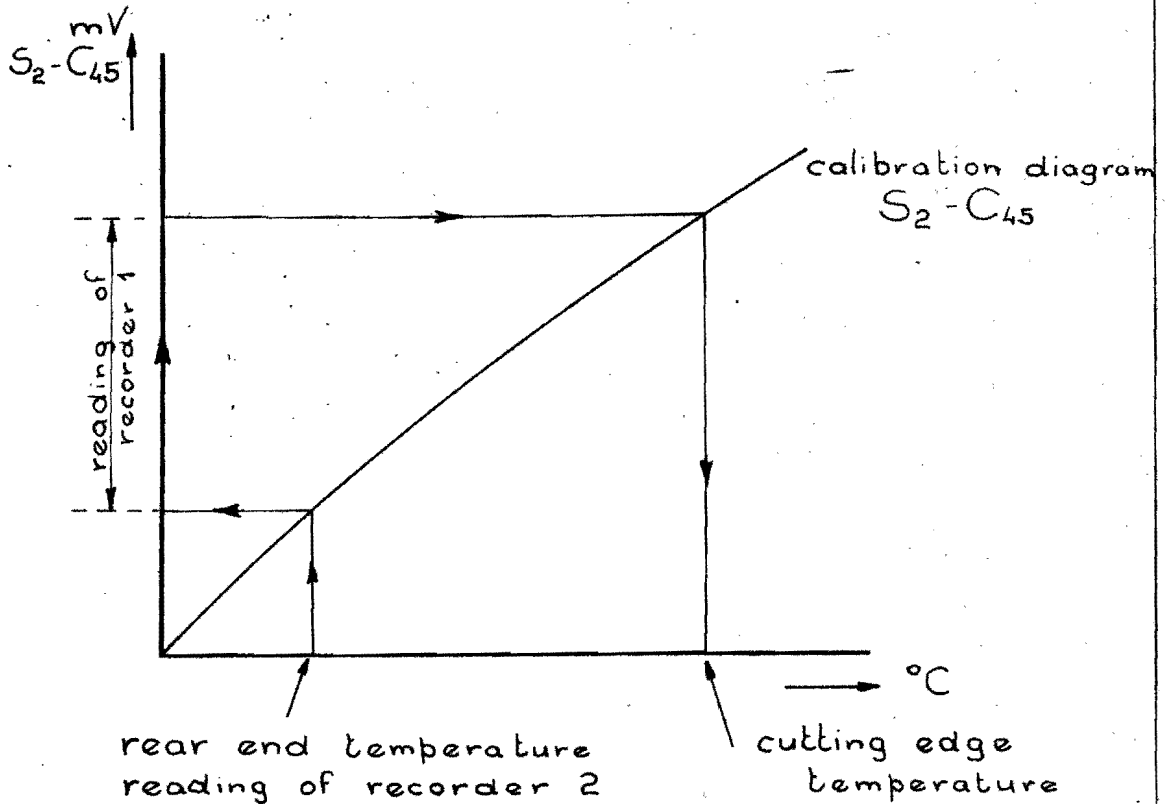


FIG. 4 USE OF THE CALIBRATION CURVE TO DETERMINE CUTTING-EDGE TEMPERATURE

The reading of recorder 2 in °C is plotted on the horizontal axis of the calibration diagram. The reading of recorder 1 is plotted in the way shown. Intersection with the calibration curve of the horizontal line drawn from the point defined in this way on the vertical axis determines the temperature of the cutting edge. It is clear if quite a number of asynchronous intersections is made in the recordings of fig. 3 all of them have to result in the same temperature as the equilibrium of the cutting edge is reached in a very short time.

This allows to get a very good accuracy of the measurement of the average value according to the principle shown in fig. 5.

