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NATIONAL INSTITUTE FOR NON DESTRUCTIVE TESTING AND QUALITY CONTROL, BUENOS AIRES*

DU/ARG/71/537

ARGENTINA

Technical report: Applications of dye penetrant methods

Prepared for the Government of Argentina by the
United Nations Industrial Development Organization,
as an agency associated with the International Atomic Energy Agency,
the executing agency for the United Nations Development Programme

Based on the work of Hermann B.W. Thier, expert in
dye penetrant techniques

United Nations Industrial Development Organization
Vienna

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Explanatory notes

The following abbreviations of organizations are used in this report:

CNEA	Comisión Nacional de Energía Atómica
DGZfP	Deutsche Gesellschaft für Zerstörungsfreie Prüfung (German Society for NDT)
DIN	Deutsche Industrie Norm (German Industrial Norm)
DVS	Deutscher Verband für Schweisstechnik (German Society for Welding Techniques)
FNM	Fach-Normenausschuss Materialprüfung (Norm Committee for Testing Materials)
IAEA	International Atomic Energy Agency
INEND	Instituto de Ensayos no Destructivos
INTI	Instituto Nacional de Tecnología Industrial
UNDP	United Nations Industrial Development Programme

The following technical abbreviations are used in this report:

DD	dry developer
DPT	dye penetrant testing
F	fluorescent
f.c.	foot candle
lx	lux
µW	microwatt
NDT	non-destructive testing
PE	post emulsification
PoPT	principle of penetrant testing
PS	penetrant system
PT	penetrant testing
RW	red-white
SR	solvent removable
UV	ultra violet
WW	water washable

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ABSTRACT

The expert in dye penetrant techniques is one of five UNIDO experts assigned to the project "National Institute for Non-Destructive Testing" (DP/ARG/[illegible]), for which the International Atomic Energy Agency (IAEA) is the executing agency and the United Nations Industrial Development Organization (UNIDO) an associated agency.

Under this project the establishment of the Instituto de Ensayos no Destructivos (INEND) was started in 1973 and the expert in dye penetrant testing, who took up his assignment of four and a half months on 10 April 1[illegible], was required to assist that new Institute in the practical application of dye penetrant techniques on various materials and components and to advise on and guide a work programme directed at developing standards of quality assessment, their application and evaluation for dye penetrant methods.

The expert gave lectures on specific topics in penetrant testing and visited with the non-destructive testing (NDT) staff of INEND steelmaking and machine factories to advise these companies on quality control and the future prevention of faults. The expert also developed a welded test piece with very fine cracks that can be reproduced in all manufacturing plants and used as a standard.

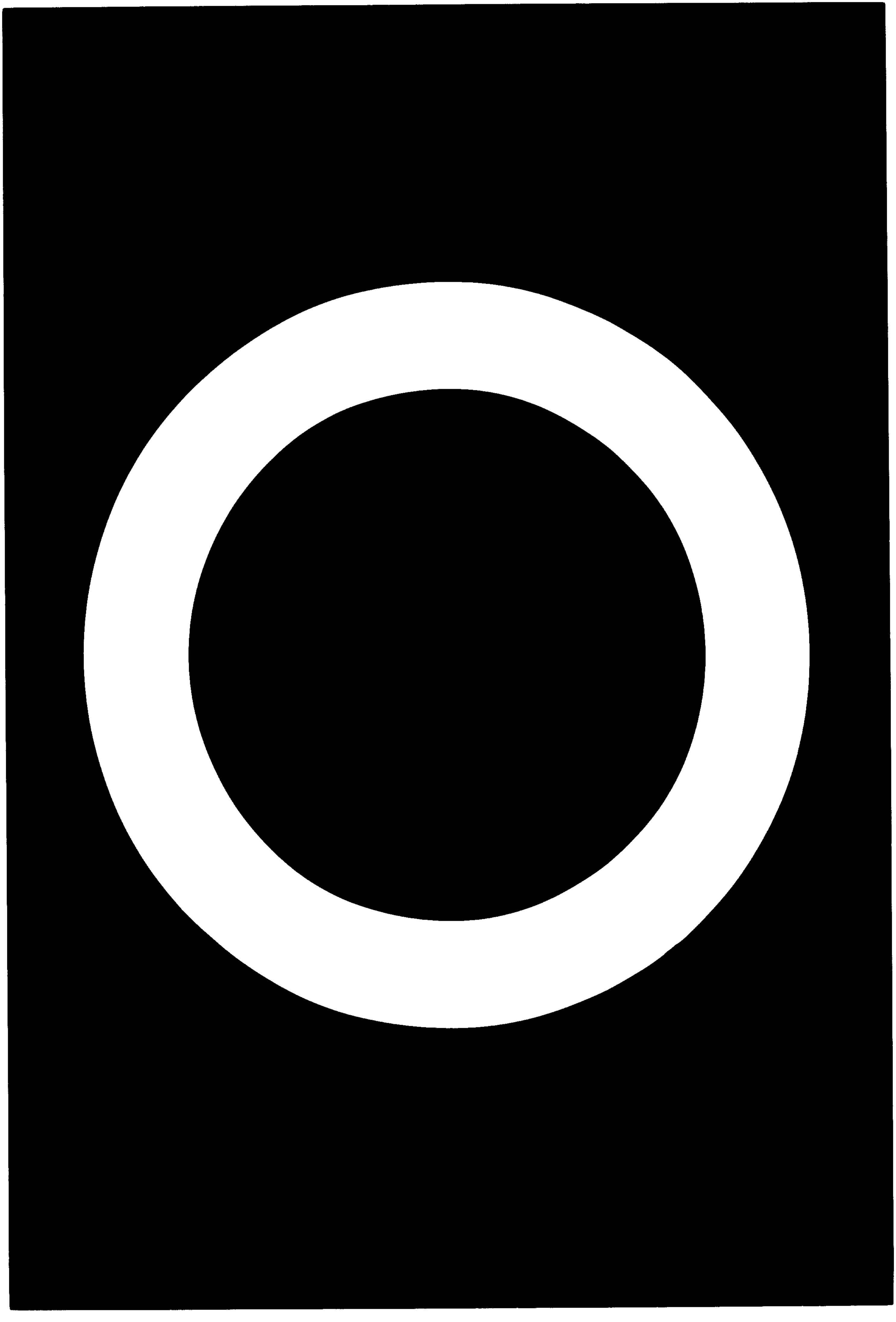
Relevant standards of the Federal Republic of Germany and the United States were studied and an effort made to develop Argentine standards for penetrant testing (PT) systems and the behaviour of penetrants. After a discussion of existing standards for the qualification of PT personnel and a comparison of the organization and the programmes offered by some training institutes in this field, an attempt was made to define the best suitable system for Argentina.

