HIGHER TECHNICAL INSTITUTE
NICOSIA 1968 CYPRUS

# Review

No. 5 June 1976 Nicosia

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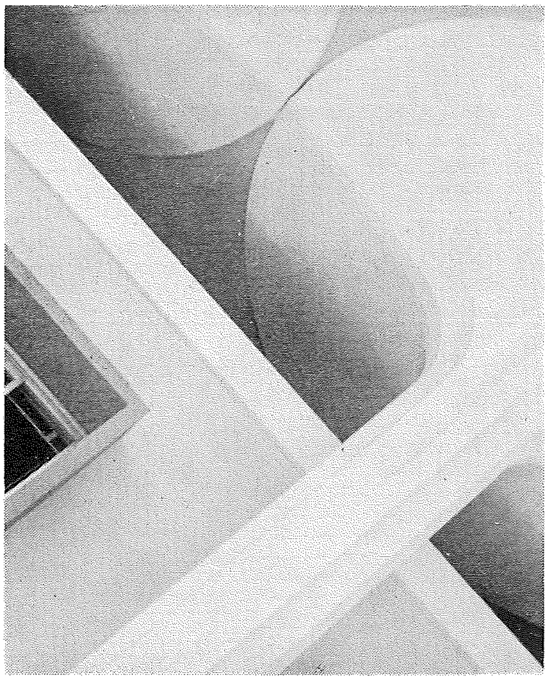

**Cover photo by K. Georgakis, Librarian, HTI.**

**A VIEW OF A COLUMN AT HTI PHOTOGRAPHED IN A TILTED POSITION.**

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HIGHER TECHNICAL INSTITUTE NICOSIA CYPRUS 1968

# Review

No. 5 June 1976 Nicosia

# EDITORIAL

Almost two years have passed since the Turkish invasion of Cyprus in July 1974. Two long years of problems hardships and struggle, but also of firm determination to survive and see our land free again and united.

The Cyprus economy is reactivated and month by month more jobs are created. The 200,000 refugees are neither sitting idle and nor are they demoralised begging for help. They are spreading out temporary roots, raising up their stature and their voice demanding justice from the world conscience.

The HTI having quickly recovered from the crippling effect of the shock wave of the invasion, continued to offer trained manpower for the needs of industry and to provide opportunities for self-betterment in the engineering fields. In fact it is doing more than that. It is responding to the spirit for reactivation by opening up its laboratories and workshops for industrial testing; it is sending out its expert staff on consultancy assignments to Cypriot firms operating locally and abroad; it is starting new programmes and courses of training. A bigger number of Cypriot students are undergoing training and more places are made available for applicants from neighbouring countries.

The HTI Review is an annual publication of the Institute providing a venue for staff and students to write on engineering and other topics. This fifth issue reflects the spirit of determination to continue to do a job well and to stay on course.

GENERAL EDITOR

# LASERS IN INDUSTRY

**A. Z. Achillides**
**Lecturer, H.T.I.**

*ABSTRUCT:*

Lasers can now be regarded as practical and economic tools with unique properties which have been utilized effectively in several applications in industry. Major applications of Lasers are in thermal processes and measurements. Large amounts of concentrated energy allow microdrilling, welding, cutting and fracturing to be simply effected in even the hardest materials. The coherence properties provide ideal sources for alignment instruments and interferemeters for accurate length measurements. This article describe these applications and their typical capabilities.

## I. **Introduction:**

A laser is a device which generates a beam of light. The light from a laser is very much more intense than light from other sources and, in addition, possesses the property of coherence which ordinary light beams do not possess. The angular spread of the laser beam is usually very much smaller than that of ordinary light beams.

It has been indicated that a necessary condition for laser action to take place is the establishment of a population inversion between three levels of an atomic or molecular system. In order to make such a system work it is necessary to find a material which has three energy levels separated by energy gaps equivalent to visible frequencies. One of the

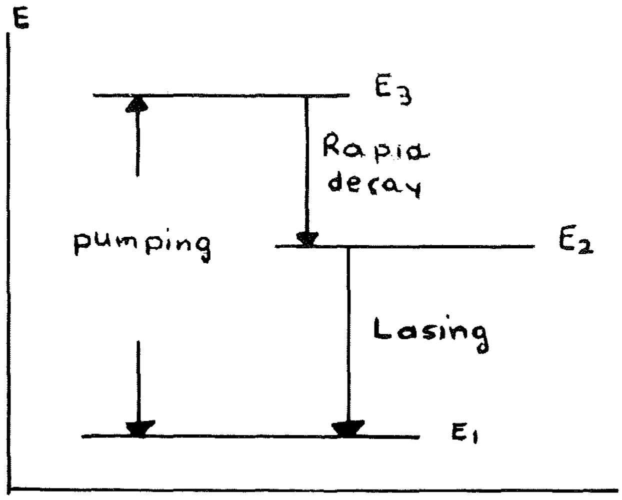


Fig. 1

most successful materials to be used has been ruby which consists of aluminium oxide ($Al_2O_3$) to which has been added between 0.01 and 1% of Chromium, the atoms of which take up positions as ions $Cr^{3+}$ within the crystal lattice. Chromium ions in the ground state are excited by an intense flash of white light from a lamp, from the ground state to an upper state which actually consists of a large number of levels forming a band. This make the pumping of electrons from a lower to an upper state more efficient because an exact pumping frequency is not required. Fig. 1 indicates the steps in this process.

The transition down into the middle state is accompanied, not by the emission of a photon, but by the direct transfer of energy to the surrounding crystal lattice which causes the ruby rod to heat up. Once an electron reaches the middle state $E_2$, it spends an unusually long time there before dropping down, by spontaneous emission, to the ground state $E_1$. States such as these are said to be metastable and it is because of this characteristic that the population of the middle state builds up while that of the bottom or ground state is depleted i.e. a population inversion is achieved. This method of obtaining a population inversion is very inefficient because as the middle state is effectively empty at the start of the pumping process (owing to the Boltzmann thermal distribution) at least half the population of the ground level must be pumped up to the middle level before a population inversion is achieved. In addition very little of the electrical energy which is supplied to the flash lamp ends up in pumping photons and carefully designed reflectors are essential in order to concentrate as much light as possible onto the ruby rod. The pumping flash is necessarily brief and hence only pulsed operation is possible normally. A pulse duration of about 1 ms is usual with a power of as much as 10 KW.

Many materials have been shown to be capable of lasing; however, relatively few materials are used in practical laser systems. The most widely used lasers are outlined below.

Ruby was the first material operated and remains widely used in pulse high energy processes, such as welding and cutting. When Q-switched (a technique providing for extremely short pulses of very high peak powers) it is used for measurement studies as well as in processing. The essential components of a ruby laser are shown in fig. 2.

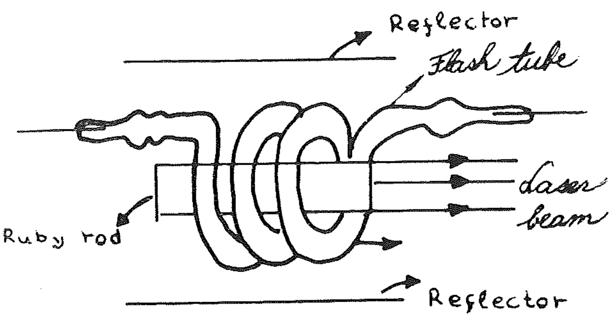


Fig. 2

Other materials which are proving in many cases to be better than ruby (Cr doped $Al_2O_3$) are those doped with Neomidium. The primary host materials are glass and Yttrium aluminium garnet (Y A G). A very efficient laser is the semiconductor junction laser. However, the low output power and low coherence properties have limited its use up to now. The first gas laser was the He–Ne and it has remained a popular laser for low power (up to 100 mW) applications where coherence properties are the main requirement. These applications include interferometry, holography and diffraction effects. Other gas lasers which have produced higher powers and shorter wavelengths are the argon ion and krypton ion lasers operating either pulsed or continuous. Recent developments are permitting radiation into the near ultraviolet to be produced with high coherence properties and at comparable cost to the He–Ne laser. A longer wavelength laser of much higher power ($>$ 1 kW) and efficiency (20 per cent) is the $CO_2$ – $N_2$ – He laser. This laser is finding a useful place in both processing and measuring systems. It can be operated with single or multimode output and may be run either continuously, pulsed or Q–switched.

## II. Processes

The properties of intensity and spatial coherence of the laser give a source of radiant energy which can be concentrated to achieve extremely high power densities. When absorbed by matter, this energy can be sufficient to overcome the binding forces associated with the atomic and molecular structures of materials, so that high temperature phase changes are easily effected. When radiant energy is focused by a lens, the power density within the focused spot can be often represented by the following relationship.

$$P = \frac{4E}{\Pi^2 t \ \Theta^2 f}$$

where P = power density at focal plane of the lens
E = energy output from the laser
f = focal length of the lens
Θ = beam divergence (full angle)
t = laser pulse length

The minimum beam divergence of a light beam is a function of its wavelength and beam diameter. The Rayleigh criterion for the minimum beam divergence of a spatially coherent light beam is

$$\Theta_{min} = \frac{1.22\lambda}{R}$$

where λ – wavelength and
R – radius of the beam or aperture.

If it is assumed that the beam divergence of the laser is 5 m rad and that its radiation is focused with a 25 mm focal length lens, then the power density within the focal spot is 2000 times the power within the unfocused laser beam. Typically, the peak powers obtained from pulsed laser systems range from $10^4$ to $10^6$ W. In a typical pulsed laser system the focused spot size S may be adequately approximated by the equation

$$S = f\Theta$$

Typical value of the spot size is $< 0.25$ mm.

There are several areas of material processing and they will be discussed in the following sections:

(1) Welding, (2) Material removal (including drilling, drimming and evaporation), (3) Material shaping (which covers cutting scribing and controlled fracturing).

### 1. Welding:

In considering pulsed laser systems for welding applications, one major factor that must first be determined is the capacity of the system in energy or power output and in duration of lasing action. These basic parameters, along with other secondary factors, are normally used in characterizing a laser Energy: The output energy of a laser is a function of a charging voltage (obtained from the power supply) on a bank of capacitors (designated the energy storage unit). The stored energy is dissipated in a high intensity flash lamp which by proper coupling design excites the laser rod for stimulated emission. Ruby and Neodymium in glass, are the two lasing materials used in most commercial pulsed welding systems. Ruby is generally more rugged and can be pumped harder to produce higher powers. In some respects, the shorter ruby wavelength has an advantage over that for neodymiun in glass.

**" The more we stick to simple foods and work with our hands, cleave to the great our of doors and the sunshine — the better for us ".**

ELBERT HUBBARD

Output duration or Pulse length:

The parameter of pulse length is essentially determined by the amount of capacitance (or capacitance-inductance groups) in the excitation circuit. The proper matching of the flash lamp to the electronics and the optical coupling geometry in the laser assembly both greatly aid in optimizing the laser pulse characteristics for effective welding practice.

In general, the longer the pulse length, the more the work-piece or weldment will react along the fusion mechanism of energy absorption, heat transfer, melting, intermixing of constituents, and subsequent solidification. With good control of the laser beam, vaporization and possible particle expulsion can be minimized. Welding speed is limited by the pulse-repetition rate of presently available equipment. A rate of 1 pulse/sec is commonplace today, and at an appreciably high energy level ($>$ 10 J). Pulsed-laser welding is a slow process when compared to other welding techniques, averaging between 0.5 and 5 cm/min. On the other hand "CW" welding with $CO_2$ laser (pulsed at 25–300 pulses sec) has the potential of welding at relatively higher speeds of 1.3 to 15 cm/min. With higher powered $CO_2$, as well as with the rapidly pulsed argon ion and YAG systems welding speeds as high as 130 cm/min can be expected. Pulsing techniques of high powered CW systems hold promising expectations in large area metal melting.

As present, it can be said that the laser is quite applicable to the miniature area of manufacture, and has a somewhat limited applicability to the standard joining operations where the mass of material in the weldment increases. As a general rule, a potential application for using the laser can be considered if the particular job cannot be accomplished any other way or the economics and or the engineering requirements are difficult to meet using conventional methods.

2. **Material removal:**

(1) Laser piercing (Drilling): The first major industrial application using the laser was in the general area of hole drilling, or more properly piercing. One can readily appreciate the advantages of using laser energy for hole piercing with consideration of the following factors:

1) Because there is no physical contact between the hole-forming tool and the material, problems such as drill-bit breakage and wear are non-existent.

2) Precise hole location is simplified because the optics used to focus the laser beam are also used to align and locate.

3) Large aspect ratios (hole depth to hole diameter) can be achieved because of the basic characteristics of laser light.

As with the case of welding, material properties also have an influence on the laser parameters used in hole piercing.

Laser drilling in hard (high temperature fired) alumina ceramic is attractive because drilling ceramics by conventional mean is not a simple task; it usually requires diamond tipped, hardened steel drill bits. Small size holes less than 0.25 mm in diameter, are extremely difficult for current tool technology. Breakage of the drill often results when the thickness of the ceramic is appreciably greater than the diameter of the hole to be drilled.

3. **Component trimming:**

The laser is also be investigated as a mean of modifying electronic components either by selective evaporation of by heating. The high power densities, small spot size and short pulse lengths achievable with lasers make them ideal tools for this purpose. In addition, it is usually possible when using the laser, to constantly monitor the device thus allowing it to be trimmed or adjusted to a specific value.

The determination of the exact characteristics required of a laser for material removal is done empirically because effects of parameters such as material emissivity, conduction losses etc. cannot be calculated exactly. However, sufficient information usually exists to make preliminary calculations that will indicate which lasers are likely to be practical in a particular application.

4. **Evaporation and deposition:**

The use of the laser to evaporate material not for the purpose of removing the material but for the purpose of obtaining vapour which may then be deposited on a subtrate, is a promising area. While the vaporization and deposition of material have

**" KEEP that great secret of youth — to live in the present moment, and let the future and the past take care of themselves".**

CANON P. A. SHEEHAN

been accomplished by many techniques, the laser offers some unique advantages:

(1) The vapour can be generated in any atmosphere transparent to the laser radiation.

(2) No contaminants are introduced by the laser radiation.

(3) Essentially all of the laser energy may be used for evaporation with little of it being absorbed by the subtrate.

(4) Small selected areas of the source material may be evaporated.

(5) The evaporant source may be located very close to the subtrate.

(6) Compounds may be evaporated with little change in composition.

Jackson et al (3) have reported a technique whereby the laser is used to vaporize material which is then deposited on a substrate. They propose that a substrate having a complete coating of some material be placed adjacent to a blank substrate such that the coating on the one substrate is very close to the surface on which it is desired to obtain a pattern. A laser is then positioned such that its energy is focused, through the first substrate, onto a thin film. As the two substrates are moved with respect to the laser beam, the material is vaporized from one substrate and redeposited on the second substrate in a pattern which duplicates the movement of the substrates with respect to the laser beam. This technique could be used in several different applications, such as the generation of photomasks, the generation of conducting paths on thin film or integrated circuits, etc.

## II. Measurements:

In this section the exploitation of the laser as a measurement tool will be described with emphasis on industrial applications. Lasers are becoming sufficiently low cost that in many experiments they are now used more for convenience than anything else. In many cases the phenomena involved in the measurements are well known and have been under study in the physics and optics laboratory; for example, interferometry and light scattering. Here the laser has provided a much improved source and extended the range of measurement. From the vast group of industrial measurements a small number of applications may only be described.

### 1. Velocity measurement:

Doppler shifted light, scattered from moving particles, is a well known and well studied phenomenon. Until recently, however, due to spectrometer limitations, only relatively large velocities could be detected. Using the laser with optical heterodyning (4) very accurate determinations of frequency shifts can be made; Cummins (4) states his system has a 10 Hz bandwidth and is able to measure velocities of $4x10^{-5}$ ms–1. This instrument was used to measure liquid velocities by scattering light from suspended particles. Velocity profiles could be determined by measuring the light scattered from various regions of the liquid.

An application of the Doppler effect which could have more immediate petential in industry is the use of a Doppler radar instrument to measure vibration. Again this has the advantage of no contact with the object and so no interference with the object or its surroundings.

The optical tranducer also has no limitations due to resonances, which are experienced with mechanical transducers. Laser light is scattered from the vibrating object and then mixed on a photodector with the Laser reference beam (local oscillator) in the usual manner (for heterodyning). The movement of the vibrating object puts a phase modulation on the scattered beam; this is analyzed with a discriminating circuit on the detector. Sensitivities to $10^{-7}$ m in displacement are quoted for the experimental system reported.

### 2. Alignment:

The first and simplest application of the spatial coherence of the laser was the use of the collimated beam as an alignment aid. General alignment instruments have been developed which are com-

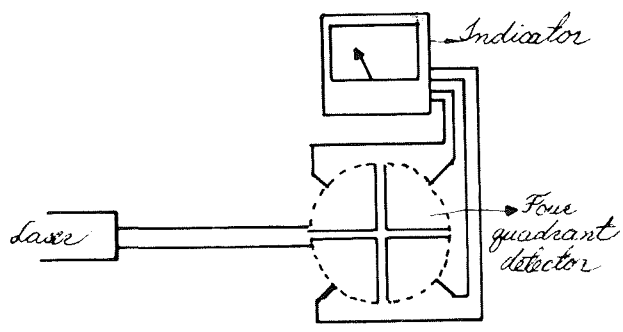


Fig. 3

mercially available and in use, especially in the aircraft industry. They use a 1.5mW, single trans-

> **"I AM, in plainer words, a bundle of prejudices — made up of likings and dislikings".**
> CHARLES LAMB

verse mode, He–Ne laser of wavelength $6.33 \times 10^{-7}$m, with beam collimating optics to produce a plane parallel beam of 10mm diameter. This is the optical line; along the line is placed a detector to determine whether objects are correctly aligned to it (Fig. 3).

The detector is a circular disk divided into four quadrants, thus forming four detectors. When the beam is in the centre of the detector, each quadrant receives the same light. Misalignment varies the light falling on each quadrant, and from the variation in readings an indication of the misalighnment results. Accuracies are quoted for this instrument of $10^{-6}$ rad. This kind of alignment aid is simpler to use than the telescopes previously used and requires only one person to operate it efficiently. Because misalignment is read out by the detection system, operator judgement is not required and removes one source of error. This kind of instrument is providing a good machine shop alignment tool.

3. **Interferometry:**

The laser has brought improvements to interferometry and there are now interferometer systems marketed for industrial use which incorporate a laser and are automated to the degree of giving a direct digital scale improvements which the laser brings
(i) increased temporal coherence length
(ii) increased intensity.

These make the interferometer a practical tool to be considered for industrial applications where very accurate measurement for control, within a few microns, is required over large distances.

Fig. 4 shows the Twyman–Green interferometer used in the commercial distance measurement systems.