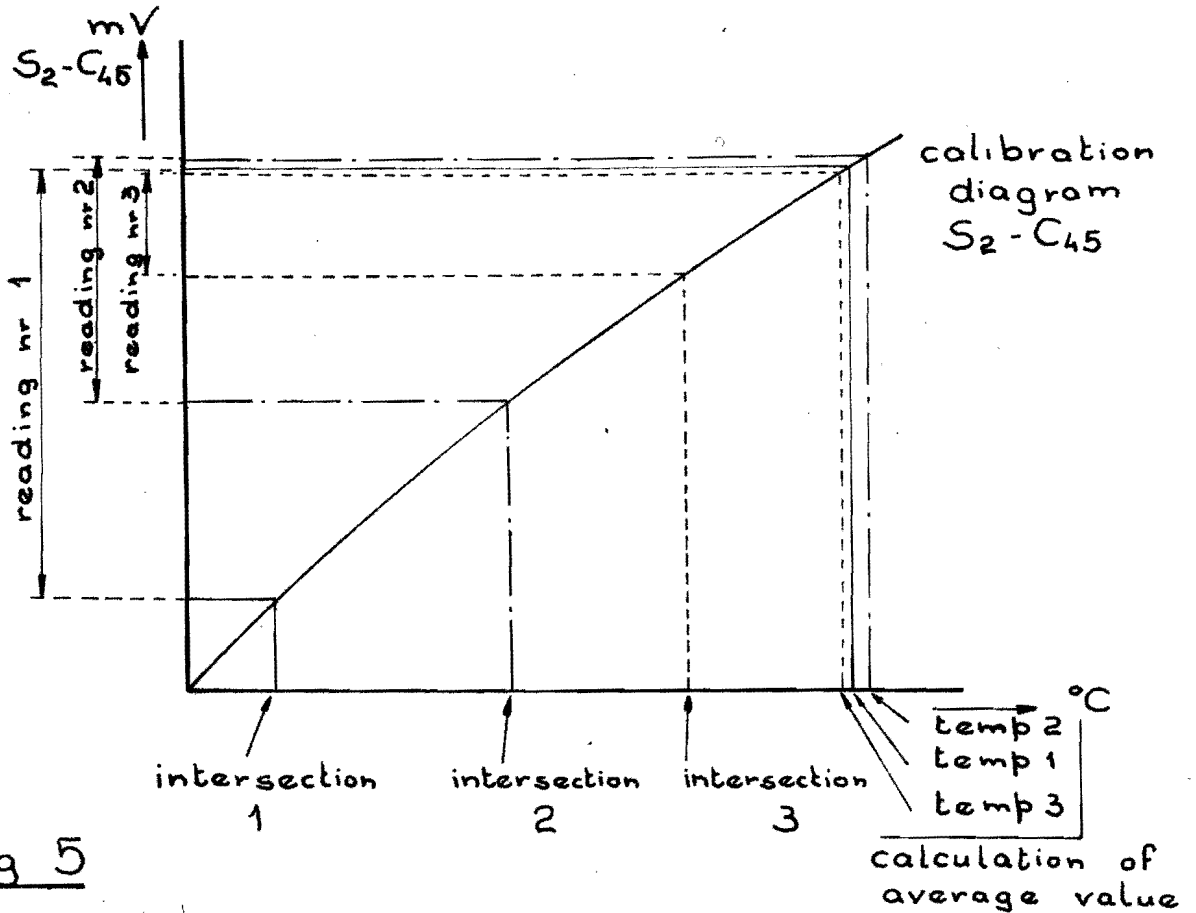


fig 5

**PRINCIPLE OF SYNCHRONOUS INTERSECTIONS**

Though the quality of Sandvik bits is of a very high standard there occur slight variations in the composition which are of some influence on the thermo-electric properties.

This forces to a correction for systematic errors in the measurements.

To this purpose three out of the four cutting edges of the bit are used for normal measurements.

The fourth one is applied for cutting using standard conditions of cutting geometry and cutting speed.



Applying the method described earlier and using a standard calibration curve the measurement delivers a well defined cutting-edge temperature involved with an unknown systematic error. Next the cut is repeated with identical standard conditions but now using a solid rod of S2 material carefully ground to a cutting tool with the same geometry as the bit. This long rod allows a cooling of the far end either to room temperature or to the ice-point. The thermo-electric potential corresponds merely to the system S<sub>2</sub>/C<sub>45</sub> and is recorded. The same rod is used in the calibration array as described later. This calibration gives the standard calibration curve. In this way it is possible to determine the "true" temperature corresponding with the standard conditions of cutting and the method allows the fixation of a point of reference as shown in fig. 6 and the determination of a "correction factor" for each particular bit.