The expert's recommendations include the following:

(a) Increase the effectiveness of the existing mobile laboratory by furnishing it with additional equipment;

(b) Prepare written test instructions and check-lists for operators testing mass-produced items;

(c) Continue the efforts to establish Argentine standards not only for penetrant testing, but also for all other kinds of non-destructive and destructive testing and for the surveying of atomic power plants and that of dangerous but important technical products.



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Annexes

I. INTRODUCTION

Following a request for assistance by the Government of Argentina, the United Nations Development Programme (UNDP) set up the project "National Institute for Non-Destructive Testing and Quality Control, Buenos Aires" (DU/ARG/71/537). The executing agency for the project is the International Atomic Energy Agency (IAEA), with the United Nations Industrial Development Organization (UNIDO) as an associated agency. The purpose of the project is to assist the National Commission of Atomic Energy (CNEA) in the creation of a national centre for non-destructive testing and quality control. The establishment of the centre, called "Instituto de Ensayos no Destructivos" (INEND) started in 1975 and at present the Section for non-destructive testing (NDT) of the Institute is organized as shown in annex I.

The expert in dye penetrant techniques is one of five UNIDO experts working under the overall guidance of the Project Director. He took up his assignment on 10 April and completed it on 20 August 197 after an extension of his three-month contract by six weeks. According to his job description (annex II) he was required to:

(a) Assist and advise on the practical application of dye penetrant techniques on various materials and components;

(b) Advise on and guide a work programme directed at developing standards of quality assessment, their application and evaluation for dye penetrant methods.

The expert found the Institute well equipped for penetrant testing, with respect to both, skilled labour and technical facilities. During the first weeks he gave lectures, followed by discussions and practical applications, on the following subjects:

(a) Problems in the application of penetrant testing methods;

(b) Troubles with ultra-violet light in fluorescent penetrant testing;

(c) Modern equipment for, penetrant testing and documentation by photography in ultra-violet light;

(d) Special penetrant systems, e.g., testing with radio-active isotopes as penetrants.

All the participants from the Institute were very interested and discussed the subject enthusiastically. It was not deemed necessary to give further lectures on principles of penetrant testing since a very good report on that subject by Juan N. Báez, "Cursos de Reciclado para Profesionales de la Industria - Líquidos Penetrantes" (CNEA-AC 48/75-Proyecto ARG/71/537-PNUD/OIEA/ONUDI) was available. The same lecture was also presented, in the Mechanics Department of the Instituto Nacional de Tecnología Industrial (INTI).

During visits to a steelmaker and various machine factories many testing and related problems were found to exist. It was observed, that different German and United States Standards for quality control were in use. Various systems of penetrant testing could be applied to find cracks, pores and other inhomogeneities. Discussions to prevent the faults in future concluded the visits. Everybody was very co-operative and particulars of the various fabrications were made known to the group in order to have [illegible] details for defining the best non-destructive testing method and for eliminating the often rather serious defects in machine parts. One of the firms visited also produces penetrants with good success and there, as well as in other factories, more or less good equipment and suitable personnel for non-destructive testing (NDT) was found.

The Institute's testing programme includes machine parts of steel and light metal brought from various factories. Therefore it was possible to train the young staff of INEND in the practical application of various systems of dye penetrant testing. They were interested in both the theory and the practice of penetrant testing and discussed the subject at length. They also had the possibility to apply their knowledge and experience in other parts of the country, driving with their mobile laboratory which is furnished with a wide variety of NDT equipment.

Another duty assigned to the expert was the development of standards for quality assessment of dye penetrant systems. Together with I. N. Báez the relevant American standards, the new German draft (Standard DIN 54152, part 1) "Non-destructive testing, penetrant operation, execution" and the first presentation of part 2 "Testing means" were studied. For the purpose of discussion with the staff of the Institute part 1 was translated by the expert into English (see annex III). The draft for a further German standard, DIN 54160, "Non-destructive testing, requirements for testing personnel" (annex IV) was also discussed in detail, and the courses offered by the Deutsche Gesellschaft für Zerstörungsfreie Prüfung (DGZfP), the organization of their educating centres, their lecturers, their boards of examiners etc. were analyzed. This private organization was compared to the other private organizations, such as the Deutscher Verband für Schweisstechnik (DVS) with its technical welding schools and research institutes or similar institutions in the United States. It was found that, in order to develop suitable standards, the interested parties in the Government and in the industry will have to form committees with a view to formulate Argentine standards for constructing and testing, following as closely as possible the new international recommendations.

The duration of the assignment was not long enough to permit visits to the light metal, plastics, ceramics and enamel industries in order to discuss their problems and to help in NDT to eliminate or avoid harmful defects in their production.

II. RECOMMENDATIONS

1. To increase the effectiveness of the mobile laboratory, it should be furnished with additional non-destructive testing equipment such as a hardness tester, a mobile microscope and preparation equipment for this purpose, a spectroscope etc. All these apparatus which are necessary to obtain additional data for fault investigation should be portable.

2. For testing mass-produced items written test instructions and check-lists for penetrant testing operators should be prepared.

3. Efforts to establish Argentine standards should be continued. These standards should not only cover penetrant testing, but also all other kinds of non-destructive and destructive testing and the surveying of atomic power plants and dangerous but important technical products.

III. ACTIVITIES

1. Lectures in penetrant testing

Introduction.