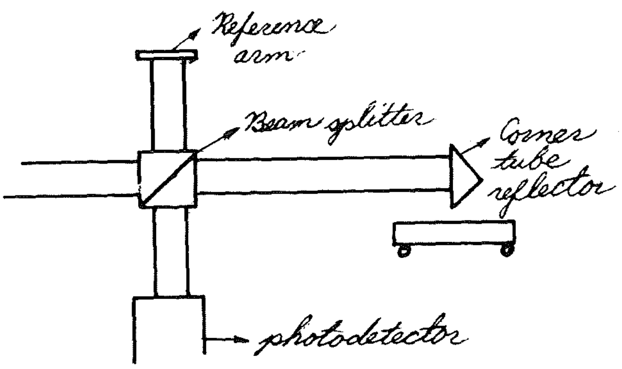


Fig. 4

The laser beam is split into two paths–measurement and reference. In the reference arm is a mirror which returns the beam back to the beam splitter. The measurement path is parallel to the distance to be measured, and on the moving object is placed a corner cube reflector which also returns the beam to the beam splitter. The beam splitter recombines these two waves and sends them to the detector. The amplitude of the light received by the detector depends on the phase between the reference beam and the measurement beam and will go through one period as the measurement light path length changes by one wavelength. This corresponds to a movement of the measurement arm reflector of half a wavelength. Some interferometers use a double path measurement to produce one period for every quarter-wavelength movement of the reflector. The detector counts the periods, usually measuring quarter periods, and then a computer translates this to a distance measurement. To determine direction of movement, two detectors are required in some kind of quadrature phase arrangement.

Various interferometers are available with varying accuracies which are useful for such applications as accurate machine tool calibration or control, x –y table calibration or measurement and any other measurement where a large linear distance up to 30.5 m or more, must be measured very accurately to 1 part in 108. The most refined system can measure to better than $5 \times 10^{-8}$ m over a distance of 12 m and has compensation for atmospheric humidity, prussure, and temperature; it also allows for part temperature compensation. A simpler, less accurate instrument gives half-wavelength $3 \times 10^{-7}$ m resolution over a distance of 30.5 m.

The types of interferometers and their applications are numerous; Herriot reviews some of them (5) and indicates how the laser has changed the interferometer from a sophisticated laboratory instrument into a regular tool for industry. An area already well acquainted with interferometry is the optics industry.

**Conulusion:**

The information provided in this article has shown some of the applications of lasers in industry. There is no doubt that the laser has made considerable impact on the scientists and has in fact, become a standard research tool. I believe that the economic

**" I still find each day too short for all the thoughts I want to think, all the walks I want to take, all the books I want to read, and all the friends I want to see".**

JOHN BORROUGHS

advantages of lasers as practical tools will become more apparent as laser properties, and in particular the interaction of laser light with matter, is more widely understood.

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# SOME PROBLEMS OF GUIDANCE OF VEHICLES AGAINST A MOVING TARGET IN SPACE

**G. D. CHRISTODOULIDES**
**B. Sc. (Eng.), M. Sc. (Eng.)**

The following expose gives a method of computing the point at which a vehicle can intercept a moving target in space.

Let:–

target be at point A,
and vehicle be at point O
$V_T$ = Velocity of target
$V_R$ = Velocity of vehicle
$A_Y$= point of interception
$\vec{D}$ = vector OA
$\vec{D_Y}$ = vector $OA_Y$

If ty = time of flight of target, and of vehicle till interception,

then $A\ A_Y = V_T \cdot ty$ (i)

$D_Y = V_R \cdot ty$ (ii)

From trigonometry

$D = Dy \cos\varphi + A\ Ay \cos\xi$

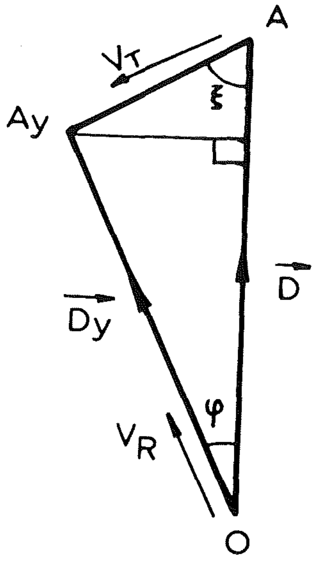



Fig. 1

If φ is small (a true situation when distances are large)

then $\cos\varphi = 1$

$\therefore D = Dy + A\ Ay \cos\xi$

Substituting from equation (i)

$D = Dy + V_T \cdot ty \cos\xi$ (iii)

by differentiating

$\dot{D} = V_T \cdot \cos\xi$ (iv)

Substituting (iv) in (iii)

$\therefore D = Dy + \dot{D} \cdot ty$

Substituting ty from equation (ii)

$$D = D_Y + \dot{D} \cdot \frac{D_Y}{V_R} = D_Y \left(1 + \frac{\dot{D}}{V_R}\right)$$

$$\therefore D = D_Y \frac{V_R + \dot{D}}{V_R} \text{ or } D_Y = \frac{D \cdot V_R}{V_R + \dot{D}} \qquad \text{(v)}$$

Thus we can estimate the value of $D_Y$ from the value of D (which we can estimate using radar methods), and from the value of $V_R$ (which could be known from the characteristics of the vehicle). The value of $\dot{D}$ can be computed with the use of a differentiating circuit of the following type.

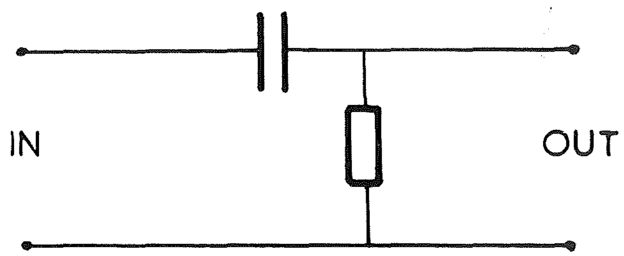



Fig. 2

The computation of $D_Y$ with electronic circuitry can be achieved as follows:

The expression $Dy = \dfrac{D \cdot V_R}{V_R + \dot{D}}$

is similar to the case of $x = \dfrac{y}{z}$ which can be found with an analogue computer by the method of implicit computation.

Thus, if $x = \dfrac{y}{z}$ then $xz = y$ or $xz - y = 0$

But if we feed this into a difference amplifier of large gain, k, then $k(xz - y) = \Delta$ and if this is amplified sufficiently enough Δ can be made equal to x.

The circuitry for this implicit computation can be as follows:

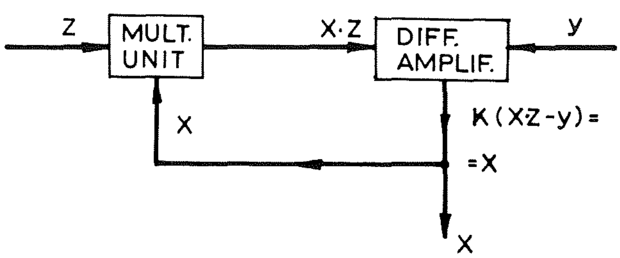
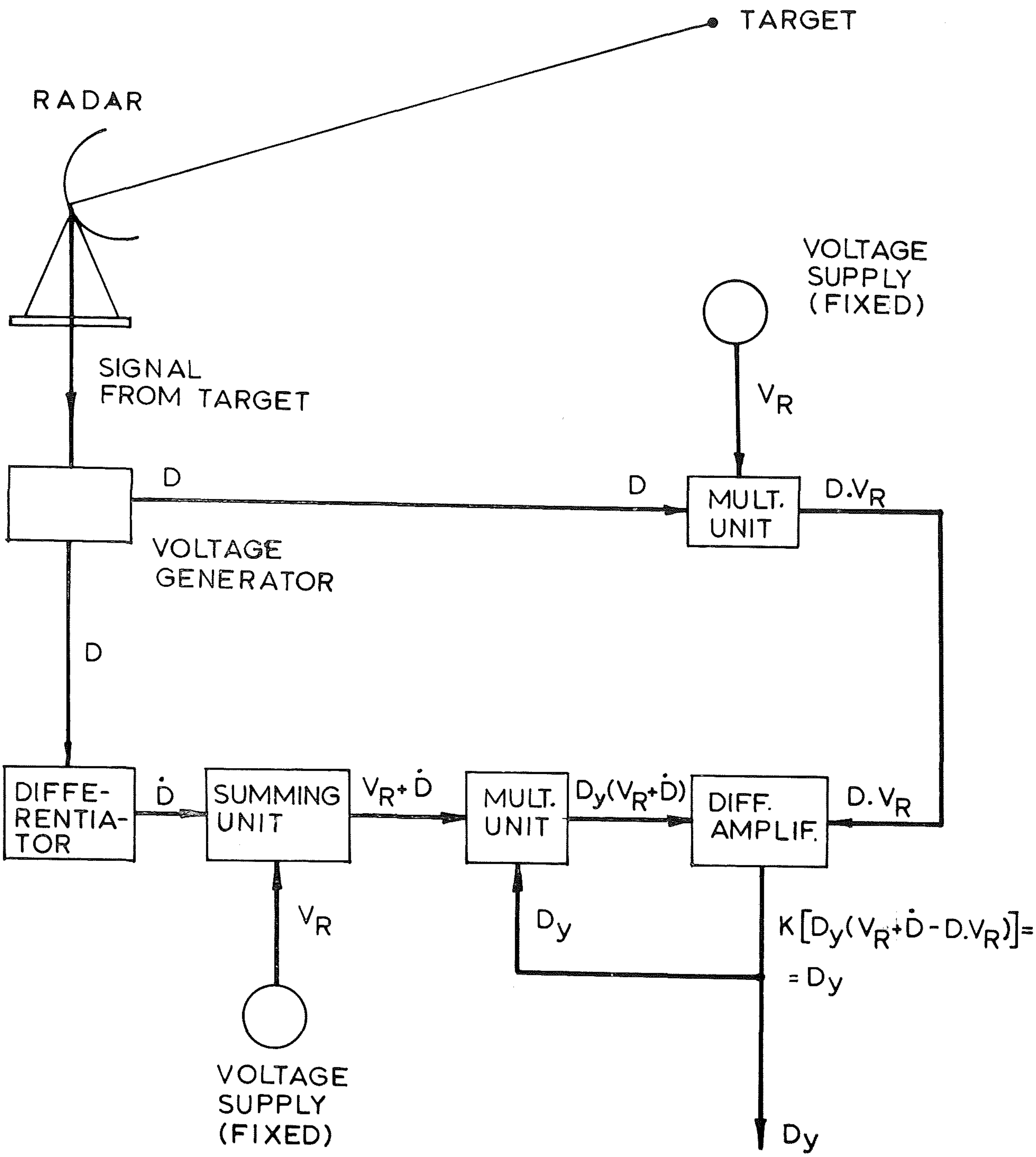



Fig. 3

In the particular case of having to compute the value of Dy, the total circuitry to produce the expression

$$K\,[D_Y\,(V_R + \dot{D}) - D \cdot V_R] = D_Y$$

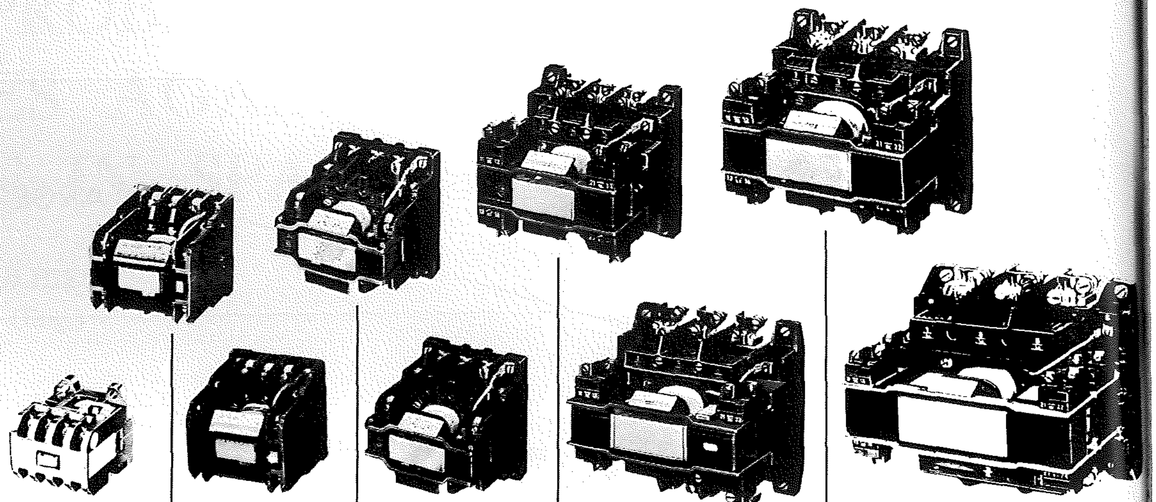
is as given below:




> **"To husbands and wives everywhere I offer these suggestions: appreciate each other, respect each other, try to bring out the best in each other".**
>
> RUTH S. PEALE

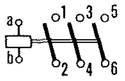
# DIL Universal Contactors

- Device life – Machine life: without maintenance or contact replacement
- Unit construction system with numerous possible conversions and accessories
- Common terminal markings to DIN 46199
- Exceptionally good pick-up and drop-out characteristics
- Climatic proofed



1 Million switching operations– 100 Operations/hour for 40 hours/week for 5 years

| Device life under load conditions | Utilisation category | Supply voltage | DIL 00–40<br>DIL 00–41<br>DIL 00–52 | DIL 00a–52 | DIL 0–11<br>DIL 0–22 | DIL 0a–22 | DIL 2v–22 | DIL 2–22 | DIL 3–22 | DIL 4–22 | DIL 6–22 | DIL 8–44 | DIL 8a–44 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 phase motor ratings 50–60 Hz | | | | | | | | | | | |
| Operations | | | kW | kW | kW | kW | kW | kW | kW | kW | kW | kW | kW |
| 1 | AC 2 | 220 V | 3,7 | 3,7 0,5 Mill. | 5 | 7,5 | 15 | 22 | 32 | 55 | 65 | 90 | 100 o.3 Mill. |
| | AC 3 | **380 V** | **4** | **5,5 ops.** | **7,5** | **11** | **18,5** | **30** | **45** | **75** | **110** | **160** | **200 ops.** |
| | including | 500 V | 4 | 5,5 | 7,5 | 15 | 22 | 37 | 55 | 90 | 132 | 200 | 250 |
| | approx. | 660 V | 4 | 5,5 | 7,5 | 11 | 11 | 15 | 55 | 90 | 132 | 200 | — |
| | 0.1%AC 4 (inching, | | | | | | | | | | | | |
| 3 | plugging, | 220 V | 1,3 | 1,3 | 3,7 | 5,5 | 7,5 | 11 | 16 | 30 | 35 | 37 | — |
| | reversing) | **380 V** | **1,5** | **1,5** | **5,5** | **6,5** | **11** | **18,5** | **22** | **37** | 55 | **75** | — |
| | | 500 V | 1,5 | 1,5 | 5,5 | 9 | 15 | 22 | 30 | 50 | 75 | 90 | — |
| | | 660 V | 1,5 | 1,5 | 5,5 | 6,5 | 7,5 | 11 | 30 | 50 | 75 | 90 | — |
| 10 | | 220 V | 0,4 | 0,4 | 1,5 | 2,2 | 3,7 | 5,5 | 7,5 | 11 | 18,5 | 22 | — |
| | | **380 V** | **0,55** | 0,55 | **2,2** | **3** | **5,5** | **7,5** | **11** | **18,5** | **30** | **45** | — |
| | | 500 V | 0.55 | **0,55** | 2,2 | 4 | 7,5 | 11 | 15 | 22 | 37 | 55 | — |
| | | 660 V | 0,55 | 0,55 | 2,2 | 3 | 5,5 | 11 | 15 | 22 | 37 | 55 | — |
| 30 000 | AC 2′ | 220 V | 1,1 | 1,5 | 3 | 4 | 7,5 | 11 | 15 | 22 | 37 | 55 | 75 10.000 |
| | AC 4 | **380 V** | **2,2** | **3** | 5,5 | 7,5 | **15** | **22** | **30** | **45** | **75** | **110** | **132** ops. **H** |
| | | 500 V | 2,2 | 3 | 5,5 | 11 | 18,5 | 30 | 37 | 55 | 90 | 132 | 160 |
| | | 660 V | 2,2 | 3 | 5,5 | 7,5 | 7,5 | 11 | 37 | 55 | 90 | 132 | — |
| 300 000 | AC 4 | 220 V | 0,55 | 1,1 | 1,5 | 2,2 | 4 | 5,5 | 7,5 | 21 | 15 | 22 | — |
| | (AC 2′)1) | **380 V** | **1,1** | **2,2** | **3** | **4** | **7,5** | **11** | **15** | **22** | **30** | **45** | — |
| | | 500 V | 1,1 | 2,2 | 3 | 5,5 | 11 | 15 | 18,5 | 30 | 37 | 55 | — |
| | | 660 V | 1,1 | 2,2 | 3 | 4 | 5,5 | 7,5 | 18,5 | 30 | 37 | 55 | — |
| | (AC 1) | Continuous current Ith2 | 20 A | 20 A | 40 A | 35 A | 80 A | 85 A | 140 A | 260 A | 300 A | 400 A | 450 A |
| Main contacts | | Aux. contacts<br>M = Make<br>B = Break | 1M<br>1M+1B<br>2M+2B | 2M+2B | 1M+1B<br>2M+2B | 2M+2B | 2M+2B | 2M+2B | 2M+2B | 2M+2B | 2M+2B | 4M+4B | 4M+4B |



# Selectivity

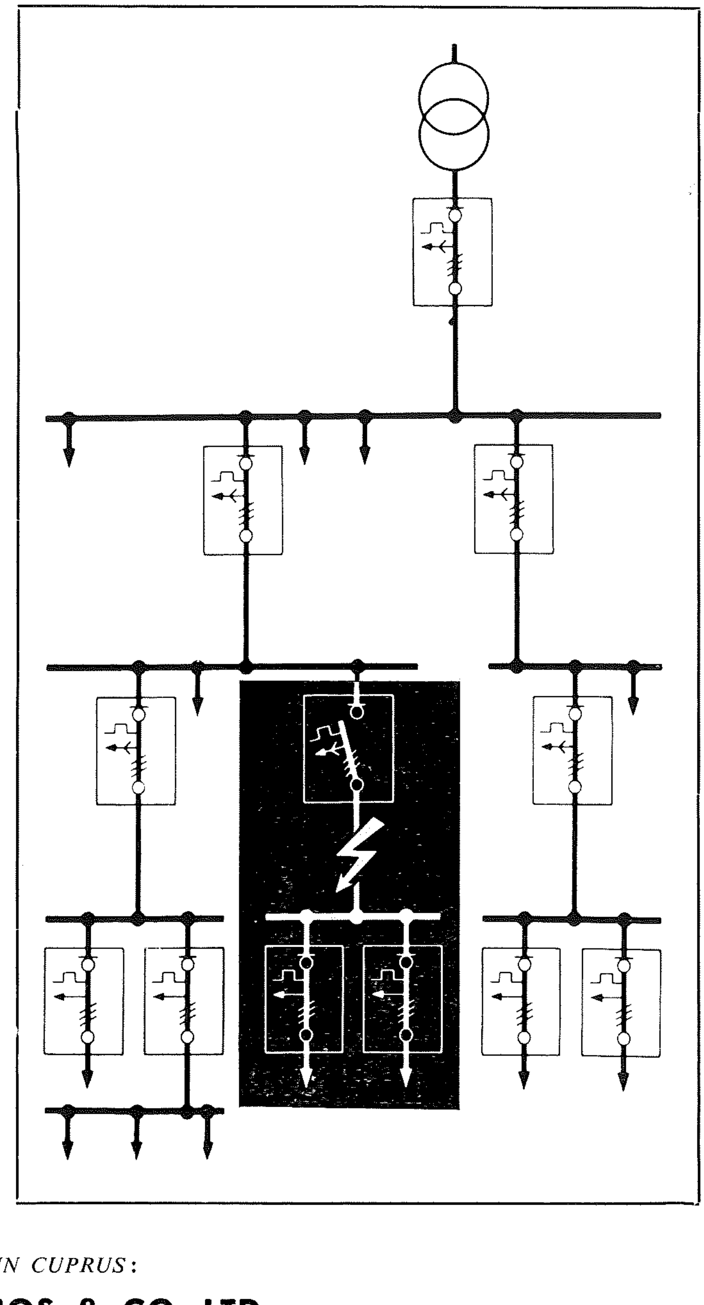
If a fault occurs in an electrical distribution network which is operating with full selectivity then only the out-going circuit directly affected will be automaticaly disconnected.