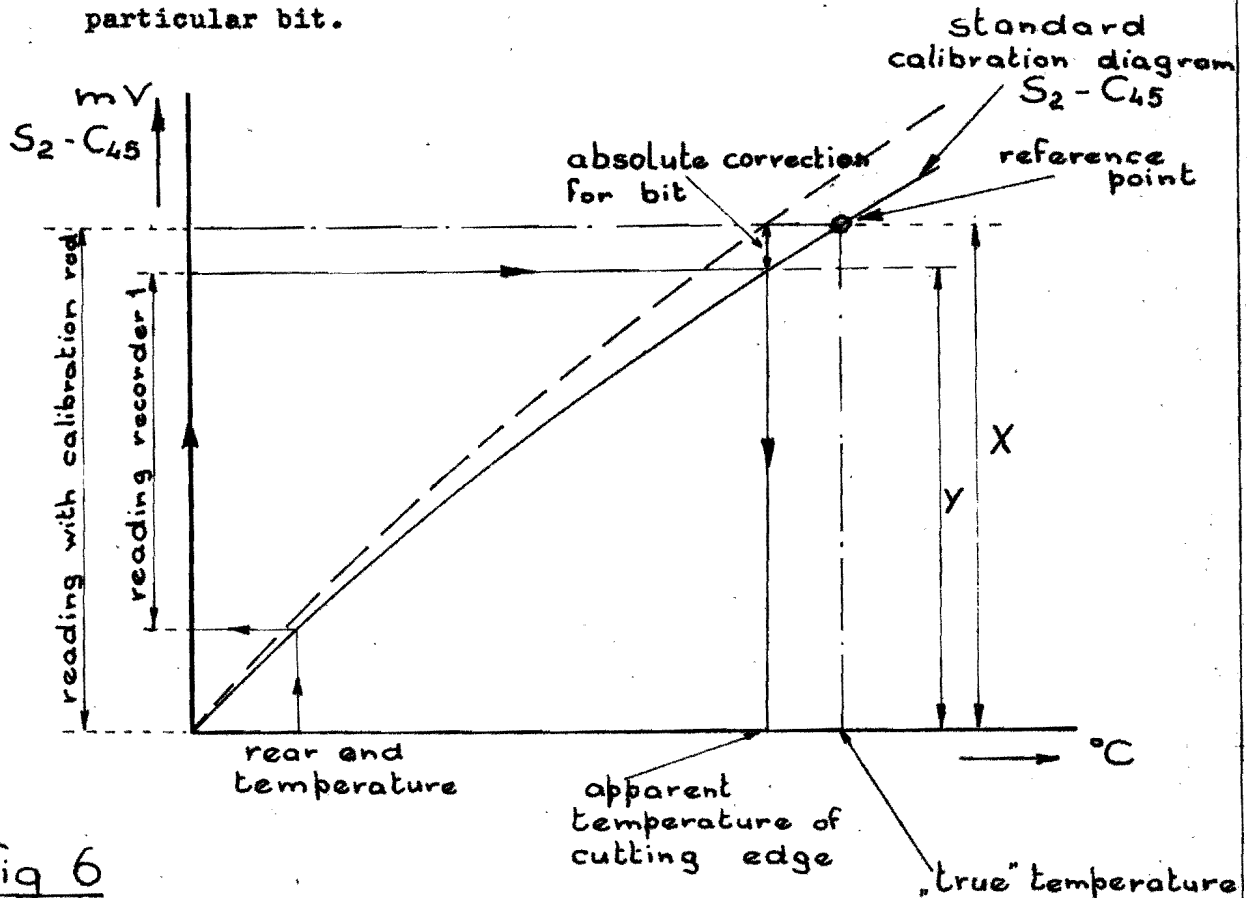


fig 6

DETERMINATION OF CORRECTIONFACTOR FOR A PARTICULAR BIT

0

As easily will be derived from fig. 6 the "correction factor" of a bit can be defined as  $\frac{x}{y}$ , i.e. the value  $y$  obtained with that

5

particular bit and using the standard calibration curve should be multiplied with the factor  $\frac{x}{y}$  to obtain the real value "x",

10

defining with the same calibration curve the "true" temperature. In practice it proves that the correction factor shows 0,98 to 1,12 as ultimate values.

15

Synchronous intersections define very well the average apparent value of temperature while on the other hand a long run with the standard rod defines the "true" temperature to a high grade of accuracy, assuming reliability of the calibration.

20

25

30

35

40

45

50

b. The calibration of the system carbide/steel.