Job Description DU/ARG/71/537/11-26/31.3.D (Annex II) stated that the NDT Laboratory of Constituyentes Centre would be equipped with a range of NDT facilities (also for Penetrant Testing) and metallurgical equipment and a supporting mechanical workshop. This was all in good condition and sufficient for the experiments necessary in the work. There is also a mobile laboratory (Figs. 1 and 2) 11 m long, 2.50 m wide and 3.70 m high, built as semi-towing vehicle. This unit transports equipment for non-destructive testing, also for penetrant testing, with a darkroom for fluorescent penetrant removing and inspection. The mobile laboratory was observed working in the field. INEND also has good personnel for penetrant testing.

1. In 1977 Ing. Juan N. Báez of INEND wrote a penetrant testing guide for use in the instruction of students professionally qualified in engineering disciplines. It was agreed that the expert should give some lectures with regard to the problems in performing penetrant testing, to instruct engineers, students and inspectors. For this reason a basic knowledge of theory and practice of PT is necessary.

1.1. Problems in manufacturing materials for PT.

The recognition of these problems is very important for the user of penetrant methods, because the preservation of quality during storing and use is of extraordinary importance for the successful use of PT.

1.1.1. Penetrants.

The central problem of PT is to bring a maximum amount of penetrant into the surface defects, to leave this while cleaning the surface and remove most of it with the developer. The main part is played by the capillarity effect of the penetrant (Fig. 3).

Of major importance for a good penetrant is its wetting ability with the part to be tested. Water rises in a capillary and mercury shows depression. Water has high adhesive forces and mercury higher cohesive forces. Water is a good wetting agent and mercury a bad wetting liquid. Good spreading of a drop of penetrant on the clean surface of a test piece and a high relation of $\frac{\text{adhesive forces}}{\text{cohesive forces}}$ is necessary. Both properties are easy to test.

The following is a list of the requirements of liquid penetrant:

1. Flash-point not below 60°C.
2. High wettability.
3. Low viscosity (but minimum of dragout).
4. Penetrating time as short as possible.
5. Colour permanance.

Mobile Laboratory (Outside)

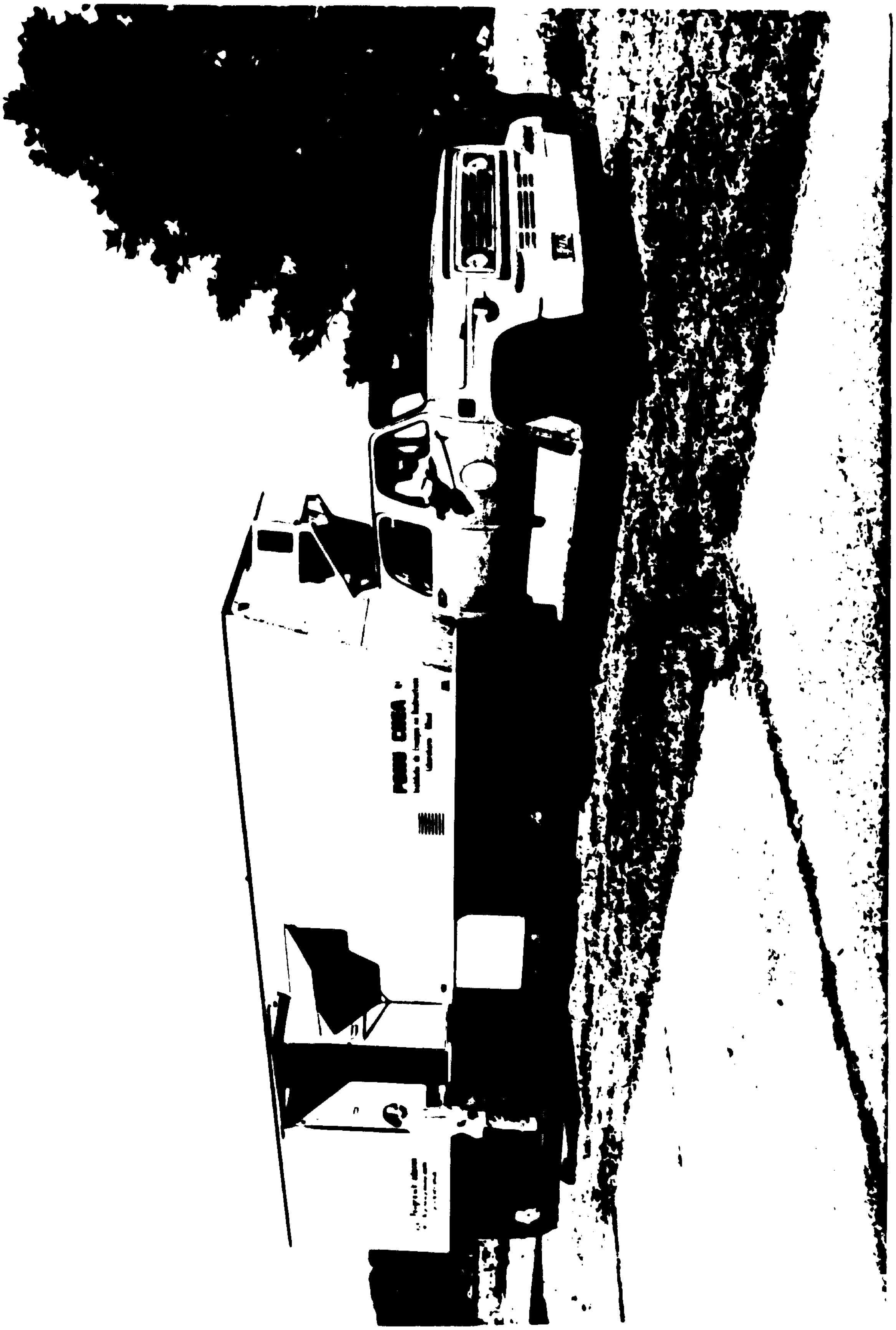


Fig 1.