The remainder of the plant will continue to operate as usual.
It does not need to be interrupted at all, even for a short time.

Moulded case circuit breakers NZM and NZM . . . V allow the distribution networks to operate with full selectivity. Circuit breakers NZM . . . V not only have the adjustable bimetal trips as fitted as standard on all NZM circuit breakers, but also have short time delayed magnetic trips where the time delay can be present exactly. As the total disconnecting time for the NZM range of circuit breakers is only 30 ms, the graduated time between 2 circuit breakers need only be 60 ms.

Therefore out moulded case circuit breakers have these advantages/

- Selectivity is ensured in the overload and short circuit current range.
- Selectivity is maintained even after a short circuit has occurred, because the short circuit current does not after the tripping characteristics of circuit breakers, as is the case with H.R.C. fuses.
- The electrical plant as a whole is affected as little as possible by a short-circuit current as the total disconnection time and thus the graduated time of the automatic circuit breaker are very short.



Mains Networks
which operate with full Selectivity
increase productivity

# DEVELOPMENT OF PROFESSIONAL THINKING

**NIKI KYPRAGORA**
**3rd year student**

**Civil Engineering Department**

An engineer in order to be a Professional Engineer in his business, i.e. advising and designing for constructed work, he must be first of all technically capable to apply his knowledge, to be creative in any kind of work he faces. In that way he provides safety and economy for his client. He must be honest in his thinking and in his decisions in order to be respected by the people he deals with. He strives to do work and to win his clients' confidence and satisfaction in his technical capability, practicality, honesty. All those attitudes cannot be separated from him; those are for him a way of life acquired from his environment.

Let see now the genesis of the attitudes. A child from his day of birth is affected from his parents and his environment. Parent try to give him a sence of what is right or wrong and a sence of honesty. The child is bathed every minute and everyday in that situation, and as a result he adopts that as his own way of life. It is very difficult then when a child has formed his character — at the age say of 18 — to try and charge his attitudes, or rules he follows.

The same happens with the student engineer. The student seeks instruction, guidance, from his lecturers. The lecturer now takes over where the parent left off, in order to fill some gaps, to teach the technical principles and to instill in him the professional attitudes he must adopt so that he may be succesful when he leaves these training groups. Student must be bathed daily in that professional way of thinking in order to get used to it, to like it, to believe it, to try it and lastly to adopt it as a way of life.

Thus the basic knowledge and the proper attitude form the professional education. BUT the student has to be modivated to acquire those attitudes and desires. This can be achieved by:

1. Understanding the meaning of professional thickning.
2. Understanding why he must be technically capable and practical in his application, by examples.
3. Understanding that attitudes cannot be taught from textbooks by the appropriate knowledge, understanding and practice from the instructors point of view.
4. The lecturer must love professional life, must love to teach so that students believe him, trust him and try to be like him.

A question now arises. What are the significant characteristics that lead in the successful professional thinking?

1. Complete knowledge of basic engineering principles.
2. Knowledge of when and how a particular method is used and how does it apply, without taking out formulas blindly.
3. Knowledge of materials and construction methods that can achieve economy as well as safety.
4. Good work habits in order to isolate the problems, to find the necessary information to solve it succesfully.
5. Making decisions with self-confidence in order to gain the client's confidence, to facilitate in design methods.
6. Willingness to train subordinates.
7. Desire to advance welfare of his field by being an active member in his field i.e. publishing technical or professional articles etc.
8. Civil engineer must be kept abreast for any development of his field, attend significant seminars, bearing in mind the technology, day by day improve and change.
9. Honesty with his client, his employer but firstly with himself.

**When a graduate engineer enters the consulting office** must have the basic technical knowledge and the professional attitude. But he is not expected to satisfy fully the nine characteristics mensioned earlier or take full responsibility. The practitioner expects the college to provide:

1. Adequate technical and humanities curricula.
2. A capable teaching power.
3. Teachers who understand and practice the professional attitude, who live the professional life and teach this by examples.
4. Teachers who are involved in practical engineering and who can impart to their students.

Bearing in mind that to achieve any goal successfully motivation of people is required, teachers must eastablish the proper environment, must believe what they teach it they are to truly teach. Because nobody can teach effectively if he cannot teach what he believes.

Coming to the **Conclusion** it can be said the professionalism is an important part of the student's training and on that factor his success or failure mainly depends on. Thus great responsibility lies on the educator who must be practically oriented, and must be able to establish the proper environment. In that way real motivation will be fully developed.

To attain the goal of motivation, a real communication shall be maintained between college, graduate engineers and industry. Such communication will strengthen the cooperation between education and practice and that will more effectively prepare the yound trainees for the professional life.

Before closing this chapter I would like to give an American popular verse that shows clearly the aspect of motivation and that we cannot teach what we do not believe.

*If a child lives with criticism*
*He learns to condemn*
*If a child lives with hostility*
*He learns to fight*
*If a child lives with ridicule*
*He learns to be shy*
*If a child lives with shame*
*He learns to feel guilty*
*If a child lives with tolerance*
*He learns to be patient*
*If a child lives with encouragement*
*He learns confidence*
*If a child lives with praise*
*He learns to appreciate*
*If a child lives with fairness*
*He learns justice*
*If a child lives with security*
*He learns to have faith*
*If a child lives with approval*
*He learns to like himself.*
*If a child lives with acceptance and friendship*
*He learns to find love in the world.*

# CORROSION AND ITS PREVENTION

**P. VASSILIOU, B. Sc. (Eng.) London.**
**Lecturer, H.T.I.**

**Introduction:**

Corrosion and its prevention is a problem of great importance to the engineering industry; perhaps it is one of those problems which still face civilisation, and cost people a lot of money every year in protecting metals and alloys from rusting.

Extensive researches which have been devoted to the elucidation of the causes of corrosion have now fairly well established the main facts that the actual attack is electrochemical in character, although the various hypotheses differ largely as to the factors by which the electrolytic action is brought about.

## METALLIC CORROSION

Metallic corrosion can take one of two forms:–

(a) General corrosion, and
(b) Local or Pitting corrosion.

## TYPES OF CORROSION

### Electrolytic Corrosion

This arises from the fact that when a metal is immersed in an electrolyte i.e. a solution of one of its salts, it tends to dissolve. Solution of the metal occurs because the metal atoms lose valency electrons. These atoms then become positively charged particles or metal "ions", which pass into solution into the electrolyte:–

$$\text{METAL} \rightleftharpoons +\text{ve metal ion} + \text{electrons}$$

Metals and alloys vary considerably in their ability to lose electrons in this way. The chemically reactive metals i.e. alkali earth metals, and to a lesser extent Zinc and Iron, lose electrons more readily than those not so active i.e. the noble metals Gold, Silver, Platinum, etc.

As the concentration of metal ions increases in the electrolyte an opposite effect arises tending to drive ions back to the immersed electrode and ultimately reaching an equilibrium condition. The tendency for metal to dissolve and form ions is known as *solution pressure*, and the force developed tending to drive them back is known as *osmotic pressure*.

In practice a condition is rapidly attained in which the osmotic pressure just counter balances the solution pressure.

In the noble metals, Au, Ag, Pt, and Cu, when immersed in a solution of one of their salts, osmotic pressure is greater than solution pressure, and equilibrium between the two is only obtained when positive ions pass from the electrolyte to the metal surface which then acquires a resultant positive charge. Similarly, when the solution pressure is greater than the osmotic pressure the metal tends to dissolve, metal ions passing into the electrolyte leaving a resultant negative charge on the metal. Thus, when the solution and osmotic pressures in these two cases have become equal there is a resultant positive and negative charge on the electrode. This is known as the *electrode potential* of the metal, which varies according to the nature and state of the metal serving as an electrode, and the nature, concentration and temperature of the electrolyte.

In order to measure the single electrode potential of a metal it is necessary to combine the electrode under examination with another electrode regarded as a standard or reference electrode. This is known as a *hydrogen electrode* having an electrode potential of zero.

The electrode potential is an indication of the tendency of the metal to corrode, and those having a high electrode potential, found at the top or noble end of the electrochemical series are much more resistant to corrosion than those lower down. Such metals are also terned to *cathodic metals*, and those at the other end of the series exhibiting opposite tendencies, the *anodic metals*, with lower electrode potentials.

A metal will normally displace, from solutions of its salts, any other metal, including hydrogen, having a more positive electrode potential. Thus Zn will displace Cu from copper sulphate solution, and hydrogen from sulphuric acid solution. In a similar manner the connection of one metal to another, of lower electrode potential, when both are immersed, causes corrosion of the less noble metal.

Insertion of an assembly, made jointly of Cu and Zn, in sea water leads to corrosion of the Zn by causing the metal to function as an anode which dissolves, whilst the Cu functions as a cathode and is thus protected.

Alloys may be listed in an electrochemical series in the same way as metals and it can be seen which metal or alloy is likely to function anodically i.e. become corroded, in a given combination of metals and alloys. The further apart the metals or alloys stand in these series the greater will be the tendency for corrosion to occur.

In order that corrosion shall take place it is not necessary in every case for components of different composition to be in metallic contact. Such cases are as follows:–

1) Parts of metal surfaces which have suffered mechanical deformation will exhibit a different electrode potential from those regions which have not been mechanically deformed to the same degree.

2) The presence of inclusions at the surface' having different electrode potentials from the parent metal i.e. graphite in cast iron, precipitated phases in certain heat treated alloys, usually give rise to pitting corrosion.

3) If a single metal or alloy is immersed in a electrolyte of differing concentration at various points on its surface, a so called *concentration cell* is set up, with the result that some portions of the metallic surface will function as anodes with respect to others, and become corroded.

4) Alloys exhibiting coring will be prone to corrosion due to the different composition throughout the material.

5) Differing oxygen concentration in the electrolyte in contact with the metal surface is sufficient to set up local anodic and cathodic areas and subsequent corrosion.

Electrolytic corrosion arises when metals are immersed in water, this being responsible for the greater part of corrosion in every day life. This type of corrosion occurs by reason of atoms of the anodic or corroded metal passing into solution as ions, which in turn leads to breakdown of the water and the formation of gaseous hydrogen, which bubbles from the surface of the cathode.

## CORROSION OF IRON AND STEEL

Normally in the presence of moisture and oxygen, the corrosion product on iron is a mixture of oxides and hydroxides known as *rust*, and since this is neither an impervious nor a very adherent film the progress of corrosion although slowed down, continues. Discontinuities on the iron or steel surface, allow the formation of anodic and cathodic areas, and in the presence of moisture, electric currents are produced leading to corrosion of the anodic areas, providing there is sufficient oxygen present to allow for removal of hydrogen. The corrosion product formed, being a mixture of iron oxide and hydroxide, cracks, exposing the underlying metal, which allows a continuation of corrosion.

On the other hand, metals such as Cr and Al, develop an impervious adherent oxide film on the metal surface which prevents any further corrosion. This film is produced almost immediately on such metals when the conditions are oxidising, and confers corrosion resistance, in this case to oxidising conditions, known as *passivity*. Providing these oxidising conditions are maintained, the film, if broken, will readily reform. Such metals, Cr in particular, impart this property to alloys in which they are present, and the greater the amount of Cr the greater the corrosion resistance of the material, since the passive oxide film is more stable and more readily formed.

## UNDERGROUND CORROSION OF FERROUS METALS

In certain waterlogged clay soils in which, under normal circumstances, access of atmospheric oxygen is more or less impossible, severe corrosion of iron or steel may still occur due to the action of certain bacterior in the soil. These are capable of reducing sulphates in the soil, liberating oxygen and forming a corrosion product of iron sulphide. A sign of this microbiological corrosion of iron and steel is the local blackening of the soil in the vicinity of the metal due to the presence of iron sulphide.

One way of combating this type of corrosion is to surround the ferrous component with about 12″ of sand or gravel which provides conditions most unfavourable for the growth of these bacterior.

## ATMOSPHERIC CORROSION

Most metals and alloys, when exposed to dry air at ordinary temperatures slowly become coated with a thin transparent protective film, usually of oxide, by reason of dry corrosion or surface oxidation. This film usually adheres to the material and since it is relatively impervious to the atmosphere, the rate of corrosion is practically nil.

**" A FAILURE is a man who has blundered but is not able to cash in on the experience".**
ELBERT HUBBARD

There are however, in the atmosphere, other constituents besides oxygen and nitrogen such as moisture, sulphur dioxide, carbon dioxide and suspended solids and these may be capable of breaking down the film and giving rise to continuous but slow corrosion. Of these constituents moisture is the most important since its presence or absence decides whether the harmful electrolytic corrosion takes place or the much less harmful surface oxidation, the former being continuous and the latter ceasing after a short time. When the air humidity is such as to cause condensation on the metal then the relatively harmless dry corrosion changes to a damaging wet or electrolytic corrosion, e.g. when the humidity is less than 60% practically no rusting occurs on iron and steel; up to 80% there is a small amount, but exceeding this value raises this corrosion rate appreciably.

There is also the fact that the corrosion product itself may accelerate corrosion if it is capable of absorbing sufficient moisture to give rise to electrolytic corrosion. Once the critical humidity in the atmosphere is exceeded i.e. that which causes condensation, the presence of pollution such as sulphur and carbon dioxide, can seriously increase the rate of corrosion. Thus it follows that:–

a) in atmospheres where pollution is present it is important to ensure that the humidity does not exceed the critical value.

b) where the critical humidity is exceeded, the presence of pollution has a serious effect on corrosion.

**DIRECT OXIDATION OR TARNISHING**

This is the production, by metal-gas reactions at room or slightly elevated temperature, of a thin-oxide layer on the surface of the metal or sometimes other compounds, which give rise to the characteristic sequence of interference colours.

Cu and Ag tarnish readily in the atmosphere, the presence of sulphur dioxide gas being responsible for the blackening of Ag.

The *blueing* of steel is brought about by heating the polished surface of hardened steel to a specific slightly elevated temperature, the colours produced being attributed to the formation of oxide films and interference effects.

As the temperature is raised, oxide films on metals thicken. Some are adherent, but others crack and scale e.g. heating iron and steel to elevated temperatures increases the rate of oxidation. Under the action of working at such temperatures, the oxide scale readily breaks off, forming what is commonly known as *miliscale*.

**PREVENTION OF CORROSION**

Methods of prevention:–

1) Preliminary treatment of the corrosive media,

2) Coating of the metal with a protective layer,

3) Electrochemical protection,

4) Use of corrosion resistant materials.

Attention must also be paid to the following:–

a) Absence of contact of dissimilar metals in the design of a component.

b) Removal of internal stress by annealing, as these are points at which corrosion is most likely to occur.

c) Metal must be clean and free from dirt etc.

d) Metal must be free from pits and crevices as these are likely to give rise to concentration cells.

**TREATMENT OF THE CORROSIVE MEDIA**

Atmosphere control is sometimes practised, but is limited in extent. Liquids may be treated by:–

a) Removal of oxygen — heating under reduced pressure,

b) Addition of alkalis to remove free acid,

c) *Permutive* method — where water is passed over hydrated Na or K silicate, the Ca and Mg salts in the water being replaced by the less harmful Na salts,

d) Addition of substances favourable to the formation of a passive film on the metal i.e. solution of Na or K dichromate giving chromium oxide films on iron and steel.

**PROTECTIVE COATINGS**

These may be:–

1) *Metallic*,

2) *Paint* — lacquers or varnish,

**"Work is far more fun than fun".**

Sir NOEL COWARD

3) OXIDE or PHOSPHATE FILMS.

Metalling coatings use one or more of the following metals:- Zn, Sn, Ni, Cu, Al, Cr, Cd.

a) *Dipping* as in tin plate or galvanised iron — Tin, Zinc.

b) *Electrolytically* as in a plating bath — Ni, Cr, Cd.

c) Zinc and Aluminium may be applied by heating the component in metallic dust:-

*Sherardising* – iron heated in Zn dust at 350$^0$C.

*Calorising* – heating in a mixture of Al and Al oxide at 800–1000$^0$C.

d) *Metal spraying* — suitable for articles too large for dipping. Consists of spraying a fine mist of molten metal onto the component.

e) *Mechanical application* — Cu clad steel sheets or Al cladding of Al alloys and also steel.

In all cases it is important that the coating be continuous as discontinuities set up pitting corrosion.

Coatings of paint etc. include the metal paints of red lead and Al paint and also varieties of tar and bitumen.

## PROTECTIVE OXIDE AND PHOSPHIDE COATINGS

a) The addition of chromate salts to a solution in contact with a metal (steel) produces thin films of chromic oxide on the surface which serves as a barrier to corrosion.

b) A thin oxide layer may be produced on iron and steel by immersion in a fused nitrate bath.

c) Coslettising involves the production of a phosphate film on metals. It is produced by immersing the article in a boiling solution of phosphoric acid saturated with ferrous phosphate, and also by the application of certain pastes. Mainly applied to iron and steel.

d) Anodic Treatment — *Anodising*. Applied to Al and it's alloys producing an oxide film on the surface resistant to corrosion. This surface may also be coloured by use of certain dyes.

## ELECTROCHEMICAL PROTECTION

This involves joining the component externally to a metal of lower electrode potential so that under corrosive conditions it is corroded preferentially to the component. This is commonly known as *sacrificial corrosions*.

## USE OF CORROSION RESISTING MATERIALS

The most satisfactory protection is the use of a material which has a high inherent resistance to corrosion under the particular conditions, rather than coat a less resistant material. Such materials may be divided into three groups:-

1) NOBLE METALS Au, Ag, Cu, Pt. These have low affinities for oxygen and possess positive electrode potentials. Cost and the fact that in most cases they are mechanically unsuited, limits their use.

2) PASSIVE METALS—those which develop passivity towards any set of conditions e.g. Cr. Al, Sn, Pb. These readily form oxide or compound films under certain conditions which seals of the rest of the metal and prevents corrosion. Corrosion resistance is dependent upon the formation and maintenance of this film and protection is only produced under such conditions as allow formation and or repair of this film if it becomes broken.

3) Alloys in which the resistance to corrosion of the main metal is increased by the presence in solid solution of a more highly resistant metal. In general the most widely used corrosion resistant alloys are those which fall into this group e.g. the addition of Cr and Ni to steel produces the stainless steels. Cu and Ni alloys have appreciable corrosion resistance under certain conditions, in particular the alloy *monel.*

Small amounts of Al and Sn confer corrosion resistance on brasses and bronzes.

From the stainless steels, plain Ni–Cr–Fe and straight Ni–Cr alloys have been produced, all having high corrosion resistance in their respective fields.