As mentioned before the reliability of the Gottwein method depends greatly on the accuracy of the calibration of the thermo-electric system.

Points of attention of major importance are:

1. the conditions of the calibration have to be comparable with the conditions of cutting.

The contact surfaces between the workpiece material and the carbide must be precision ground and thoroughly cleaned in order to provide a real intermetallic contact. Precautions must be taken to avoid oxydation of those surfaces, hence the calibration has been performed in a protective gas atmosphere. The specific mechanical load of the contact surfaces has to be pretty high, i.e. the two components of the thermo electric system are spring-loaded and the area of mechanical contact has been minimalized as far as the construction of the calibration-unit allows.

This is also of importance from a thermal point of view.

2. the temperature of the system is to be measured in the very spot of contact between carbide and steel. As this is physically impossible the temperature is measured in the centre of a circular area, the greater part of it being the contact surface. The smaller this area is chosen, the greater the certainty of temperature equality throughout the contact surface.

3. temperature variations in the area of contact should be minimalized by reducing the heat flow originating from this zone either into the workpiece material or into the carbide rod. This can be done by reducing the effective diameter of both the rod and the workpiece material to a very small size.

The calibration unit is shown in fig. 7.

As mentioned before the carbide rod is used on dual purpose. In the array according to fig. 7 it is used as a calibration rod. In the experimental cutting technique it is used as a tool to provide points of reference with respect to carbide bits which are selected at random from a lot of equal grade and quality.