Mobile Laboratory [illegible]

Fig. 2

capillarity

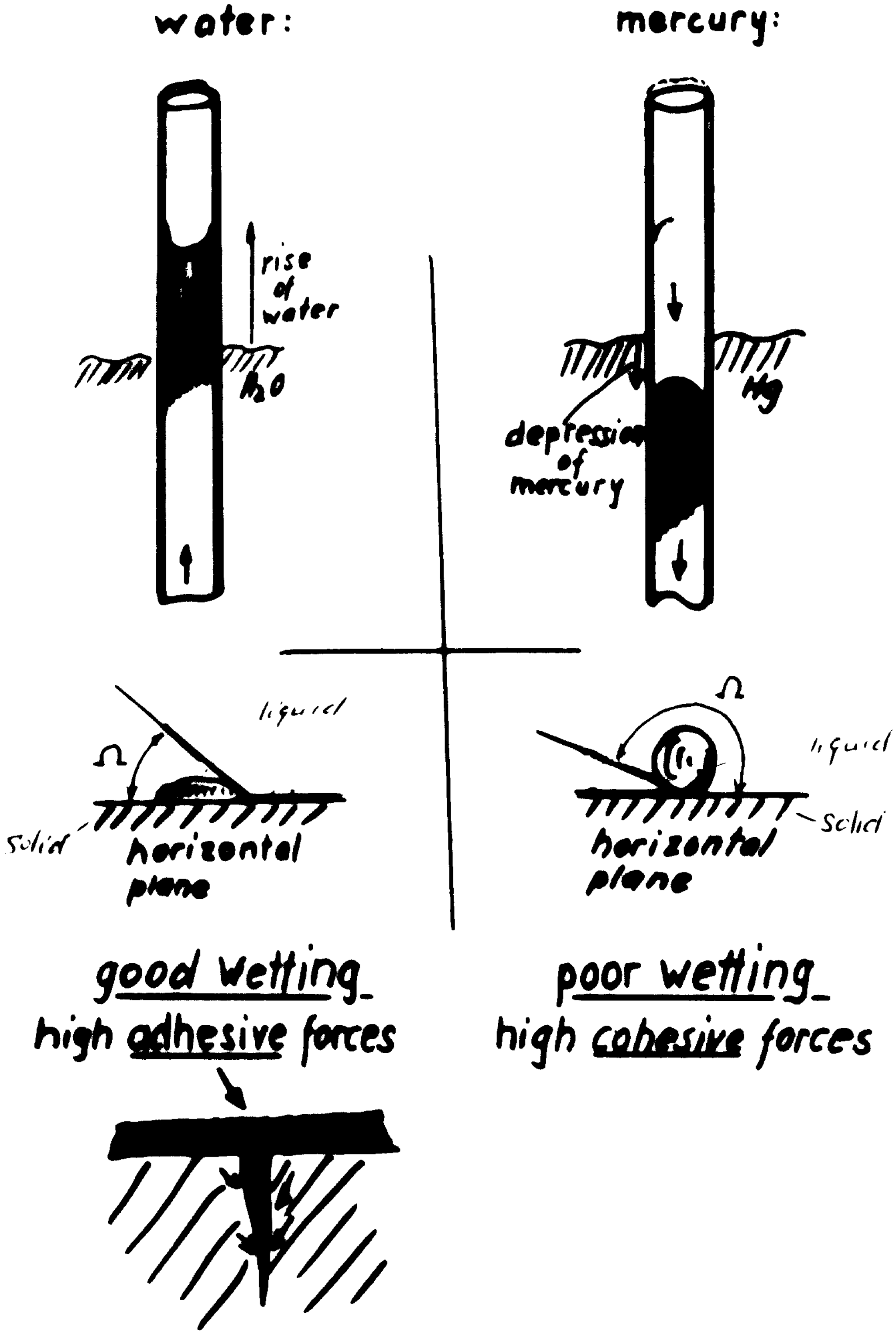


Fig. 3

6. Colour brightness.
7. Chemical stability.
8. Chemical inertness.
9. Lowest toxicity.
10. No bad odour.
11. Very low cost.

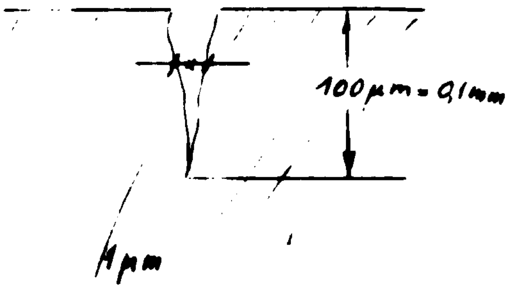
The list of requirements is long but above all PT should have very low costs.

1.1.2. Remover.

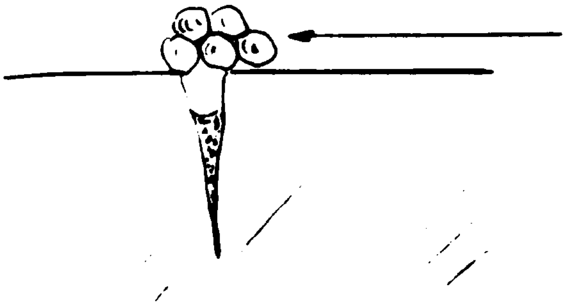
Removers are liquids for cleaning the excess of penetrant from the surface. This means the use of water in WWPT, PEPT, WWFPT and PEFPT and other solvents in SRPT and SRFPT. (For abbreviations see explanatory notes).

The problems of removers are practical ones. For this reason they are discussed later in 1.2 as are the problems of toxicity and dangerous materials.

1.1.3. Developer.

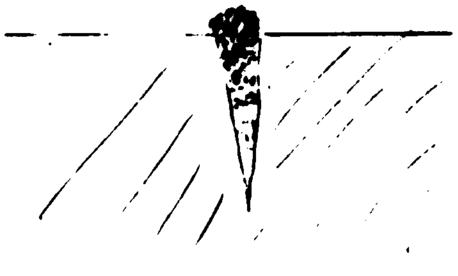


A crack 0.001 m wide (middle) and 0.1 mm deep has a plane of 0.0001 mm^2. This shows that the amount of penetrant in fine cracks is very minute.



"Large" lumps of 3 µm and more of dry developer are too big to leave in a crack of 2 µm width. Often DD powder forms lumps up to 100 µm and more during storage.

For this reason it was necessary to develop very fine powders



We now have micro-crystal powder with a grain-size from 0.1 to 0.5 µm which during long storage periods does not stick together.

Soluble developers do not have this problem. There is no solid material suspended in a liquid, but the developer is dissolved like sugar in water. There is no separation and no stratification of solids. We have water soluble developers and developers dissolved in organic liquids. The cleaning after inspection is very simple.