**" Sometimes a situation is only a problem because it is looked at in a certain way. Looked at in another way, the right course of action may be so obvious that the problem no longer exists".**

E DE BONO

## DISADVANTAGES OF METALLIC COATINGS

1) Possibility of pin hole formation in the coating during actual manufacture.

2) Breakage of coating during service.

3) Certain metals used as coatings only confer corrosion resistance under certain conditions, and any change in conditions may allow complete breakdown and corrosion of the parent metal.

Any discontinuity in the coating causes exposure of the base metal, and small electric currents are set up around the points of contact of the dissimilar metals.

If the base metal is less noble than the coating metal i.e. steel coated with Sn, Ni or Cu, penetration of the coating leads to preferential corrosion of the steel. In this case iron is dissolved continuously and is converted to hydroxide i.e. *rust*. Corrosion continues providing the hydrogen is removed.

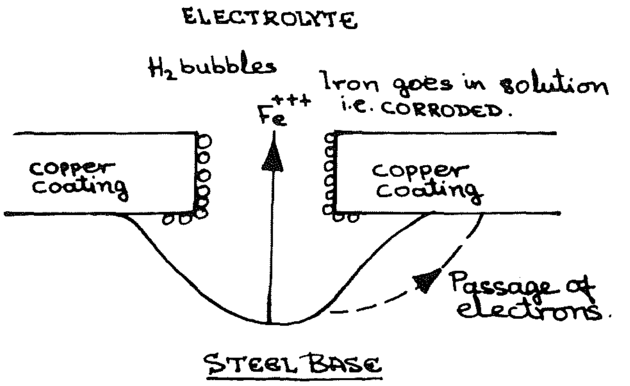



Fig. 1

If however the coated metal is less noble than the base metal i.e. Zn, it will corrode preferentially, and serious corrosion of the underlying metal will

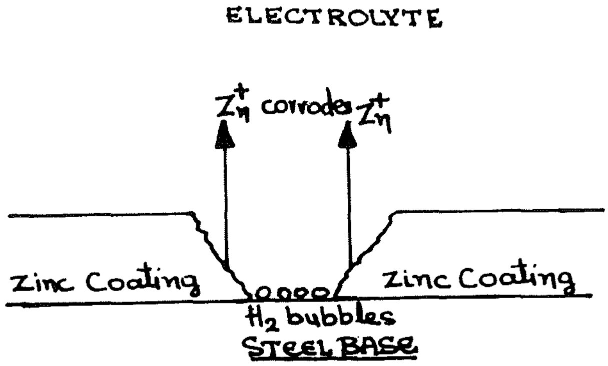



Fig. 2

not occur until substantial amounts of the coating have been removed. This is *sacrificial corrosion*, in this case of the Zn. Corrosion dissolves the Zn preferentially until a sufficiently large area of steel has been exposed for electrolytic corrosion over that surface to take place, when the steel will commence to rust. The Zn will continue to corrode away at the junction of the Zn coating and the steel which has been exposed.

## SPECIFIC CORROSION PHENOMENA

1) *Uniform corrosion*—even corroding of the metal surface. Occurs only seldon.

2) *Pitting corrosion* — Encountered in localised corrosion and caused by the presence of small heterogeneous areas i.e. inclusions, cored structure, mechanically strained zone, discontinuity in protective surface film. Such areas function as anodes with high current density and consequent rapid corrosion. Once the pit is initiated the anodic attack proceeds helped by the formation of a concentration cell. The amount of metal actually dissolved is small but the damage is severe.

3) *Stress corrosion cracking* — This is caused by the presence of static tensile stresses at the metal surface. Regions with varying degrees of distortion are then formed on the surface by lattice movement along the slip planes, and these give rise to potential differences on the surface. Minute grooves are caused by corrosion along the slip planes and in turn these grooves cause a concentration of stress sufficient to start cracks which propogate inward under the joint action of mechanical and chemical forces. The initial tensile stresses are necessary to induce failure and may be caused either by internal or external means. The former is usually more important in giving rise to stress corrosion cracking. The time required for failure varies, but an increase in the severity of either corrosion or stress can greatly reduce the time.

4) *Corrosion fatigue.* A combination of cyclic stresses and corrosive media. A metallic material subject to cyclic stresses has a much lower strength than when given a slowly applied undirectional load. The presence of a corrosive media causing roughening of the surface, results in a concentration of stress at this point, and produces a reduction in strength of the material. A corrosion fatigue normally shows only slight general corrosion, but pits having many cracks running from them are usual.

5) *Erosion corrosion* or "impingement" attack occurs in pipe lines or assemblies handling moving liquids. If the speed of the liquid exceeds a

**" Can anybody remember when times were not hard and money not scarce"!**
RALPH WALDO EMERSON

critical value and also impinges on a protective film found on the surface of many metals and alloys, the film may be removed at a greater rate than it can be replaced and fresh metal will be continuously exposed to anodic attack by pitting. These films may be those formed on stainless steels as well as films of corrosion products. The greater the speed of the moving liquid the more severe will be the attack.

6) *Cavitation Corrosion.* Caused by the liquid in contact with the metal being subjected rapidly to alternating changes in pressure. The result is that at a high relative speed between a metal surface and a liquid the pressure on the liquid may be reduced to such an extent as to cause it to boil. Small local vapour cavities are thus produced, which collapse as the pressure returns to normal, and when they are in contact with the metal surface the liquid strikes it with a high velocity. The result is that the surface becomes cold worked to an extent, and roughened or pitted.

**SUMMARY**

1. Corrosion is caused by the direct exposure of a metal to an acid.
2. Corrosion of metals is caused by a process similar to that in a galvanic bath, in which two metals seperated in the galvanic series are connected by an electrolyte, usually water.
3. Corrosion may also be caused by "concentration cells". When two metals, are in nominal contact, there are always minute spaces between the surfaces. In these confined spaces, galvanic action may be set up which will cause the corrosion of one of the metal surfaces.
4. To prevent corrosion:

   Avoid contact of metals with corrosive, especially acid, substances.

   Seal the edges of weld back-up plates by welding or otherwise.

   Thoroughly paint exposed steel at all points.

   Report all leaks, especially in wood-stave tanks with steel hoops.

   Do not paint over rusted steel; clean it thoroughly.

   Clean corroded reinforcing bars.

   Reject corroded material of any sort.

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1. Metallurgy for Engineers, by Rollason.
2. Engineering Metallurgy, by Higgins.
3. Data book for Engineers, by Seelye.


**" Our bodies do not need to become tired, sick, exhausted and old. Change your 'image' of yourself; see yourself well, of course observing and practicing all the rules of health, and you will tend to be that which you visualize and practice".**

Dr. NORMAN VINCENT PEALE

**" As the day wears to evening and evening deepens into night, can you look back over the waking hours and recall something you have said or done that was really worthwhile? You can? That's good. You can't? Why?**

FRANCIS GAY

**" Almost every man thinks too poorly of himself. He undervalues his brain and his will and his stamina. He has no idea of what he can do — if he dares".**

HERBERT N. CASSON

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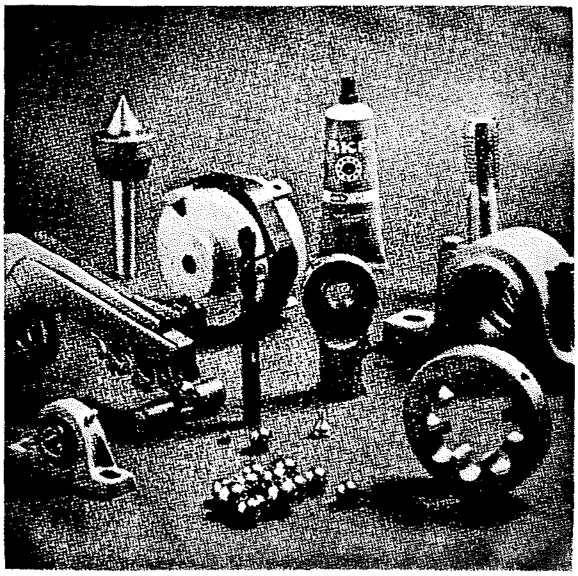

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# ERRORS IN MEASUREMENTS

**S. ANASTASIOU, B.Sc. (Eng.), C. Eng., M.I.E.E.**
**Lecturer H.T.I.**

**INTRODUCTION**

Exact measurement of an electrical quantity is an ideal which cannot be attained in practical work. Both science and industry must put up with measurements which are always in error by an amount that may or may not be significant for the particular purpose in hand. It is attemped in this article to acquaint the busy professional engineer and technician with an analysis of the various types of errors which might be present at a particular measurement.

Furthermore to make him proficient in discriminating the various errors before making the necessary correction.

**Types of Errors:-**

**Relative Error**

Let the quantity to be measured be represented by x and the possible error by δx. Then the relative error is δx/x i.e., the relative error is the actual error expressed as a fraction of the whole. The relative error may be quoted as a fraction e.g. as 5 parts in 1000 or may be expressed as a percentage, in this case as 0.5%.

The amount of the relative error is often an indication of the class of use to which a piece of apparatus may be put. Again taking an example, a resistor which is within 10% of its nominal value may be quite satisfactory in a radio set or in a shunt field regulator but is useless as a standard or in a decade resistance box. A resistor within 1% of its nominal value can be quite useful for general, not very precise, measurements, while a resistor within 0.1% of its nominal value is satisfactory in respect of accuracy for use in a good quality resistance box.

**Systematic Errors**

Systematic errors are those inherent in the construction and calibration of the apparatus used and in the method employed. Some systematic errors depend on ambient conditions, as for instance on the temperature; in such cases the conditions are chosen or modified either to eliminate or minimise these errors, or to render them calculable.

Some systematic errors are:

(i) The constructional or adjustment error.

Apparatus is manufactured and adjusted only within certain limits. One example is that of a moving-coil voltmeter of B.S. First Grade accuracy, the error of which, between half full-scale and full-scale readings, does not exceed 1%. The maximum constructional error in this case is ± 1% but the ratio of two readings may be in error by ± 2%.

(ii) The reading error e.g. on deflectional instruments, variable capacitors, etc.

The reading error of a deflectional instrument depends on the thickness and straightness of the pointer, the thickness and spacing of the scale divisions, the skill of the user, and whether or not a mirror is fitted. On an instrument with a knife-edge pointer and parallax mirror coincidence of the pointer with a scale division can be determined much more accurately than the position of the pointer between two scale divisions. A six-inch scale with 120 to 150 divisions can be read with certainty to one half of a scale division, or about 0.4% of full scale, and a twelve-inch vernier scale with 100 divisions can be read to one tenth of a division or 0.1% of full scale. Coincidence of the pointer with a scale division can usually be determined with an error not exceeding one quarter to a fifth of these figures in favourable circumstances. Similar considerations control the scale reading error of variable air capacitors and other dial indicating devices. A coarsely marked scale on a three-inch diameter dial can be read to about one degree with certainty which a finely engraved four-inch diameter scale with a well-fitted vernier can be read to a tenth of a degree.

(iii) The determination uncertainty.

In a bridge measurement for instance, no observable change may be noted for a range of ± 0.2% in one of the adjustments. This may be due to insufficient sensitivity or perhaps to circuit conditions.

(iv) Error inherent in the method.

A simple example occurs in the ammeter and voltmeter method of measuring a resistance. Here either the voltmeter reading includes the potential drop across the ammeter or else the ammeter reading includes the current taken by the voltmenter. Another example would be the error caused by ignoring the self-capacitance of a coil when measuring its inductance at radio frequency.

Errors of this kind can sometimes be allowed for or may be avoided by using a different method, although this is not always feasible.

(v) Temperature errors.

Resistance, inductance, capacitance, the frequency of an oscillator, the e.m.f. of a standard cell, the strength of magnets and of instrument springs all vary with temperature. The variation can sometimes be allowed for or may be avoided by maintaining the apparatus at a constant temperature where this is applicable and suitable.

Thermo-electric e.m.f.s. are a frequent source of error in low voltage d.c. measurements and are systematic in that they occur in known circumstances. The Diesselhorst potentiometer is an example of a piece of apparatus specially developed to avoid errors due to thermo e.m.fs.

(vi) Other sources of error include ageing and wear of apparatus (periodic recalibration is advised); resistance of leads; inductance, mutual inductance and capacitance appearing as unwanted stray effects; the effects of electrostatic and electromagnetic screens; friction and residual torsion in some instruments; contact resistances.

**Calculation of Maximum Systematic Error**

Many electrical measurements involve the determination of two or more quantities, each of which is subject to error, and the final result is calculated from the measured quantities. It is then necessary to be able to determine the maximum systematic error in this final result.

It should be noted particularly that when the only information about the errors of two pieces of apparatus is that they are within certain limits, they may be anywhere within these limits up to the extreme in either direction. In calculating the maximum possible systematic error it is necessary to assume that the individual errors concerned may all be of such a sense as to affect the result in the same direction.

Provided that the errors are small, their effect on the final result is readily determined by the use of the few simple rules outlined below:

(i) Sum of two or more components.

Let the final result be y, this being obtained by adding a number of measured results u, v, z say, each of which is subject to possible systematic errors $\pm$ u, $\pm$ v, $\pm$ z.

Then the nominal result is:

$$y = u + v + z.$$

The maximum possible value of y is:

$$y = u + \delta u + v + \delta v + z + \delta z.$$

and the minimum possible value of y is:

$$y = u - \delta u - v - \delta v + z - \delta z.$$

Subtracting $u + v + z$ from each of these, the maximum possible error in y is:

$$\delta y = \pm (\delta u + \delta v + \delta z);$$

and the corresponding relative error is:

$$\frac{\delta y}{y} = \pm \frac{\delta u + \delta v + \delta z}{y}$$

It is usually more convenient, especially when y is itself only one factor in the final answer, to express this in terms of the relative errors of the component quantities. To this end the expression is rewritten as

$$\frac{\delta y}{y} = \pm \left(\frac{u}{y} \cdot \frac{\delta u}{u} + \frac{v}{y} \cdot \frac{\delta v}{v} + \frac{z}{y} \cdot \frac{\delta z}{z}\right)$$

Since no approximations have been made in working out this particular result, it is true for all values of the errors and is not restricted to the case of small errors. It is, however, necessary to be very careful of the signs when one of the quantities concerned is negative and it may be advisable in such cases to work from first principles.

As an example consider the case of measuring a small capacitance by a difference method, the results obtained being $1000 \pm 10$ pF and $900 \pm 10$ pF. The difference lies between $1000 + 10 - (900 - 10) = 120$ pF and $1000 - 10 - (900 + 10) = 80$ pF so that the capacitance under test has a value of $100 \pm 20$ pF and the relative error is much bigger than the relative error of the component results.

(ii) Product of two or more factors.

Using the same nomenclature as above, let $y = uv$

$$\text{Then } y + \delta y = (u + \delta u)(v + \delta v) = uv + v\,\delta u + u\,\delta v$$

the second order small quantity $\delta u\, \delta v$ being neglected.

**" Without healthy self love one cannot love anyone else ".**

Dr. SMILEY BLANTON

Then $\delta y = v\,\delta u + u\,\delta v$

and $$\frac{\delta y}{y} = \frac{v\,\delta u}{uv} + \frac{u\,\delta v}{uv}$$

or $$\frac{\delta y}{y} = \frac{\delta u}{u} + \frac{\delta v}{v}$$

and the relative errors add, the same applying when the signs of the errors are negative. In this and the following analyses it is assumed that the the relative errors are sufficiently small to justify neglecting the second and higher order small quantities.

(iii) Quotient of two factors

Here $y = \frac{u}{v}$

and $$y + \delta y = \frac{u + \delta u}{v - \delta v}$$

The negative sign in the denominator being necessary because a decrease in the denominator causes an increase in the quotient.

Then $$y + \delta y = \frac{(u + \delta u)\ (v + \delta v)}{(v - \delta v)\ (v + \delta v)}$$

$$= \frac{uv + v\,\delta u + u\,\delta v}{v^2}$$

and $$\delta y = \frac{\delta u}{v} + \frac{u\,\delta v}{v^2}$$

whence $$\frac{\delta y}{y} = \frac{\delta u}{u} + \frac{\delta v}{v}$$

and again the relative errors add.

It is now possible to state the important rule that when an experimental determination involves only the products and quotients of a number of factors which have relative percentage systematic errors a, b, c, d........ respectively, the maximum systematic error in the result is $(a + b + c + d + .....)\%$.

(iv) Power of a factor.

Here $y = u^n$

where n may be positive or negative, integral or fractional.

Then $$y + \delta y = (u + \delta u)^n$$

$$= u^n \left(1 + \frac{\delta u}{u}\right)^n$$

$$= u^n \left(1 + n\frac{\delta u}{u}\right) \text{ (Binomial theorem)}$$

whence $$\frac{\delta y}{y} = n\frac{\delta u}{u}$$

Thus in a square law relationship $y = u^2$, for example, the maximum systematic error in y is twice that in u.

(v) Composite factors, such as

$$y = \frac{uv + wz}{x}$$

where there are possible errors in u, v, w, x, z. This may be treated as

$$y = m + n$$

where $m = \frac{uv}{x}$ and $n = \frac{wz}{x}$

**Random Errors**

The effect of random errors on a series of determinations of a particular quantity is to give results with various errors above and below the true value, results near the true value occuring frequently and results far from true value occuring infrequently. If a large number of determinations can be made the random error is eliminated by taking the near value of the results obtained.

For truly random errors, a plot of the number of readings of each value as ordinates, against the reading values as abscissae gives a curve of a particular shape known as the error curve.

The consistency of the readings is judged by the standard deviation and the coefficient of variation.

The standard deviation is the root mean square value of the differences between each reading and the mean value.

The coefficient of variation is the ratio of the standard deviation to the mean value expressed as a percentage. An alternative offer adopted is to guote the probable error of the result. The probable error is that value of error for which there is an equal probability that the actual error is greater or less than this value. The probable error can be found from the formula.

$$\text{Probable error} = \frac{0.6745 \text{ x standard deviation}}{(\text{number of observations})^{1/2}}$$

Examples of random errors are:–

(i) Errors of judgment in interpolating between scale readings e.g. when 7.25 may be read as 7.2 or 7.3.

(ii) Errors in setting due to random variations of supply voltage or frequency above and below mean (The reduction in mains voltage as load is increased is systematic).

**When we get up in the morning, we can choose happiness or unhappiness.**

HELEN ROSE

(iii) Personal errors of judgement or slips or mistakes. These usually become more frequent with the onset of fatigue and if too numerous must throw doubt on the validity of the whole series of results.

**Conclusions**

As seen from the above discussion it is evident that significant errors do exist in electrical measurements and therefore it is considered to be an asset for one to be able to take measurements confidently and correctly. A list of hints to minimise errors is now given.

(a) Have a good knowledge of the methods used.

(b) Choose most suitable method.

(c) Be familiar with equipment used and choose the most suitable.

(d) Work under best possible conditions.

(e) Eliminate conditions tending to increase error.