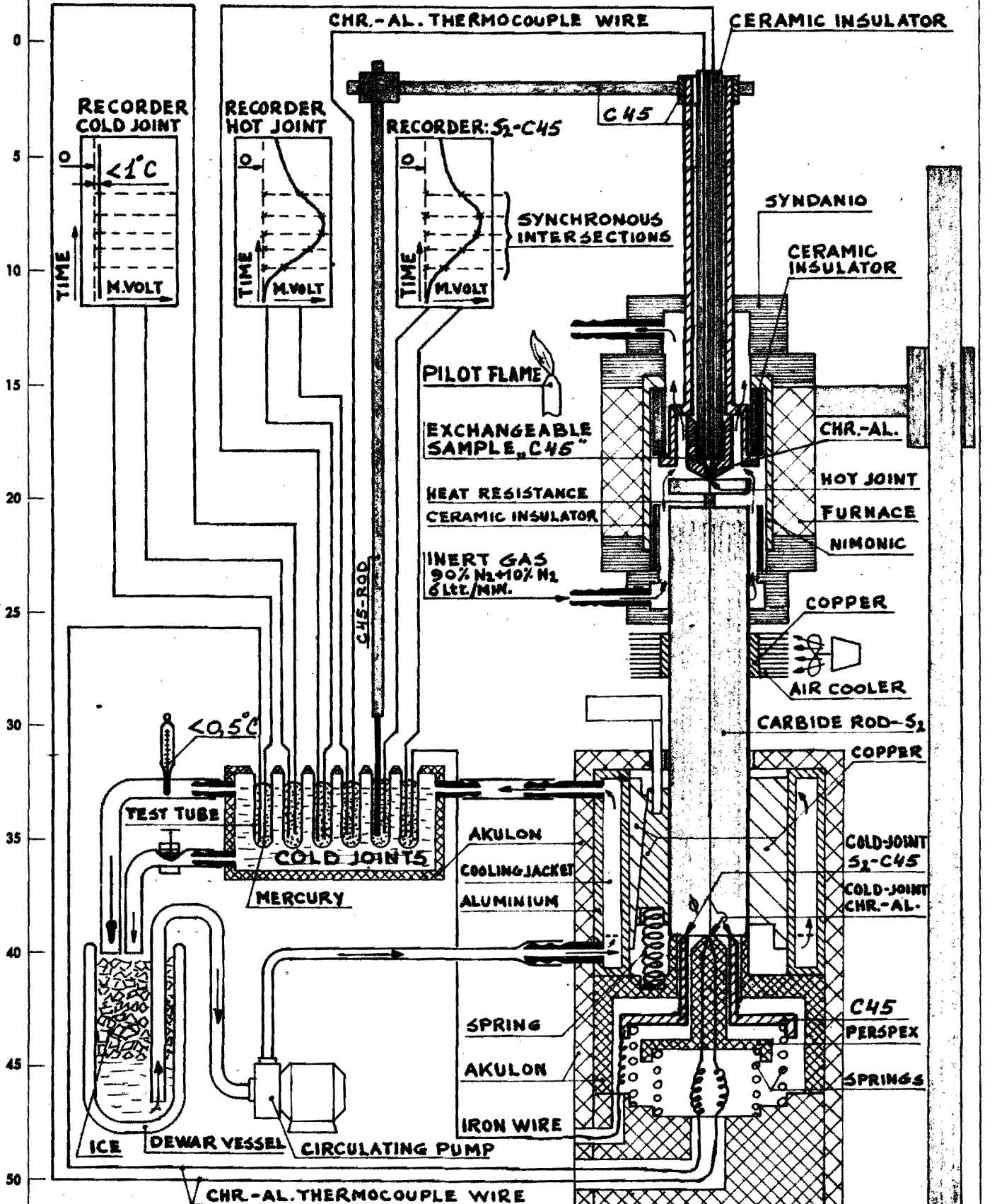


FIG. 7

CALIBRATION UNIT

werkplaatstechniek

DR. P.C. VEENSTRA

technische hogeschool eindhoven

0  
5  
10  
15  
In the construction of the calibration unit it has been carefully attended not to introduce active thermocouples in parallel or in series with the one being the aim of investigation. To this purpose both the workpiece material and the carbide rod extend up to a considerable distance from the heating furnace while all joints to different materials are kept at ice temperature. Recorded are simultaneously the temperature of the cold joint, the temperature of the hot joint by means of a Cr-Al thermocouple and the electromotive force of the system as is clear from the figure. Moreover provisions are taken that at will a measurement can be performed in a compensation circuit.

20  
25  
A special and in our opinion a very important feature of the calibration is the dynamical way of measuring. So the calibration is performed either at increasing or decreasing temperature and no stops are inserted to allow the system consisting of thermocouple and furnace reaching temperature-equilibrium.

30  
35  
Synchronous intersection of the three recordings renders reliable calibration points, on the condition that the heat flow through the thermocouple is of a negligible small amount.

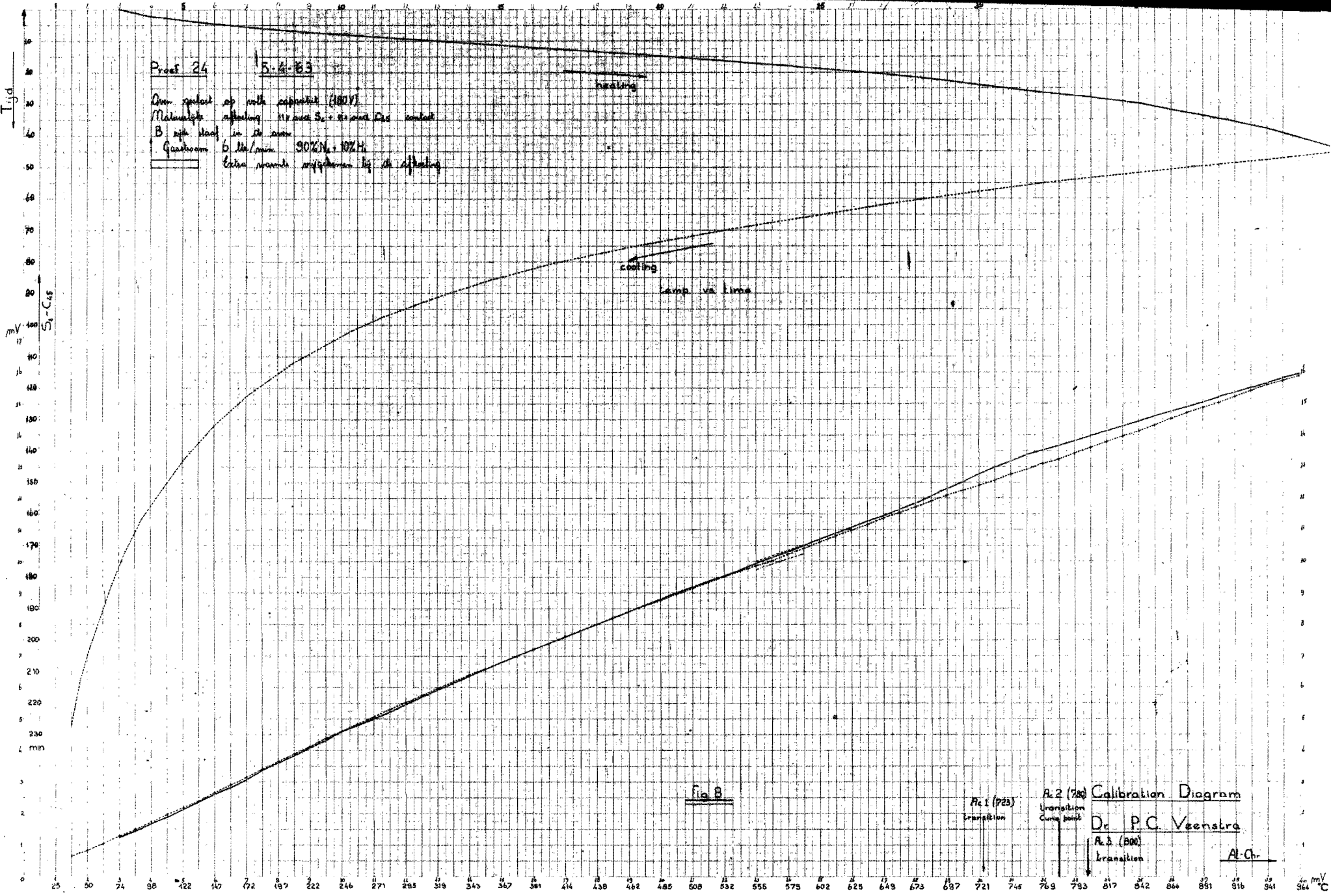
40  
45  
This method of measuring allows to account for the influence of the phase-transitions (allotropic transitions) of the workpiece material on the electromotive force of the thermocouple of which it is a partner.