1.1.4. Cleaner.

For precleaning and cleaning after inspection we often need only water. Diverse organic liquids are used for the same purpose.

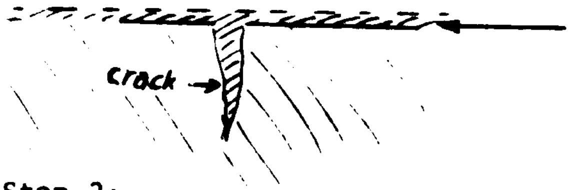
The use of dangerous and toxic liquids in general, which must be avoided, is discussed later (2.4).

1.2. Practical problems in penetrant testing

The use of PT in general is very simple, quick and cheap. But if we want to be very successful, e.g. in finding very fine cracks or other very small openings of faults on the surface of a workpiece, the performance is not so easy and the PS must be selected.

Each PS consists of at least three steps:

Step 1:



Penetrating.
(application of penetrant).

Step 2:

Removing.
(cleaning the surface only).

Step 3:

Developing.
(application of developer).

Problem: Evidently the width of the indication is not a measure of the width and depth of cracks.

Before testing we often have a big problem: "Precleaning". Well-known methods for cleaning the surface of solid, non-porous materials only are:

a) Mechanical:

1) High pressure water.
2) High pressure steam.
3) Grit blasting (steel or sand) dry.
4) Grit blasting (steel or sand) wet.
5) Tumbling with abrasive material.
6) Wire brushing.
7) Grinding (final machining).
8) Turning " "
9) Shaping " "
10) Ultrasonic cleaning.

b) Chemical:

1) Special alkali.
2) Special acid.
3) Solvent.
4) Molten salts.

The following disadvantages may give problems:

a) Mechanical cleaning by:

1) Corrosion and contamination of fine defects by water.

2) Like 1) where not all pollutants were removed, e.g., adhering cinder etc.

3) Dry grit blasting with steel shot or sand gives a hammer effect. Surface defects may be closed.

4) In addition to 3) it is possible, that the surface will be smeared with the pollutants.

5) Like 3) except using dry abrasive material; wet working like 4).

6) All contaminants are smeared into cracks and other inhomogeneities.

7, 8, 9) According to the direction of final machining cracks are "flashed".

10) Ultrasonic cleaning with solvents is often only usable after one or more of the preceding methods.

b) Chemical cleaning by:

1) Alkali sensitive materials should not be cleaned with alkali.

2) Acid sensitive materials should not be cleaned with acids.

3) Solvents often should not contain halogen or sulphur, e.g., if austenitic steels are to be cleaned.

4) This procedure can only be used for small parts. A complete cleaning afterwards with large quantities of water is indispensable as it intensifies corrosion. With solid material, cracks that are totally filled etc., are very exceptional. PT normally is successful after cleaning by a combination of the above-mentioned methods.

For the performance of PT and also for PT standards discussed later, it is necessary to define all known PS and to carry out a classification. A scheme of PTS is:

1) Water washable visible dye penetrant(s) (WWDPS).

2) Solvent removable visible dye penetrant(s) (SRDPS).

3) Post-emulsifiable visible dye penetrant(s) (PEDPS).

4) Water washable fluorescent penetrant(s) (WWFPS).

5) Solvent removable fluorescent penetrant(s) (SRFPS).

6) Post-emulsifiable fluorescent penetrant(s) (PEFPS).

7) Special Systems.

Normally, sensitivity increases in the sequence above but so also does the cost in the same manner. For economical performance it is often necessary to take the cheapest but sufficient system. The first three above-mentioned PS are well known with the name RW-methods. The systems from 4) to 6) differ from the first three in the use of fluorescent dye.

If we look more carefully at the different PS we find many problems of time:

1) Precleaning time until all remaining contaminants are removed.

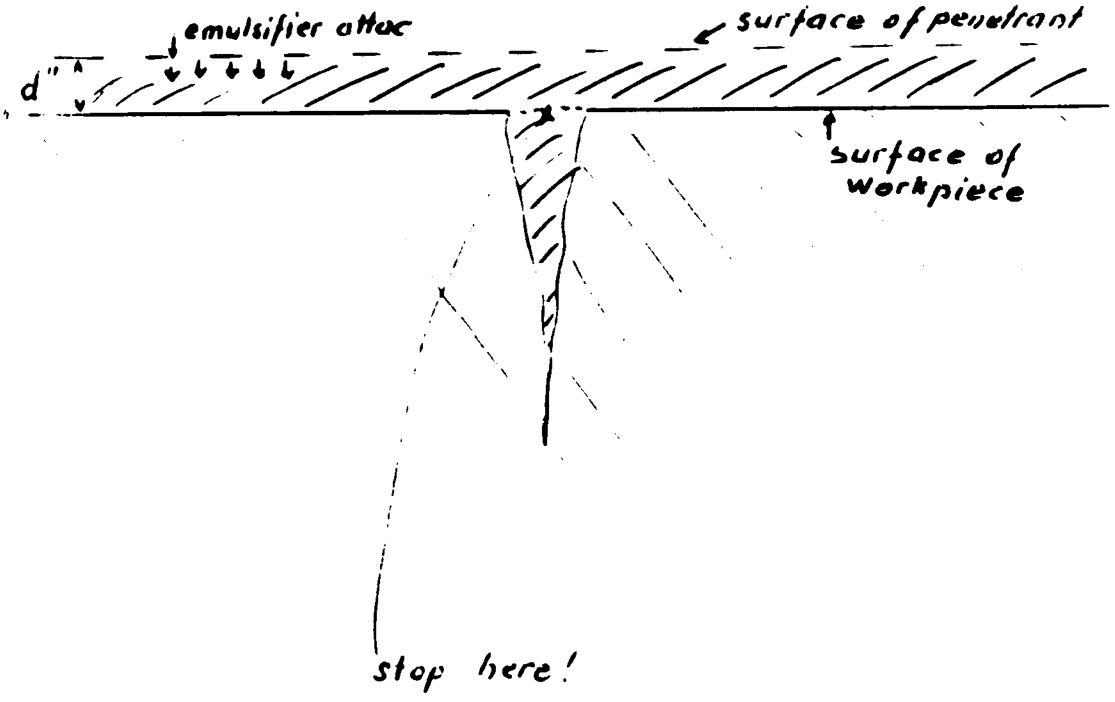
2) Penetrating time up to some hours; long enough, but time is money.