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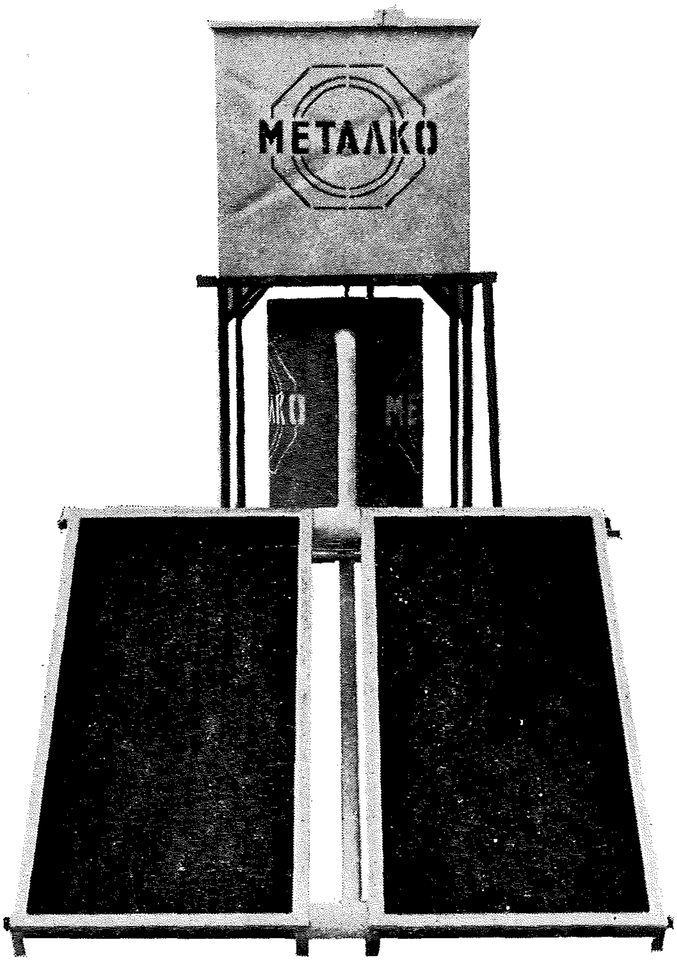


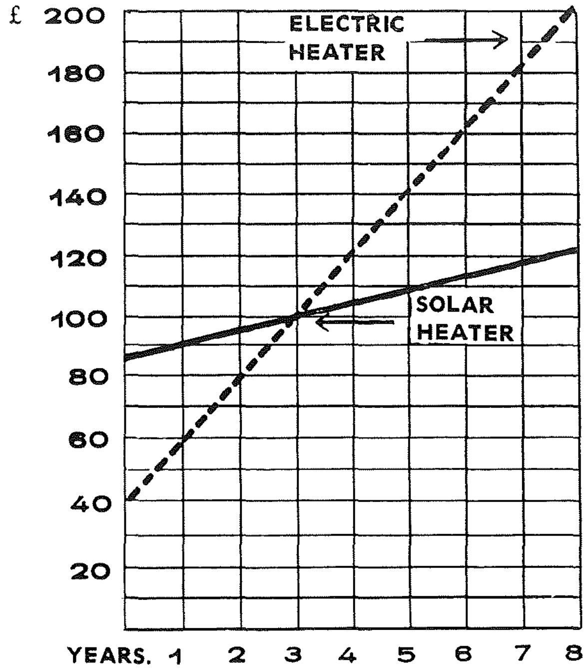


As it can be seen from the two curves drawn, the purchasing of the METALCO solar heater is higher than the electric heater. As the years go by the high initial cost of METALCO solar heater is overcome by the very low running cost. So at 3 years the total cost of METALCO solar and electrict heater is the same. After 3 years the amount of money which you save with METALCO is tremendous. So METALCO really **saves your** money.

Let the SUN and METALCO heat your water and **save** your money.

# NEGATIVE IMPEDANCE

C. LOIZOU, B. Sc. (Elect.) Eng.
Lecturer H.T.I.

### Introduction

An electrical system may be represented by a circuit having resistance, inductance and capacitance. These components can be present due to design or inherently in the system. To eliminate the effect of resistance, inductance and capacitance use can be made of elements having characteristics equal and opposite of those present in the system. Such elements can be provided by means of active devices, and permit positive values of resistance, inductance and capacitance to be cancelled by their negative counterparts.

This cancellation, if exact, produces a loss free circuit. Negative impedance elements may by produced by the use of a negative impedance convertor and a passive component or conbination of components.

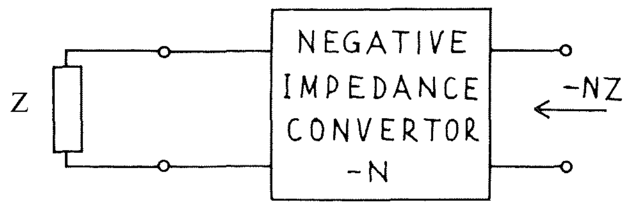


Fig. 1

In fig. 1 the passive impedance Z appears at the output terminals reversed in sign and changed in magnitude by N, the constant associated with the negative impedance convertor.

Thus depending on the nature of Z it is possible to provide negative resistance, inductance and capacitance or combinations of these to eliminate the positive components present in a circuit.

### Negative impedance principle.

The use of negative impedance, and particularly of negative resistance, can eliminate positive resistance, thereby giving amplification.

The negative resistance may be connected either in series or in shunt with a circuit.

### (a) Series connection

The insertion of a resistor $R_N$ between source and load resistors $R_S$ and $R_L$ respectively, as shown in fig. 2 gives an insertion loss IL given by:–

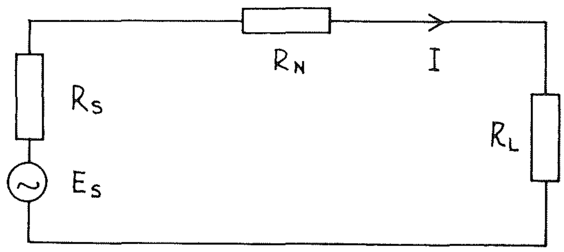


Fig. 2

$$IL = 20 \log_{10} \left(1 + \frac{R_N}{R_S + R_L}\right) \quad \text{-----} \quad (1)$$

(Appendix 1 gives the derivation of this result).

If $R_N$ is a negative resistance the IL becomes a gain instead of loss.

The current I flowing in the circuit is given by:–

$$I = \frac{E_S}{R_S + R_L - R_N} \quad \text{----------} \quad (2)$$

Thus the current is increased (provided $R_N < R_S + R_L$) which means amplification.

### (b) Shunt connection

The insertion of a resistor in shunt with the source and load resistors Rs and RL respectively, as shown in Fig 3 gives an insertion loss IL given by:–

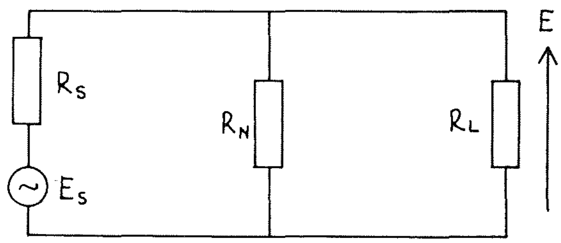


Fig. 3

$$IL = 20\log_{10}\left(1 + \frac{R_S R_L}{(R_S + R_L) R_N}\right) \quad \text{----} \quad (3)$$

(Appendix II gives the derivation of this result).

If RN is a negative resistance the IL becomes a gain.

The emf E transmitted from the source to the load is given by:–

$$E = \frac{E_S\left(\dfrac{-R_N R_L}{R_L - R_N}\right)}{R_S - \dfrac{R_N R_L}{R_L - R_N}}$$

$$= \frac{E_S\,(-R_N R_L)}{R_S\,(R_L - R_N) - R_N R_L}$$

$$= \frac{E_S R_L}{R_S + R_L - \dfrac{R_S R_L}{R_N}} \qquad \text{-------- (4)}$$

The use of a negative resistance thus increases the voltage E which means amplification.

### Circuits providing negative impedance

Transistors can be used in a variety of ways to give negative resistance. For example if a transistor has an $h_{fe}$ greater than unity this can lead to a negative resistance characteristic. With a point–contact transistor in the circuit of Fig. 4 the relation between $v_1$ and $i_1$ is as shown in Fig. 5.

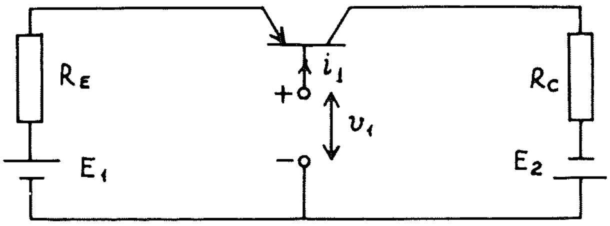


Fig. 4

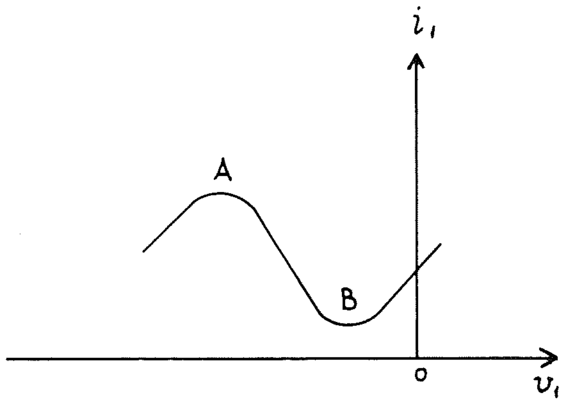


Fig. 5

Thus by suitable bias this arrangement can provide negative resistance in the region AB.

Another arrangement which can provide negative resistance is the one shown in Fig. 6.

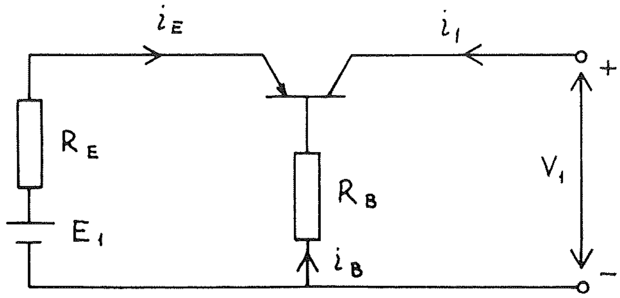


Fig. 6

The relation between $v_1$ and $i_1$ is shown in Fig. 7.

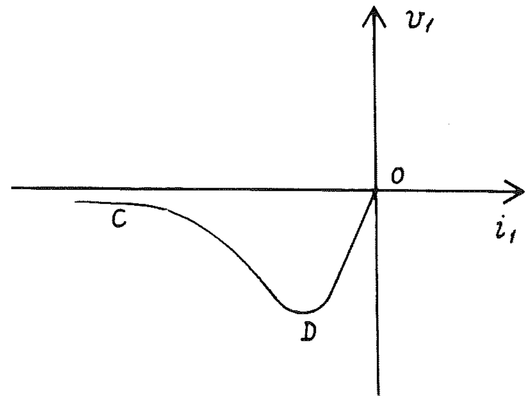


Fig. 7

Negative resistance is present in the region CD which again can be utilised by suitable biassing. The base resistance $R_B$ is used to provide positive feedback and it can be omitted. It should be noted that, in this case, the negative resistance portion of the characteristic exists uniquely for a definite range of current, whereas in the previous case of negative resistance the controlling factor is the voltage range.

### The negative impedance booster

One circuit using the negative resistance produced by transistors is the negative resistance booster developed by the British Post Office. The circuit is shown in Fig. 8 along with its a.c. equivalent circuit in Fig. 9.

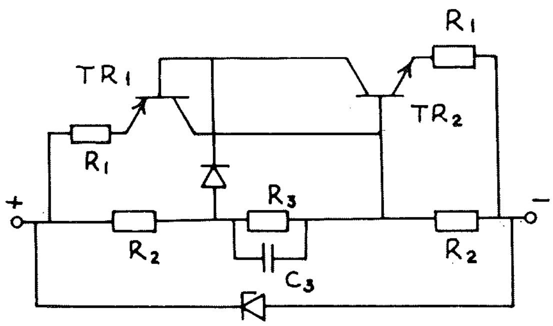


Fig. 8

| |
|---|
| **" Wealth is not his who has it, but his who enjoys it".** JAMES HOWELL |

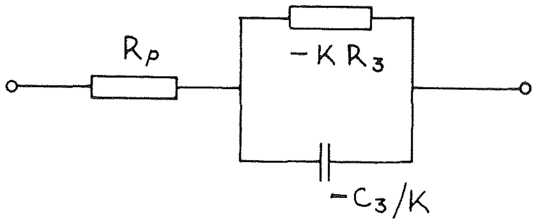

Fig. 9

The d.c. characteristics of the circuit may be explained by reference to Fig. 8. Application of low currents lead to a voltage drop across the circuit terminals of $V = I(2R_2 + R_3)$.

This relation applies up to the point when transistors $TR_1$ and $TR_2$ start to conduct, as a result of the biassing voltages across resistors $R_2$. In the active region of transistors $TR_1$ and $TR_2$ an increase in the input current leads to a reduced terminal voltage as a result of the shunt path provided by the transistors.

This is the region used to provide a.c. negative impedance. The transistors continue to provide negative slope resistance until they saturate, thereafter providing positive resistance.

Appendix III gives a simple analysis of the negative impedance booster circuit, less diodes, and shows that the overall impedance of the circuit consists of a positive resistance $R_P$ in series with a negative impedance $-KZ_3$. The design value of K is obtained by selection of suitable values for resistors $R_1$ and $R_2$.

**Appendix I**

Calculation of IL for series connection:–

$$IL = 20 \log_{10} \frac{\text{I before insertion of network}}{\text{I after insertion of nerwork}}$$

$$= 20 \log_{10} \frac{\dfrac{E_S}{R_S + R_L}}{\dfrac{E_S}{R_S + R_L + R_N}}$$

$$= 20 \log_{10} \frac{R_S + R_L + R_N}{R_S + R_L}$$

$$= 20 \log_{10} \left(1 + \frac{R_N}{R_S + R_L}\right)$$

**Appendix II**

Calculation of IL for shunt connection:–

$$IL = 20 \log_{10} \frac{\text{V before insertion of network}}{\text{V after insertion of network}}$$

$$= 20 \log_{10} \frac{E_S R_L/(R_S + R_L)}{\dfrac{E_S \dfrac{R_N R_L}{R_N + R_L}}{R_S + \dfrac{R_N R_L}{R_N + R_L}}}$$

$$= 20 \log_{10} \frac{R_N (R_S + R_L) + R_S R_L}{(R_S + R_L) R_N}$$

$$= 20 \log_{10} \left[1 + \frac{R_S R_L}{R_N (R_S + R_L)}\right]$$

**Appendix III**

Analysis of the negative impedance booster circuit.

Consister the symmetrical circuit shown in Fig. 10, the transistors having equal current gain of $-h_{fb}$.

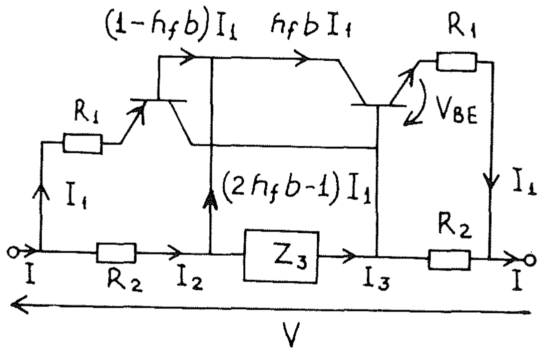

Fig. 10

Then $\quad I = I_1 + I_2$ ------------ (1)

$I_3 = I_2 - (2h_{fb} - 1) I_1$ ------ (2)

$V = 2I_2 R_2 + I_3 Z_3$ -------- (3)

$I_2 R_2 = I_1 R_1 + V_{BE}$ ------- (4)

If $V_{BE} << I_1 R_1$ equation 4 becomes

$I_2 R_2 = I_1 R_1$ ----------- (5)

From equations (3) and (5)

$V = 2 I_1 R_1 + I_3 Z_3$ ------- (6)

Eliminating $I_3$ between equations (6) and (2)

$V = 2 I_1 R_1 + I_2 Z_3 - (2h_{fb} - 1) I_1 Z_3$

or $\quad V = [2R_1 - (2h_{fb} - 1) Z_3] I_1 + I_2 Z_3$ – (7)

From equation (5) $\quad I_2 = \dfrac{R_1}{R_2} I_1$

$\therefore \quad V = [2R_1 - (h_{fb} - 1) Z_3] I_1 + \dfrac{R_1}{R_2} I_1 Z_3$ – (8)

**" Become receptive to ideas. Welcome them. Destroy such thought repellants as 'Wont work', 'Can't be done', 'It's useless', and 'It's stupid'.**

Dr DAVID J. SCHWARTZ

Finally from equation (1)

$$I = I_1 + \frac{R_1}{R_2} I_1 = I_1 (1 + \frac{R_1}{R_2})$$

or

$$I_1 = \frac{I}{1 + \frac{R_1}{R_2}} \quad - - - - - - - \quad (9)$$

Hence from equations (8) and (9)

$$V = \left[2 R_1 - (2h_{fb} - 1) Z_3 + \frac{R_1}{R_2} Z_3\right] \frac{I}{1 + \frac{R_1}{R_2}} \quad (10)$$

The impedance $Z_N$ between the negative impedance booster terminals is

$$Z_N = \frac{V}{I} = \frac{2R_1 - (2h_{fb} - 1) Z_3 + \frac{R_1}{R_2} Z_3}{1 + \frac{R_1}{R_2}}$$

$$= \frac{2 R_1 R_2 - Z_3 [ (2h_{fb} - 1) R_2 - R_1]}{R_1 + R_2}$$

Let $\frac{2 R_1 R_2}{R_1 + R_2} = R_P$ and $\frac{(2h_{fb} - 1) R_2 - R_1}{R_1 + R_2} = K$

$$\therefore \quad Z_N = R_P - K Z_3$$

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# H.T.I. CALENDAR OF EVENTS

**Mrs. O. DEMETRIADES, B.A.**
**Lecturer in English & Report Writing, H.T.I.**

## The 1975 in Retrospect

**January:-**

Another year, new hopes, but the implications of the Turkish invasion on the economy and industry are still too evident. Some 3rd–year students cannot be placed for their industrial training because of the low business activity. The problem is remedied by the assignment of work projects. A visit by a Unido Expert surveying for the possibility for a Course in Footwear Technology opens up new horizons of training activities.

**February:-**

The hectic period of the Semester exams is over. The students are relieved. A new semester begins.

Four of our unemployed graduates secure work in the Arab countries. This boosts up the morale of both students and graduates. There is no room for despair.

**March:-**

H.E. the Greek Ambassador, Mr. Michael Dountas, visits the Institute and the Students' Refugee Camp. He looks into the various problems and tries to help out. Such a friend is only too welcome!

The students welcome the news that free medical treatment has been granted by Government.

The H.T.I. team participates in the Toastmasters Interschool Debating Competition. They win in the first round but loose in the second. This is a good beginning for the future foundation of a debating society at the H.T.I. A carnival party by the Students Union provides a temporary relief to everybody's problems, both students and staff.

**April:-**

With the new Short Test and Assignment system the mid-semester exams are abolished. All indications show that this new arrangement is acceptable to all concerned.

The H.T.I. has its First Sports Day — a great event which promises to establish it as a future annual event.

The Easter Holidays provide a pleasant break in the continuity of academic work. But in no time the students are back. (We break for only one week!)

The Director visits the U.S.A. on a study tour and comes back with new ideas from the American educational system and the credit system used.

**May:-**

Arrangements are negotiated for summer industrial training with DEH (Public Electricity Co. of Greece). A very exciting prospect for the students to be selected for this overseas assignment.