50  
The effect is shown very clearly in a typical calibration curve according to fig. 8.

During the heating cycle extra heat is absorbed by the system due to the phase transition  $A_c 1$  at  $725^{\circ}\text{C}$ , the magnetic transition at the Curie point  $A_c 2$  at  $770^{\circ}\text{C}$  and the  $A_c 3$  transition at about  $800^{\circ}\text{C}$ .

These reactions result in a relative increase of electromotive force with respect to the "normal" trend.

During the cooling down of the system a decrease is observed. Due to the fact that in comparison with the grain size of the material a considerable amount of material is participating in the process. the resolving power of this particular measurement is very poor.



Proef 24 5-4-63

Omponent op milk separator (80V)

Makkelijk afkelen 10 graden C. 10 graden C. contact

B. zijkant in de zijkant

Gasroom 6 l/min 90% N<sub>2</sub> + 10% H<sub>2</sub>

Extra warmte toegevoerd bij de afkelen

warming

cooling

lamp va lime

Fig B

A.1 (723)  
Transition

A.2 (780)  
Transition  
Curing band

Calibration Diagram

D. P.C. Veenstra

A.3 (800)  
Transition

At. Ch.

mV  
°C

The effect of phase transitions is observed over a broad temperature region and not of course at one definite point of temperature. Anyhow and apart from the problem whether these phase transitions really occur in the zone of contact between tool and chip the measurement gives an order of magnitude of a "natural uncertainty" of the temperature measurement when cutting two phase materials like steel.

A second important point is that microphotographs of the contact area have been taken after a number of calibrations.

The general trend is that the electromotive force of the system increases as a function of the number of heating and cooling cycles of the system. By means of micro photography it can easily be shown that a serious decarbonizing of the steel in the contact area occurs as a function of the number of cycles.

As a matter of fact the system Carbide - steel C45 develops probably by diffusion into the system Carbide/Carbon - pure iron - steel.

It is clear that these graduate changes of the composition of the partners of the thermo-electric system have a very significant influence to the thermo-electric properties.

In general these changes result in a calibration which lags with real temperature.

In our opinion once this kind of calibration techniques being a routine job they have to be performed with fresh and carefully prepared components.

We do realise that probably the heatingtime during the calibration up to the region of cutting temperatures takes too long.

It might be useful to flash temperature up by means of high power-high frequency heating in order to obtain a calibration which with respect to time gets into an order of magnitude comparable with the cutting process.

By now development and experiments are directed this way. At the mean time attempts are made to increase the thermal resolving power of the system in order to get more detailed information on the effects of phase transitions.