3) Removing time as short as possible. The surface clean, the defect filled with penetrant.

4) Drying time after removing should be as short as possible. Elevated temperatures are limited. Penetrant in the defect should not become dry.

5) Drying time of wet developer so short that the layer of developer left is porous and thin. Practical experience is essential.

6) Emulsifying time depends on the thickness "d" and viscosity of the emulsifier.



An emulsifier of low viscosity with a water base is quick-acting and requires several seconds only. The time must be observed very exactly.

An emulsifier of high viscosity with an oil base is slow-acting and needs several minutes.

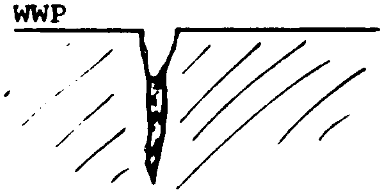
7) The shortest intermediate cleaning time conditions using fluorescent methods can be kept only by working in UV-light and in a darkroom.

8) The minimum adapting time for human eyes coming from bright white light to UV-light is 3 minutes and for observing very fine cracks up to 10 minutes in complete darkness.

9) The minimum burning time of black-light lamps from starting the lamp up to use for observation must be 3 minutes, to reach a maximum of light-energy

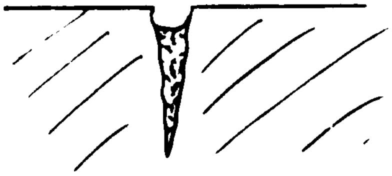
More comments on the removing problem. After removal of:

WWP



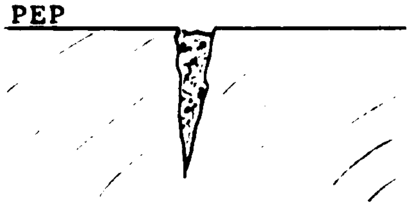
WWP, the content in defects will be removed, more or less.

SRP



SRP, the defects normally may contain some penetrant. It will be possible to have indications of shallow cracks.

PEP



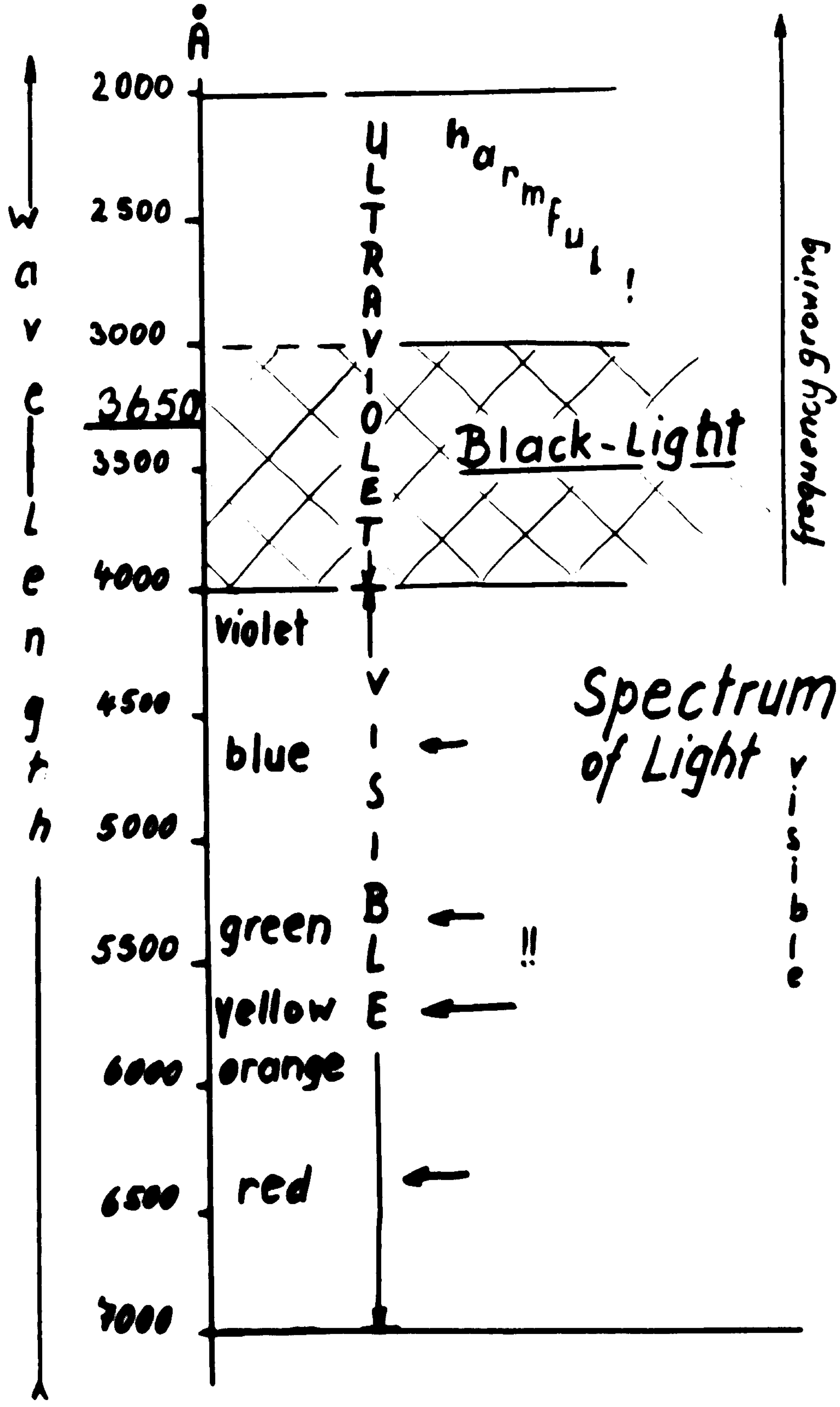
The post-emulsifiable penetrant gives the best result if the emulsifying and removing times are exactly right.

But here also the cost increase with the probability of successful testing.