The first information leaflet on the H.T.I. is published. A good beginning to attract more foreigh candidates.

Certain modifications to curricula and syllabi are decided. The H.T.I. team wins the Nicosia Interschool Chess Competition.

**June:-**

Right from the beginning of the month one is only too aware that this is the period of the end of years exams. The third year students submit their projects and the first and second year students sit for their exams.

> **" No one can conquer an enemy without coming in sight of him".**
>
> EMANUEL SWEDENGORG

The preparations for the graduation ceremony and the July entrance exams complete the picture.

The football team of the Ministry of Labour, to which the H.T.I. is heavily represented are the champions of the Amateur Soccer.

**July :-**

The 6th graduation ceremony launches into the industry of our troubled Island a new batch of graduates.

The number of candidates for the entrance exams is very high. The selection is hard.

Work on the Construction of the North Wing Extensions of the H.T.I. begins.

**August :-**

Usually not a very important month in the academic life of the Institute. But this August marks the commencement of a One-year Course in the Production of Technology for Shoe and Boot manufacturing. The opening Ceremony is attended by H.E. the Minister of Labour, Mr. M. Spanos and the Minister of Commerce and Industry, Mr. Colocassides.

Another highlight is the publication of the H.T.I. Prospectus. The H.T.I. Students Union participates in the 2nd POFNE conference held in Nicosia.

**September :-**

A new academic year begins. Classes commence as scheduled. The political problem remains unsettled and no Turkish students or Staff turn up.

Two girls from Greece and a male student from Bagladesh come to the H.T.I. for their studies.

Staffing problems are created as a result of sudden resignations of staff to take up more lucrative jobs in the Arab countries. The Part-time Diploma Course in Civil Engineering enters its 5th and final year.

The Students' Refugee Camp is open to non refugee students as well.

**October :-**

The celebration of U.N. Day is marked by a ceremony and a football match between the H.T.I. team and the U.N. soldiers. The students in the Camp organise cultural events to fill up constructively their leisure time. This seems to put the foundations for a campus atmosphere and life.

**November :-**

The Director participates in a Council of Europe Seminar in Milan on " Adult Education ". On his way to Cyprus he visits the Greek State School of Marine Officers, in preparation for a new training activity at the H.T.I.

The H.T.I. Diploma is recognised by the Greek Ministry of Education as equivalent to that of the Higher School of Sub. Engineers. The Council of Ministers approves a proposal to start training Marine Engineering Officers at the H.T.I. as from 1976.

**December :-**

All students undergo a blood test for group and rhesus. H.T.I. blood donors are continually called upon to help. The Camp committee goes on with its cultural activities. The end of the calendar year is approaching. The preparations for the Christmas festivities for both students and staff next to the tents enhance the happy spirit of bygone times. A party for the New Year to come — the spirit of survival is predominant — new targets — new ambitions — new plans. Life has to go on. The students aspire high!

**" The critical, fault-finding type of person, who always sees where others fall short and can usually also suggest a remedy, is never going to be stampeded by crowds rushing to be his close friends. Don't set up rigid personal standards of how you think other people ought to act. Give the other person the right to be himself. If he's a little peculiar, let him be. Don't insist hat he do everything you do and like everything you like. Let him relax when he is around you".**

LES GIBLIN

# FOR MAKING THE BEST OF YOURSELF

DON'T think how you look does not matter.

DO regognize that most people dislike a scruffy, grubby, untidy, unwholesome, appearance. To be unsuitably dressed for a social occasion is advertising that you think those present not worth bothering about. Things are less formal today, but do not overdo it.

DON'T think courtesy and good-manners old-fashioned.

DO recognize that most people still like to hear a 'please', and 'thank you', and 'after you', and 'excuse me'.

DON'T think the way you behave is unimportant as long as you prove your point and appear to be getting your own way.

DO recognize how much wiser it is to see other people's point of view. Consider their feelings and create goodwill which can help you as well as giving you more confidence in yourself.

DON'T think the way you speak and the language you use are your own affair.

DO recognize that it is hard work trying to listen to somebody who grunts and mumbles, does not look at the person he is talking to, drops his voice at the end of sentences, and maybe does not even bother to finish them properly. As for 'bad' language, many people are offended by it, and, when you come to think of it, is there really anything sillier than repeating those four-letter obscenities and that stupid meaningless 'bloody'?

DON'T think everybody should be interested in what you think and do.

DO recognize that most people are far more interested in themselves. Make the most of life as well as the best of yourself by sharing interest and activity and not trying to be the centre of the stage.

NEVER think you know it all.

ALWAYS recognize that this is impossible, however gifted and experienced you are. Actually, it is possible to learn something new from everyone we meet because all our attitudes and experiences are different.

**"Whenever a firm makes a conspicuous success, there is invariably at the head of it a man who is both courageous and efficient. He has learned what to do and he dares to do it".**

HERBERT N. CASSON

**"I hope I shall always possess firmness and virtue enough to maintain what I consider the most enviable of all titles, the character of an Honest Man".**

GEORGE WASHINGTON

**"To receive a present handsomely and in the right spirit even when you have none to return, is to give one in return".**

LEIGH HUNT

# LATHE TOOL GEOMETRY AND GRINDING

**G. DIKAIOS BSc (Hons) MSc, CEng, M.I.Pr.E.**
**A. ANTONIOU H.T.I. Diploma.**
**G. FLORIDES H.T.I. Diploma.**

**Introduction**

The general shape of cutting tools was developed in the workshop by the craftsmen. It is therefore expected that the angles specified were primarily defined for ease of grinding. But this is not so since various methods of specifying lathe tools angles are based on the mechanics of cutting.

Consider the general shape of the common lathe tool, as shown in figure A.

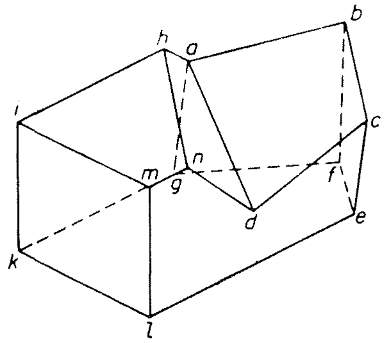



Fig. A, Common lathe tool.

The edges ab and bc are the cutting edges, ab being called the Major cutting edge and bc the Minor cutting edge.

The plane abcd is the rake face over which the chip flows. The rake face usually slopes away and downwards from the cutting edges. The greater the slope the easier the cutting becomes. The planes abfg and bcef slope downwards and away from the edges so that the tool clears the newly cut surface. These faces are called the clearance or flank faces. In plan view the cutting edges ab and bc are inclined to the tool body or shank and usually are joined in a radius at the tool tip b.

The cutting edge ab is usually inclined to the tool shank thus allowing the tool to initially contact the workpiece away from the tip which is the weakest part. In addition the tool gradually takes the full depth of cut. The plan angle or approach angle will also influence the chip-flow direction, relative to the workpiece. The nose radius is required to strengthen the tool tip and control the surface finish of the machined surface.

The main methods of specifying the lathe tool angles are the following:

(a) The Normal rake angle lathe tool specification. (See fig. B).

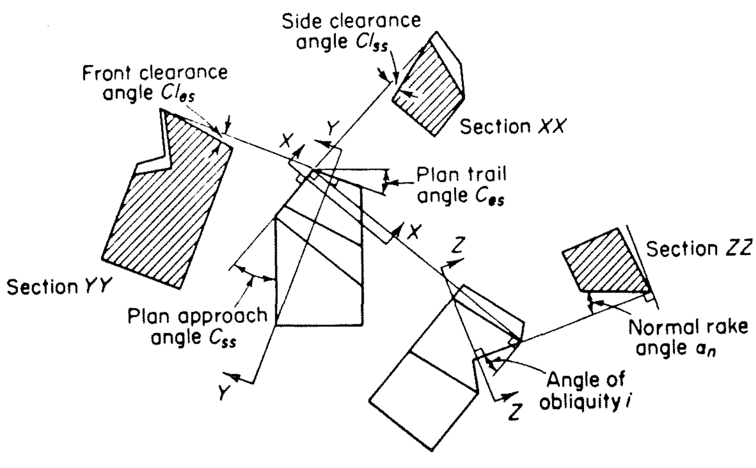



Figure B

(b) The German lathe tool specification. (See fig. C).

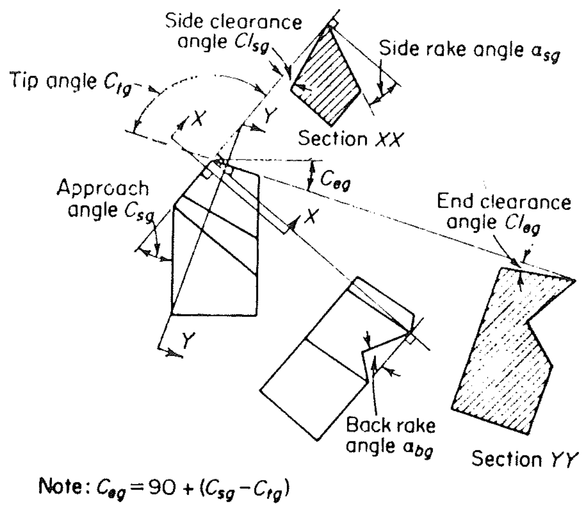



Figure C

(c) The British maximum rake lathe tool specification. (See fig. D).

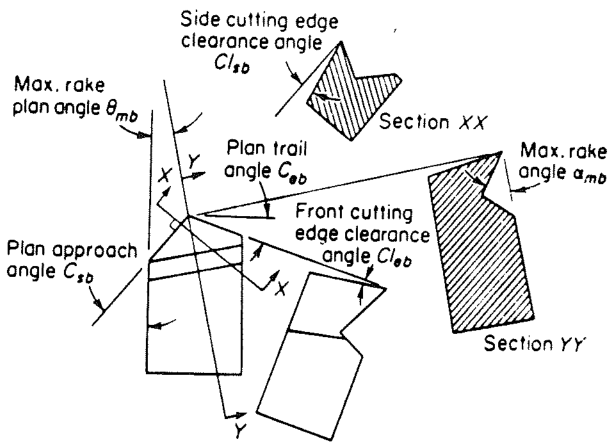



Figure D

(d) The American lathe tool specification. (See fig. E).

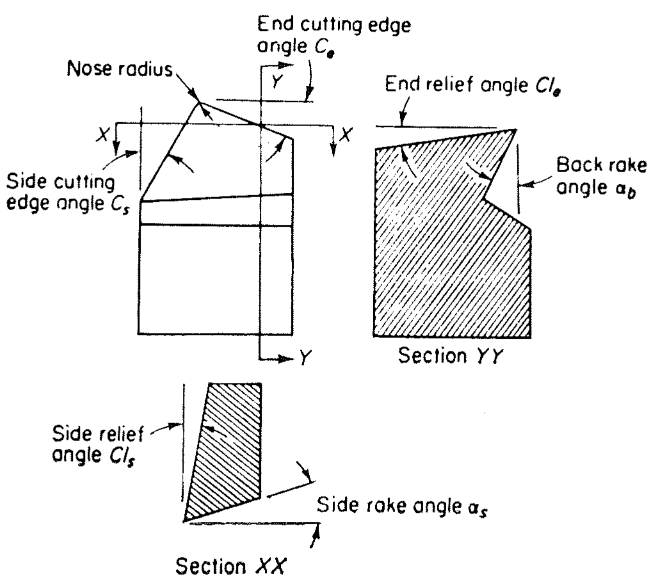



Figure E

(e) The Modified normal rake angle lathe tool specification. (See fig. F.).

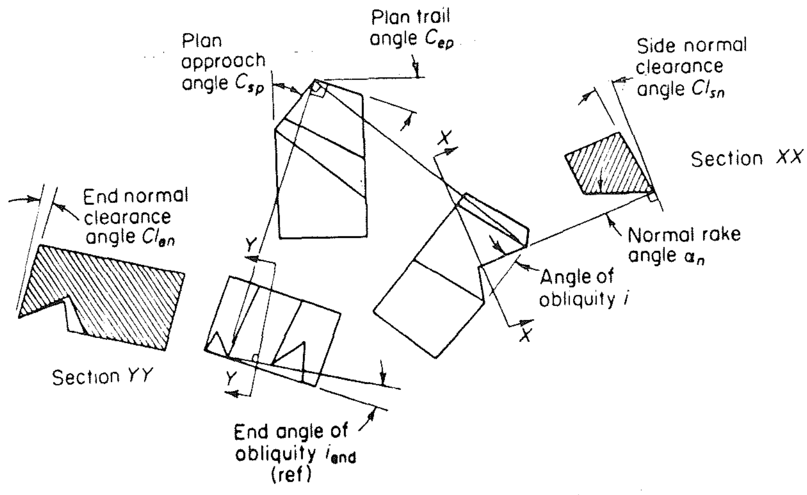



Figure F

Efforts are being made to arrive at an internationally acceptable specification based on the normal rake system.

Below, the main angles of the above mentioned system and their relation will be discussed.

**Theory**

1. Introduction to the single point tool Nomenclature.

1.1. **Reference Systems of planes**

Reference systems of planes are necessary for defining and specifying the angles of a cutting tool. One system (the tool – in – hand system) is used for defining the geometry of the tool for its manufacture and measurement. A second system (the tool – in – use system) is needed for specifying the geometry of the cutting tool when it is performing a cutting operation.

Here the planes of the tool – in – hand system will be defined.

(a) **Tool reference plane (Pr)** (figure 1)

A plane through the selected point on the cutting edge so chosen as to be either parallel or perpendicular to a plane or axis of the tool convenient for locating or orienting the tool for its manufacture or measurement. For ordinary lathe tools it is a plane parallel to the base of the tool.

(b) **Tool cutting edge plane Ps** (figure 1)

A plane tangential to the cutting edge at the selected point and perpendicular to the tool reference plane (Pr).

(c) **Tool orthogonal plane (Po)** (figure 1)

A plane through the selected point on the cutting edge and perpendicular both to the tool reference plane (Pr) and to the tool cutting edge plane (Ps)

(d) **Assumed Working Plane Pf** (figure 2)

A plane perpendicular to the tool axis passing through the selected point on the cutting edge and perpendicular to the tool reference plane Pr.

(e) **Tool back plane Pp** (figure 2)

A plane through the selected point on the cutting edge and perpendicular both to the tool reference plane Pr and to the assumed working plane Pf.

**" Make a resolution not to eat trouble".**

JUSTINE GLASS

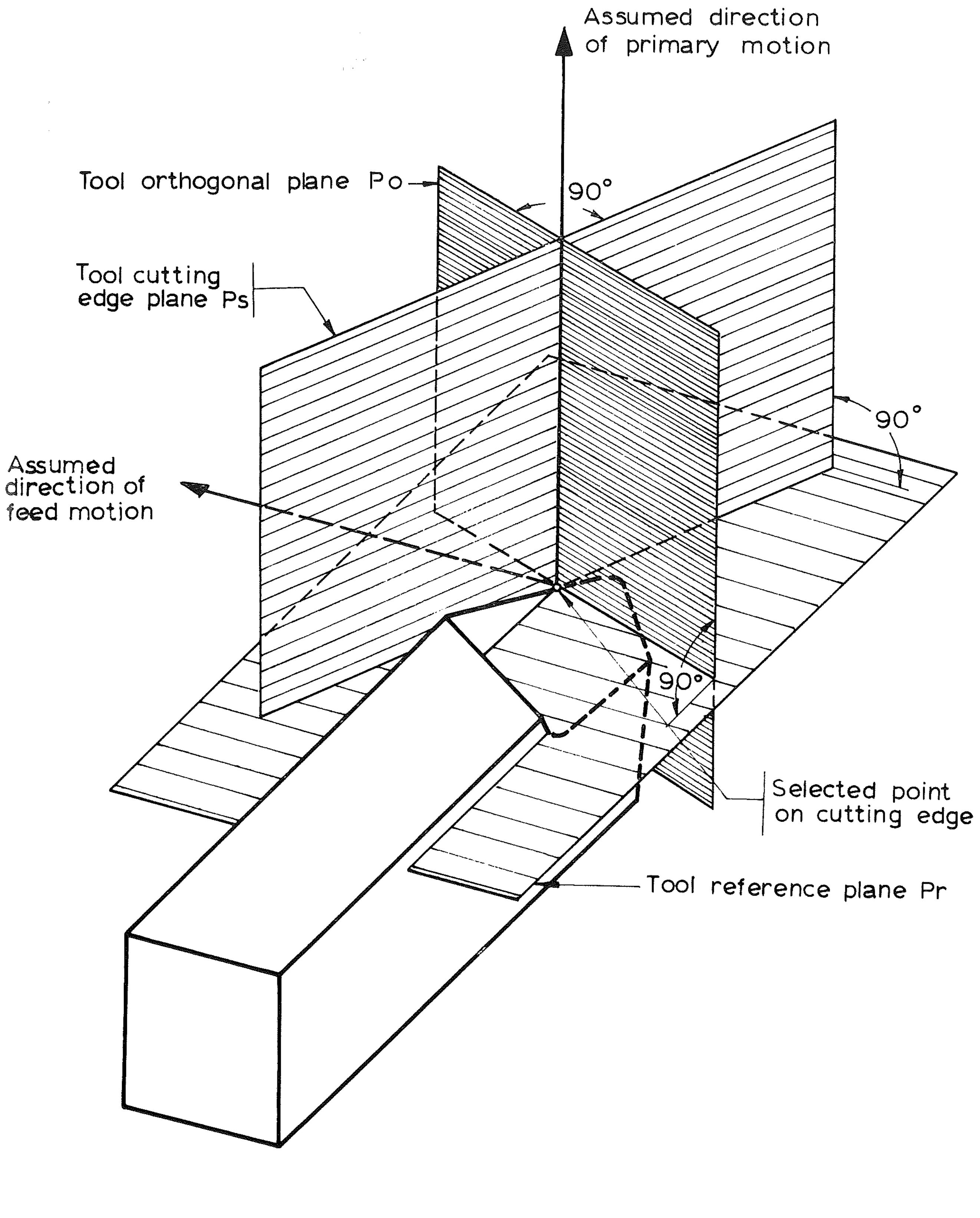

Assumed direction of primary motion
Tool orthogonal plane Po
90°
Tool cutting edge plane Ps
90°
Assumed direction of feed motion
90°
Selected point on cutting edge
Tool reference plane Pr

FIG. 1

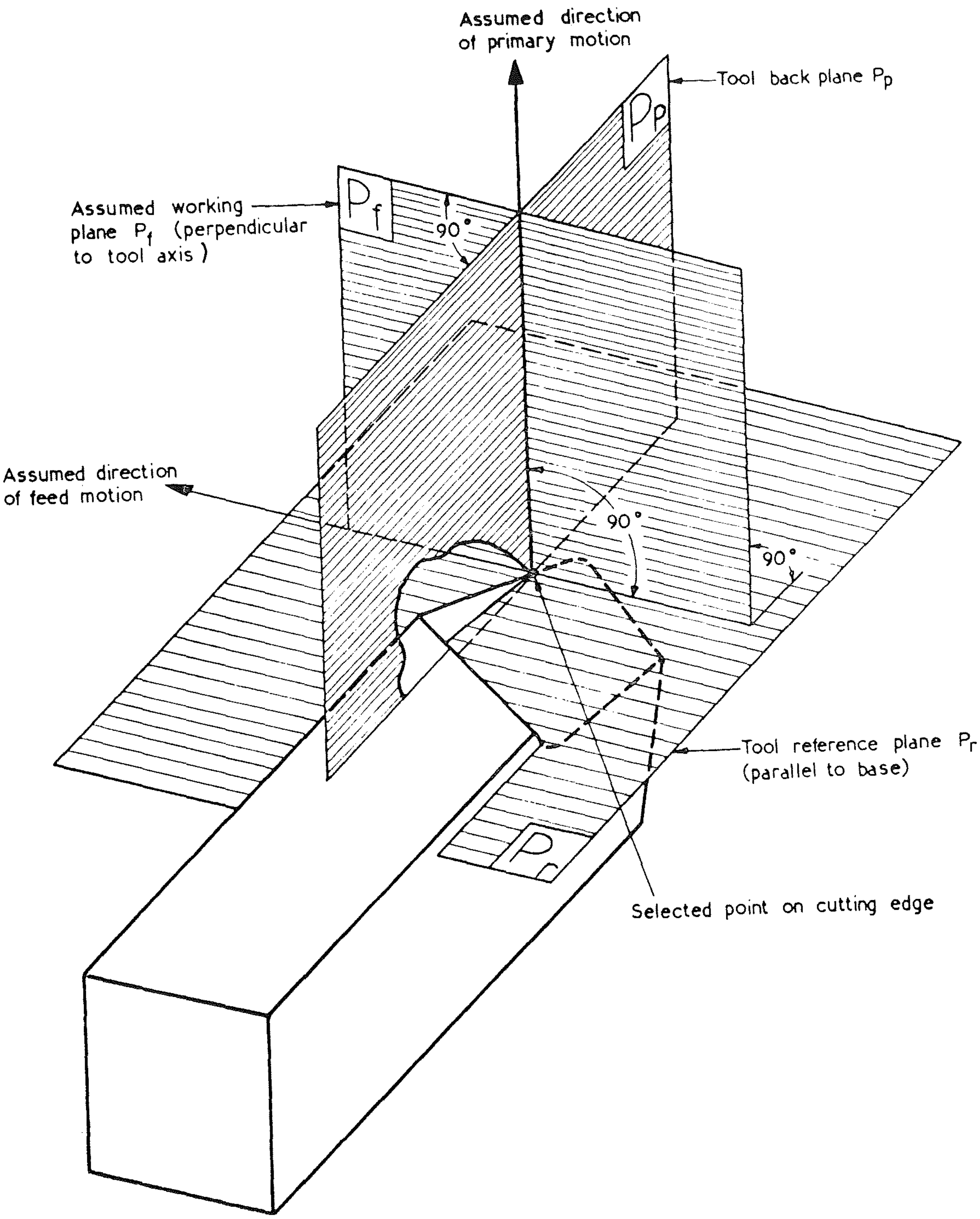



Fig. 2 Tool-in-hand system of planes

(f) **Tool minor cutting edge plane (Ps′)** (figure 3)

A plane tangential to the cutting edge of the minor flank at a selected point and perpendicular to the tool reference plane Pr.

The following table gives the definition of the most important tool angles.

**Tool - in hand Angles**

| Angle | Symbol | Angle between | | measured in |
|---|---|---|---|---|
| Tool Approach angle | $\psi r$ | Ps | Pp | Pr |
| Tool cutting edge angle | Kr | Ps | Pf | Pr |
| Tool minor cutting edge angle | Kr′ | Ps′ | Pf | Pr |
| Tool cutting edge inclination | $\lambda$ | S* | Pr | Ps |
| Tool Orthogonal clearance | $\alpha o$ | Aa* | Ps | Po |
| Tool orthogonal wedge angle | $\beta o$ | Aa* | A$\gamma$* | Po |
| Tool orthogonal rake | $\gamma o$ | A$\gamma$* | Pr | Po |
| Tool included angle | $\varepsilon r$ | Ps | Ps′ | Pr |

* Aa, A$\gamma$ and S see figure 4.

**Calculation of the angles to be used for grinding the cutting tool** (Refer to figure 5).

Consider that Y–Y is a plane parallel to the Back plane Pp and X–X is a plane parallel to the Working plane Pf. Assume also that the trace of the orthogonal plane Po on the reference plane Pr is the line M–M.

(a) Calculation of $\gamma x$

From the plan view $CD = \dfrac{b}{\tan Kr}$

From Z view $\tan(-\lambda) = \dfrac{d-c}{CD}$

But $\tan(-\lambda) = -\tan\lambda$

$\therefore \quad -\tan\lambda = \dfrac{d-c}{\dfrac{b}{\tan Kr}}$

$$d-c = \frac{-b\tan\lambda}{\tan Kr} \qquad (1)$$

From section M–M $\tan\gamma o = \dfrac{c-a}{b}$ (2)

Since $d-a = (d-c) + (c-a)$

then $d-a = -\dfrac{b\tan\lambda}{\tan Kr} + b\tan\gamma o$ (3)

From the projection of triangle AD′C on the Reference plane Pr,

$f = \dfrac{b}{\sin Kr}$ (4) where f = the projection of AD′ on Pr

From the traces, $\tan\gamma x = \dfrac{d-a}{f}$ (5)

> **" I expect to give my best to life, and I expect life to return its best to me".**
> DONALD CURTIS

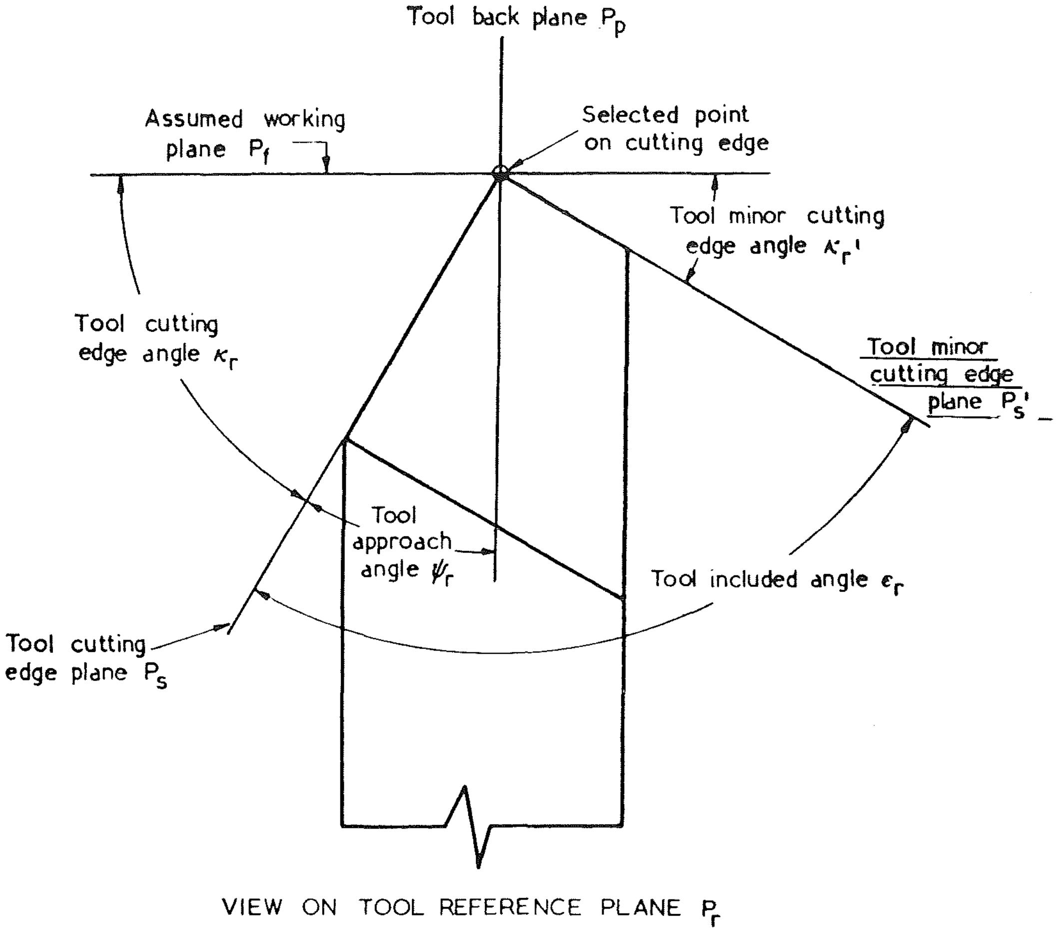



Fig. 3 Orientation of the cutting edges for the tool-in-hand

Substituting equation (4) in (5)

$$\tan \gamma x = \frac{d-a}{b} \sin kr$$

$$d-a = \frac{b \tan \gamma x}{\sin Kr} \qquad (6)$$

From equuation (6) and (3)

$$\frac{b \tan \gamma x}{\sin Kr} = \frac{-b \tan \lambda}{\tan kr} + b \tan \gamma o$$

$$\therefore \tan \gamma x = \tan \gamma o \sin Kr - \tan\lambda \cos Kr$$

**" If you are under par I suggest that you do a very scrupulous job of self – analysis. Honestly ask yourself if you are harbouring any ill will or resentment or grudges, and if so cast them out. Get rid of them without delay. They do not hurt auybody else. They do no harm to the person against whom yon hold these feelings, but every day and every night of your life they are eating at you. "**

Dr. NORMAN VINCENT REALE.

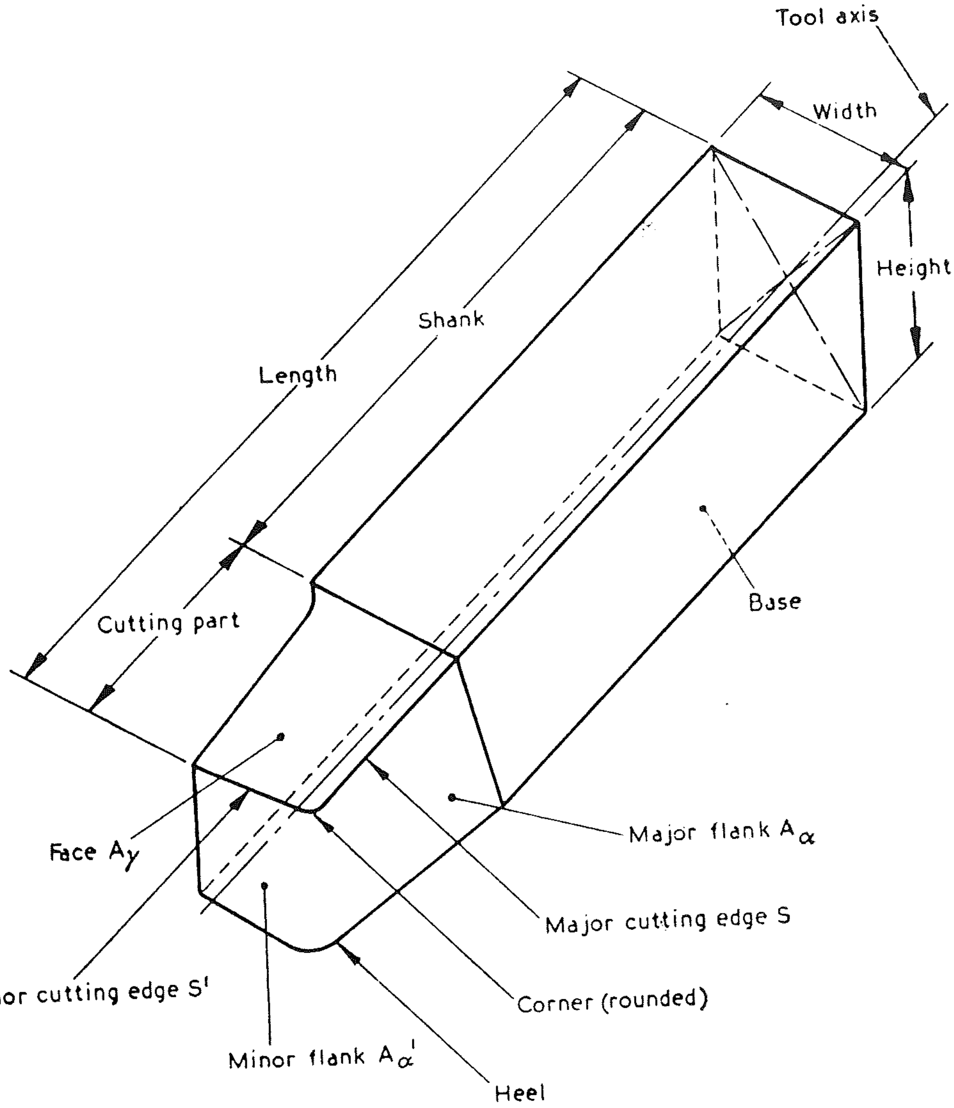



**Fig.4 General terms and tool elements**

(b) Calculation of αx

From section M–M $\tan \alpha o = \frac{b}{c}$ (7)

Also $d = (d-c) + c$ (8)

Substituting in equation (8), (1) and (7)

$$d = \frac{-b \tan\lambda}{\tan Kr} + \frac{b}{\tan \alpha o} \quad (9)$$

From the traces $\cot \alpha x = \frac{d}{f}$

but from eq. (4) $f = \frac{b}{\sin Kr}$

$$\cot \alpha x = \frac{d}{b} \sin Kr \text{ and } d = \frac{b \cot ax}{\sin Kr} \quad (10)$$

From eqs. (9) and (10)

$$\frac{b \cot ax}{\sin Kr} = -\frac{b \tan\lambda}{\tan Kr} + \frac{b}{\tan \alpha o}$$

$\therefore \cot \alpha x = \cot \alpha o \sin Kr - \tan\lambda \cos Kr$

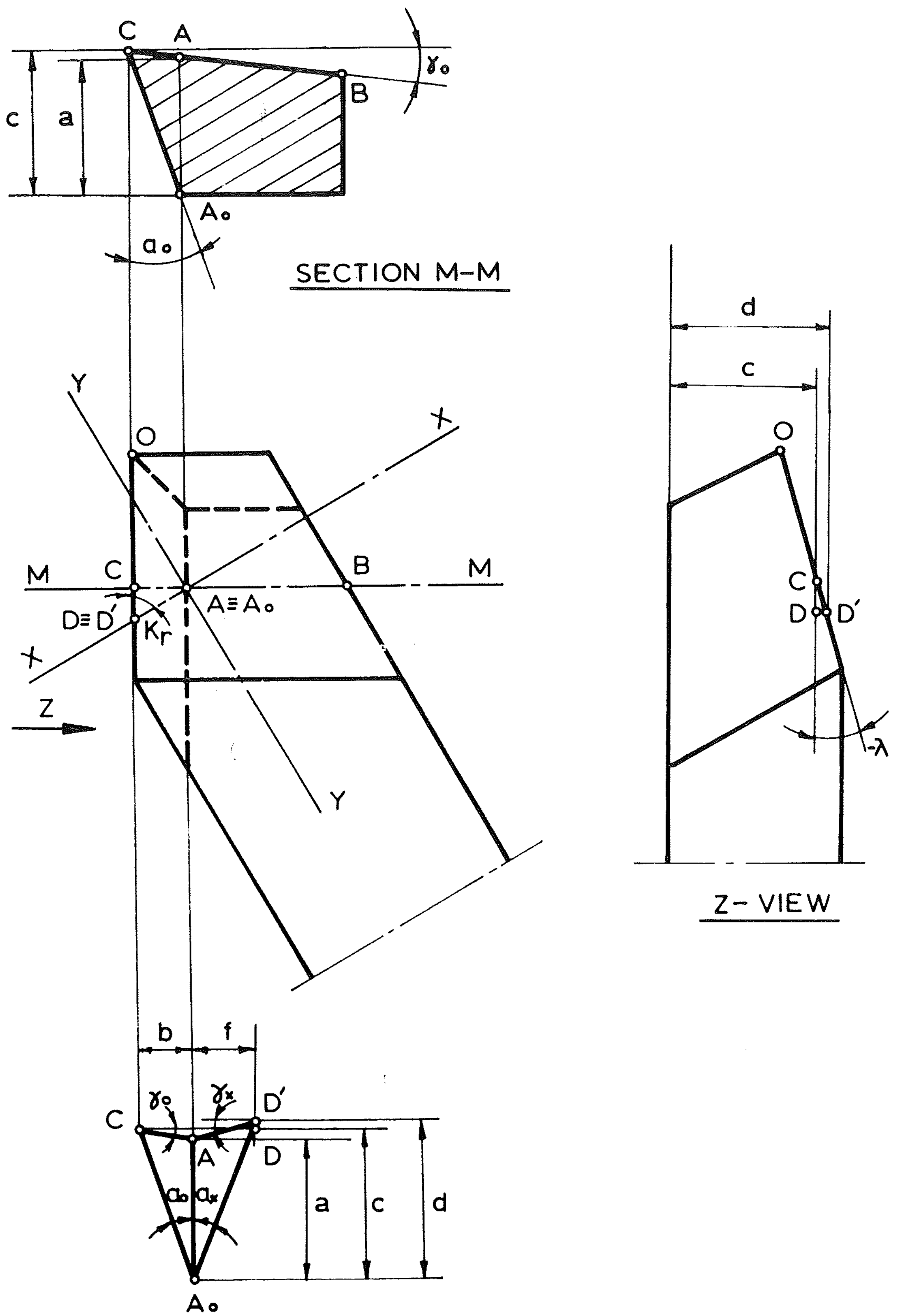



FIG. 5

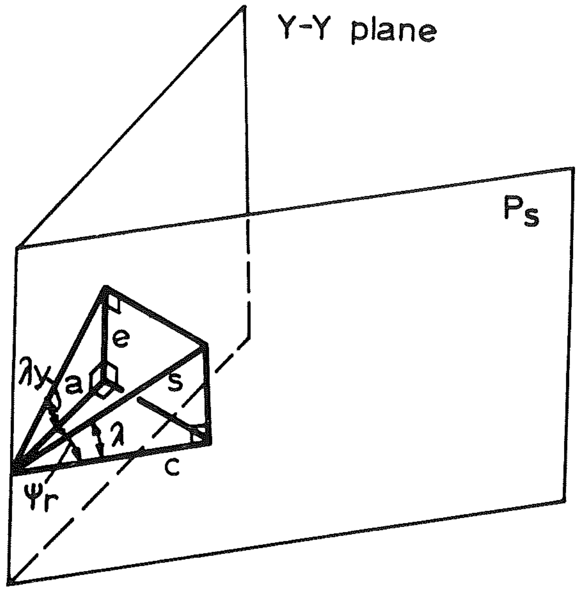



Fig. 6

(c) Calculation of λy (Referring to figure 6)

$$\tan\lambda = \frac{e}{c} \qquad \therefore \qquad e = c\tan\lambda$$

$$\cos\psi r = \frac{a}{c} \qquad \therefore \qquad a = c\cos\psi r$$

$$\tan\lambda y = \frac{e}{a} \qquad \therefore \qquad \tan\lambda y = \frac{c\tan\lambda}{c\cos\psi r}$$

$$\text{and} \quad \tan\lambda y = \frac{\tan\lambda}{\cos\psi r}$$

**Equipment**

1. Pedersen Universal Tool and Cutter Grinder (Model USL with standard accessories and tooling).

   This machine is a precision heavy built m/c and designed for use in toolrooms as well as in production. It has the following features.

   Working area in front of and on each side of the m/s. The upper part of the grinding table can be turned $45^0$ to either side and is provided with a dial and taper adjustment. The wheel stand can be turned $180^0$ to either side and is provided with 2 grinding wheels.