1.3. Troubles with light and the human eye in PT. (See figure 4)

To understand and solve the problems of PT which result from white light, black light and the human eye, we must elaborate on the nature of light and the human eye. The spectrum of electro- (Fig.4) magnetic waves from 200 to 700 nm shows the visible part from 700 nm (red) to 400 nm (violet) and the non-visible ultraviolet part from 400 to 200 nm. The non-harmful part of UV-light from 400 to 300 nm is called "black light" in NDT practice. UV-light with wavelengths from 300 to 200 nm is very harmful for people. (Fig. 5).

Spectrum of Electro-magnetic waves:



10 Å = 1 nm

Fig. 4.

UV-radiation-- Fluorescence-radiation:

Neon tube:

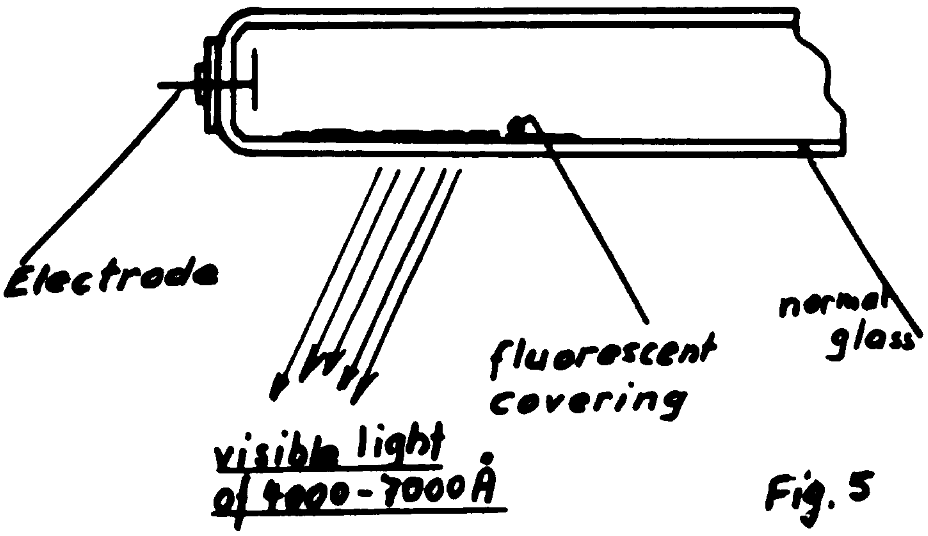


Fig. 5

Quartz-tube:

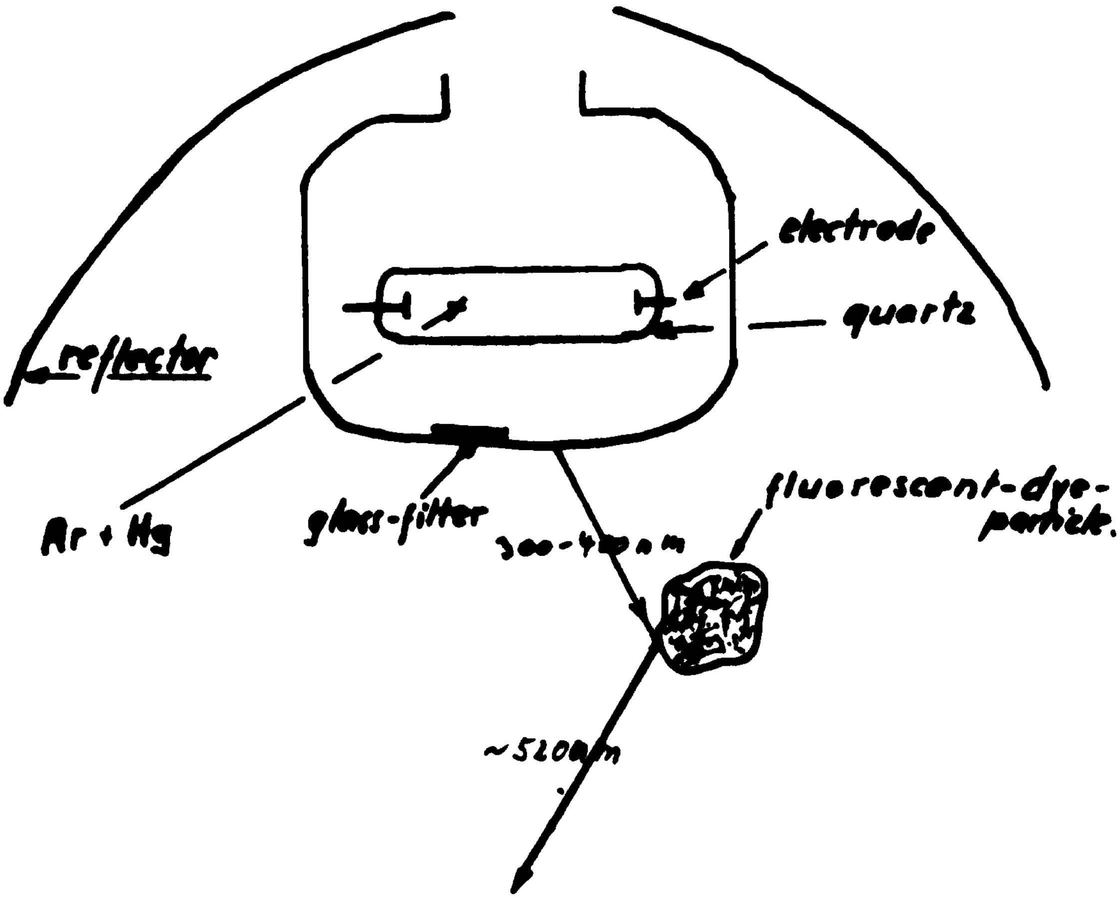


Fig. 6

The normal neon tube used for white light produces radiation with a high UV content. The UV light is transformed into visible light by a fluorescent layer on the inner surface of the glass tube. The glass tube itself stops the rest of the UV radiation. (Fig. 6).

Black light lamps for FPT should only radiate in the range of 300/400 nm. These lamps in principle consist of a quartz valve filled with an inert gas and an exactly controlled amount of mercury. The intense radiation emitted arrives at the outer glass surface with a red-purple filter which allows only radiation from 300-400 µm to pass. Hg-High-Pressure-lamps, Xe-High-Pressure lamps and Halogen metal-High-Pressure lamps are normally used. (Fig. 7).