2. $0.5^0$ Universal Bevel Protractor.
3. H.S.S. Specimen of any standard cross sectional area.

**Experimental procedure**

Cutting tool angles (to be ground) are:
$\psi r = 30^0$
$Kr = 15^0$
$\alpha o = 6^0$
$\gamma o = 10^0$
$\lambda = -4$

Calculate angles γx, αx and λy and follow the steps below:

(Note that the base plate, angle pieces and vice are numbered).

> **" How poor are they that have not patience ".**
>
> WILLIAM SHAKESPEARE

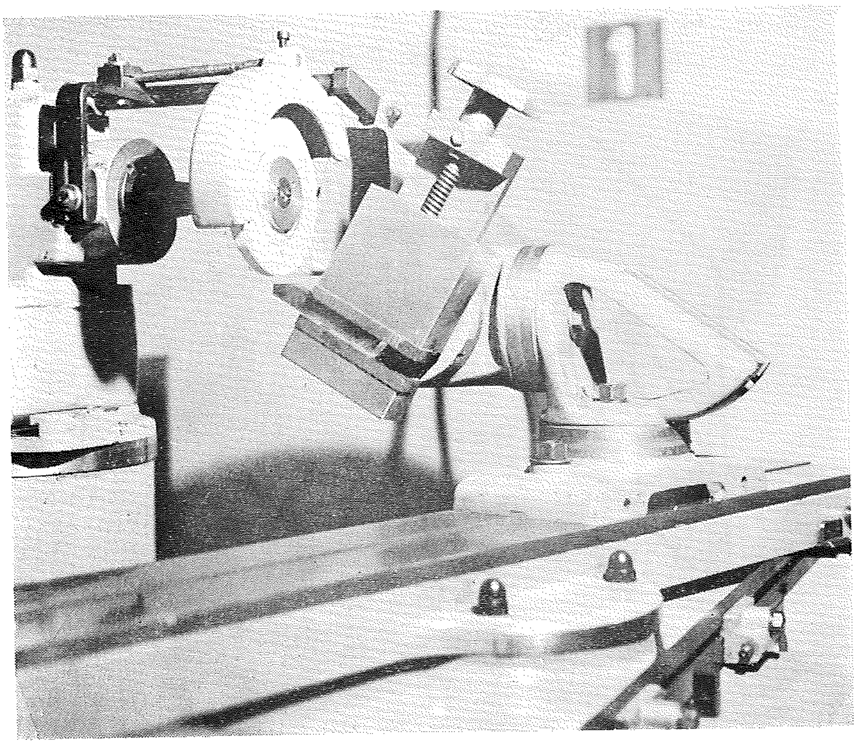


Figure 7

(a) **Major flank** (figure 7)

1. Position tool shank in vice 4 with major flank to be ground, on top.
2. Rotate vice 4, clockwise when facing the front of the vice by an angle equal to $\psi r$.
3. Rotate angle piece 3, in the clockwise direction when facing the front of the machine, by an angle equal to $\alpha x$.
4. Rotate the table of the machine, clockwise when looking from top, by an angle equal to $20^0$.
5. Rotate angle piece 2, anticlockwise when facing the front of the machine, by an angle equal to $20^0$.
6. Clamp tightly all parts.
7. Grind the major flank.

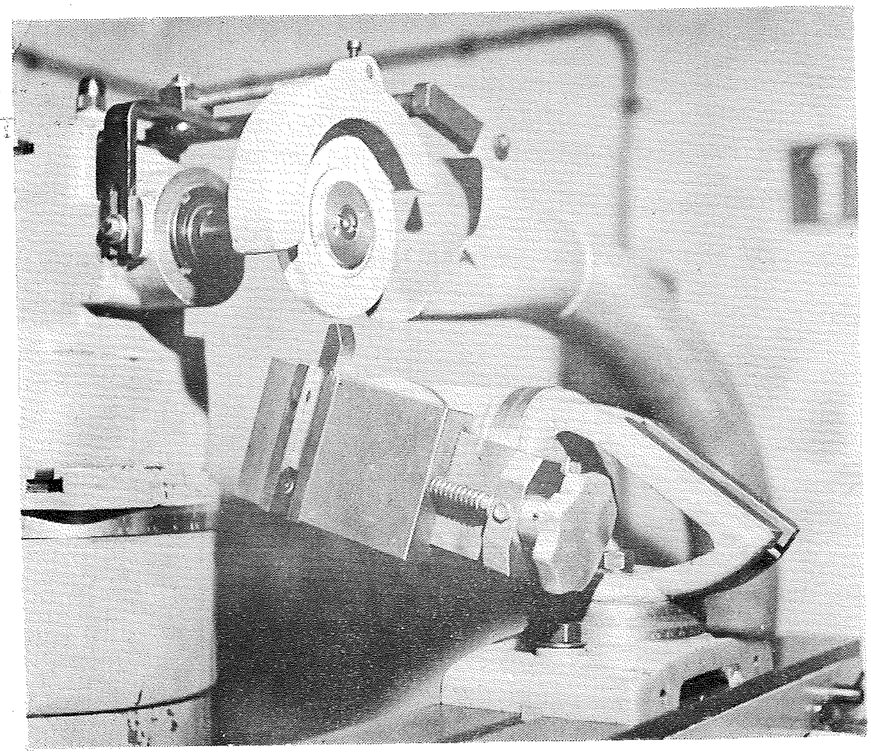


Figure 8

(b) **Minor flank** (figure 8)

1. Bring the device to its original position and also the machine table.
2. Rotate vice 4 in the clockwise direction by an angle equal to $90^0 + Kr$.
3. Rotate clockwise angle piece 3 by an angle equal to ax.
4. Clamp tightly all parts.
5. Grind the minor flank.

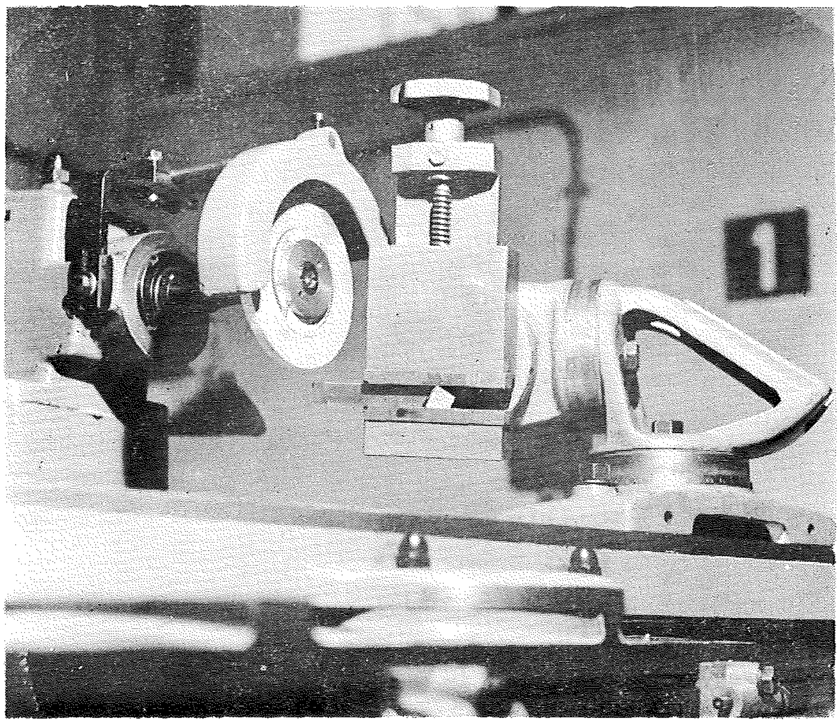


Figure 9

(c) **Rake face** (figure 9)

1. Bring device to its original position.
2. Clamp the tool shank in vice 4 so that rake face, to be ground, is on top.
3. Rotate vice 4, clockwise for –ve $\lambda$ and anticlockwise for + ve $\lambda$, by an angle equal to $\lambda y$.
4. Rotate angle piece 3, clockwise for –ve $\gamma o$ and anticlockwise for + ve $\gamma o$, by an angle equal to $\gamma x$.
5. Then rotate table of the m/c clockwise by an angle equal to $20^0$.
6. Rotate angle piece 2, anticlockwise, by an angle equal to $35^0$.
7. Clamp all parts tightly.
8. Grind the Rake face.

**Results**

1. Measure the angles $\psi r$, Kr, ao, $\gamma o$ and $\lambda$ with the universal protractor as accurately as possible and compare the results with the angles required.

The aim of this task has been to present a simple and quick method for grinding H.S.S. Lathe tools. Although such tool grinders are not found to be employed by the local industry the benefits by such grinding would be better work finish and longer tool life since hand tool grinding is inaccurate however good the skill of grinding is.

**"Perpetual devotion to what a man calls his business is only to be sustained by perpetual neglect of many other things".**

ROBERT LOUIS STEVENSON

# "We shall not remain nailed to the Earth"

## The Astronomy Club's Herald

**by GEORGE K. MICHAELIDES**
**2nd year Student**
**Civil Engineering Department**

The objectives of the Astronomy Club are the dilatation of the concerns of the students in cultural, scientific and formative levels, and the grafting of the youth's interest towards a new form of culture, synchronous to our century. The long term pursuit is the correct out-of-school orientation.

Aeronautics bears a real revolution in the consecrated perceptions concerning the world and introduces a new dissension, in our lives, the meaning of the wordly space. The introduction of new emotions to manking for a human coexistence, the sailing into an unlimited space and the desire for its conquest provoke the interest of the members and friends of the club.

In this academic year, the activities of the club included meetings of the members, lectures by Mr. Achillides, the Master in charge of the club, invited persons and students—members of the club, projection of films and the securing of an astronomical telescope.

Lectures Given:

" Telescopes and Radio-Telescopes " — Mr. Achillides

" The Planet Mars " — A. Lycoude (1C)

" The Universe and Ourselves — G. K. Michaelides (2C)

" Extra–terrestrials - The myth and the truth " — Mr. Achillides

"The birth and death of stars " — Vassiliou (1E)

" Cosmology " — Mr. Achillides

" The evolution of astronomy " — Mr. Achillides

" Teleguide of vehicles towards moving targets — Mr. G. Christodoulides, Director of the HTI

" The human being and life in the universes " — Dr. Atteslis

" Life, conscience and self–Knowledge " — Dr. Atteslis

" Alpha and Omega " — Mr. Demetriades

**Life is composed of doing the things that need doing whether one feels in the mood to do them or not.**

Sir BASIL HENRIQUES

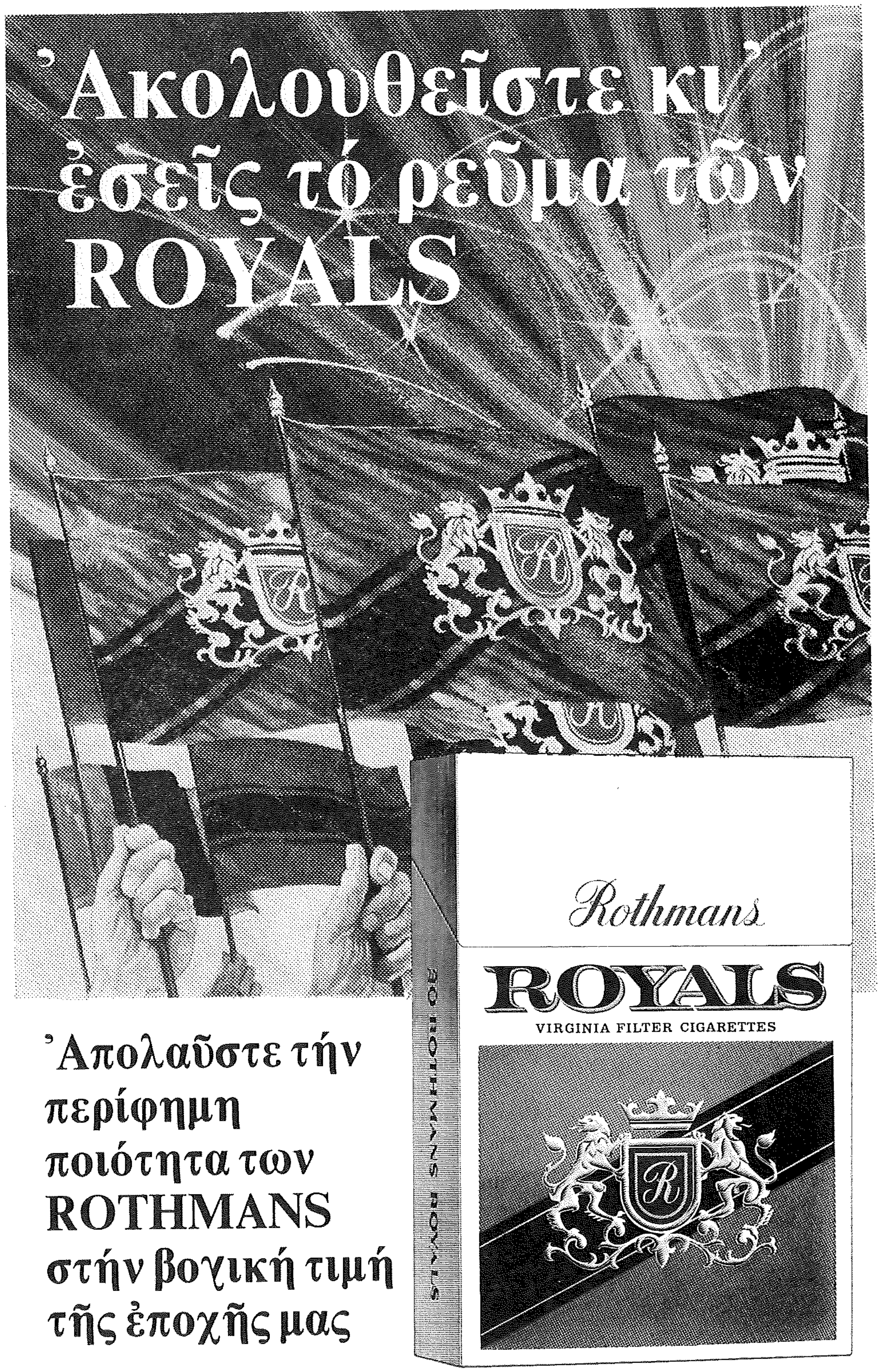
**" Scientific research has shown that an insufficient degree of everyday fun can actually destroy your emotional balance".**

ROBERT MINES

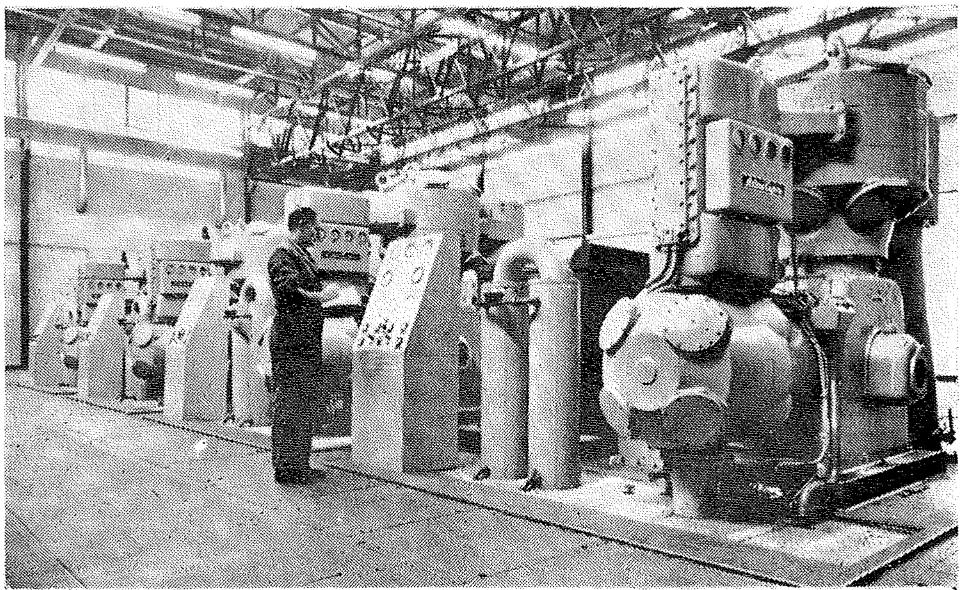
# ΓΙΑ ΕΝΑ ΚΟΣΜΟ ΧΩΡΙΣ ΜΟΡΦΕΣ

*Οἱ κύκλοι τοῦ κορμοῦ μου περίσσεψαν,*
*τόσα λιθάρια μοῦ φράξαν τὰ μονοπάτια,*
*Οἱ καρποὶ τοῦ καλοκαιριοῦ μου δὲν μέστωσαν,*
*τόσες φορὲς κατέβηκα τὰ σκαλοπάτια.*
*Ἄνεμε ταξίδι πάρε τούτη τὴ λαλιά,*
*εἶναι μαρτυρία μὲ τὸ χέρι στὴν καρδιά.*
*Μὴ μοῦ μιλᾶτε γιὰ τ' ἄκρα,*
*νὰ μὴ ξαναγροικήσω γιὰ τ' ἀντίπερα.*
*Θὰ βουτήξω στῆς λίμνης τὸν πάτο,*
*ὅ,τι φαίνεται στὴ μορφὴ πολὺ ὄμορφο.*
*Μήτε κι' ὅ,τι πολὺ ἄσχημο γύρω μου*
*θὰ ἀφήσω στὸν οὐρανὸ τὸν δικό μου.*
*Ποτὲ πιὰ τῆς βροχῆς κύκλος,*
*ἀπ' τὴν ἐπιφάνεια τῆς λίμνης ἀτμός,*
*ἀπὸ σύννεφο βροχὴ νὰ μὲ τυλίξη*
*τὴν ψυχὴ νὰ ἐρειμώση, ν' ἁρπάξη.*
*Τρεχούμενο νερό, τοῦ καϋμοῦ τὴν βάρκα*
*μὴν ἀφήσης σ' ἐκείνης τ' ἀγνάντεμα.*
*Οὐρανὲ ἀνεφέλωτε, μοῦ στερέψανε τὰ ρόδα,*
*φῶς δῶσε της ν' ἀντικρύση, νὰ γυρίσ' ἡ ρόδα.*
*Ἐμπρός, ὅλοι γιὰ ἕνα κόσμο χωρὶς μορφές,*
*μαζὶ νὰ κομματιάσουμε ὅλους τοὺς καθρέφτες,*
*σὰν νὰ γεννιόμασταν ὅλοι μὲ τὸ σῶμα ἴδιο,*
*μὲ λουλούδια γιὰ τὴν ὀμορφιὰ τῆς ψυχῆς μόνο.*
*Ἐμπρός, νὰ χτίσουμε, χωρὶς μορφὲς νἆν' ὁ κόσμος,*
*γιὰ τῆς καρδιᾶς, τῆς ψυχῆς τὸ φέγγος.*

Γ. Κ. ΜΙΧΑΗΛΙΔΗΣ (2C)



᾿Ακολουθεῖστε κι᾿ ἐσεῖς τό ρεῦμα τῶν ROYALS
Rothmans
ROYALS
VIRGINIA FILTER CIGARETTES
20 ROTHMANS ROYALS
᾿Απολαῦστε τήν περίφημη ποιότητα των ROTHMANS στήν βογική τιμή τῆς ἐποχῆς μας



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