The radiation from a mercury-high-pressure lamp ranges from 220 nm to 700 nm with a well marked peak at 365 nm. (Fig. 8).

The dense red-purple glass filter removes nearly all visible light (400 nm).

A small amount of remaining visible violet helps the inspector to see the part under test.

The filter also removes all dangerous UV-radiation below 300 nm. The transmission curve has a peak at 365 nm. (Fig. 9).

In the past it was difficult to find fluorescent dyes which transformed black light into visible light. Now we use substances and also combinations of different substances which receive radiant energy of a wavelength near UV (about 365 nm) and re-emit visible light of about 560 nm. (Fig. 10).

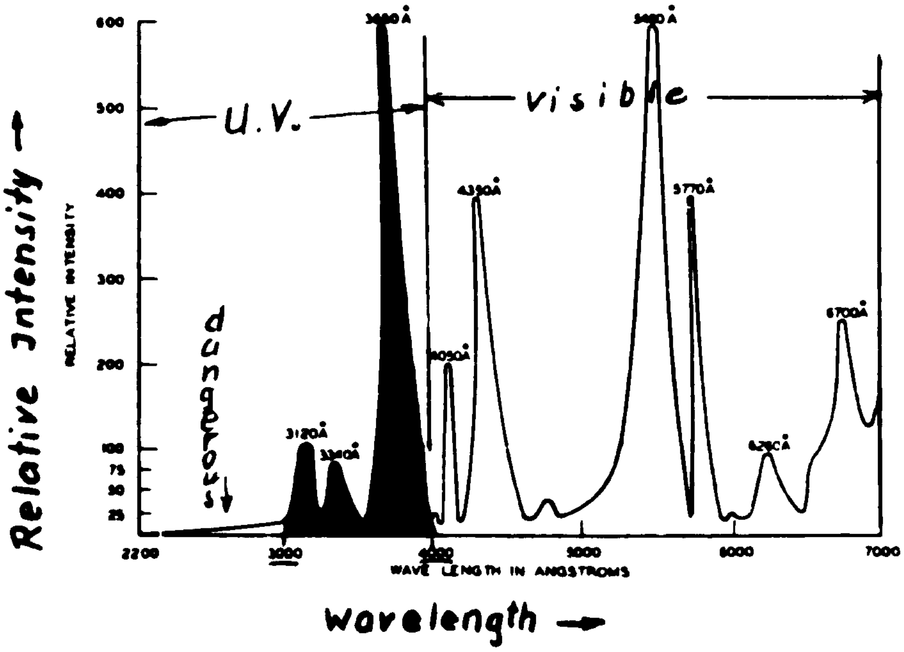
The emission spectrum of such a fluorescent dye has a peak in the yellow-green area. Now we have fluorescent dyes for all wavelengths of visible light. But we always use yellow-green fluorescent dyes for PT. Why? (Fig. 11).

We like to use yellow-green reflecting dyes because the colour response of the human eye is also a maximum in yellow-green range. Blue-green reflecting dyes are not used. Improperly cleaned surfaces reflect in the blue-green range if oil or grease are present. (Fig. 12).

Problem: What is the best illumination for the colour-contrast DPT method (red-white) and what is the best for FPT?

Our human eye is a complex mechanism. The human eye has a maximum ability to differentiate colours and degrees of contrast (curves 1 and 2) in bright white light. With decreasing illumination these properties also decrease (photopic vision). In dim light it is not possible to distinguish between small differences of colour or contrasts of colour. But there is another possibility - scotopic vision. A small, low-intensity light can be seen in dim light. In complete darkness the ability to see low-intensity,

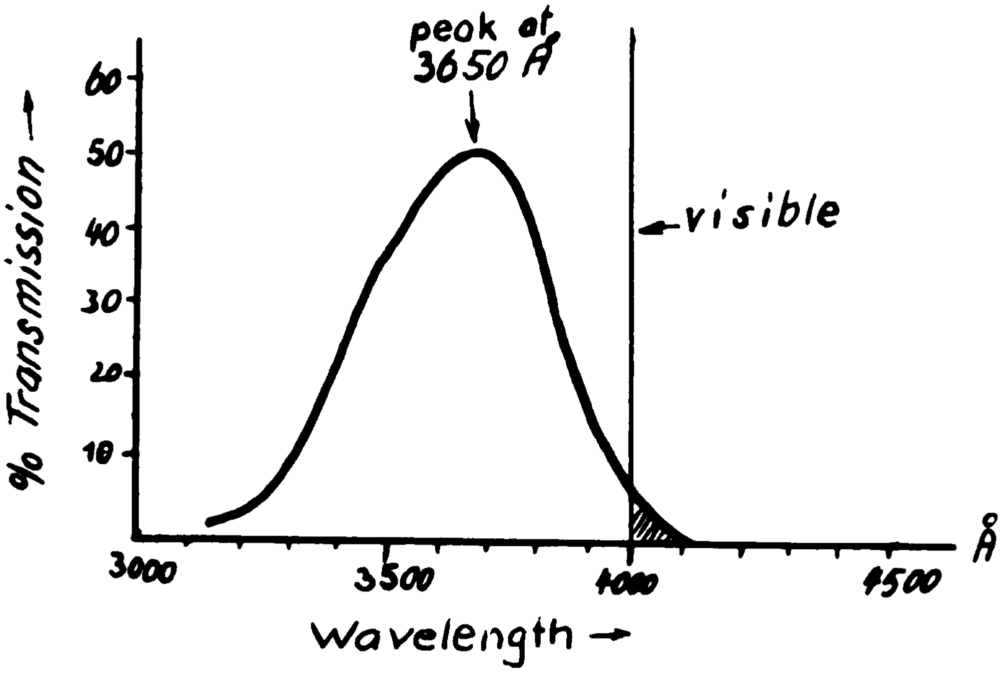
Spectrum pattern of high pressure
mercury arc



I.O.P.

Fig. 7

Transmission curve of black light glass filter



filter glass of dense red-purple colour

Fig. 8

Transformation of UV-Light (black light) to visible light by fluorescent dye

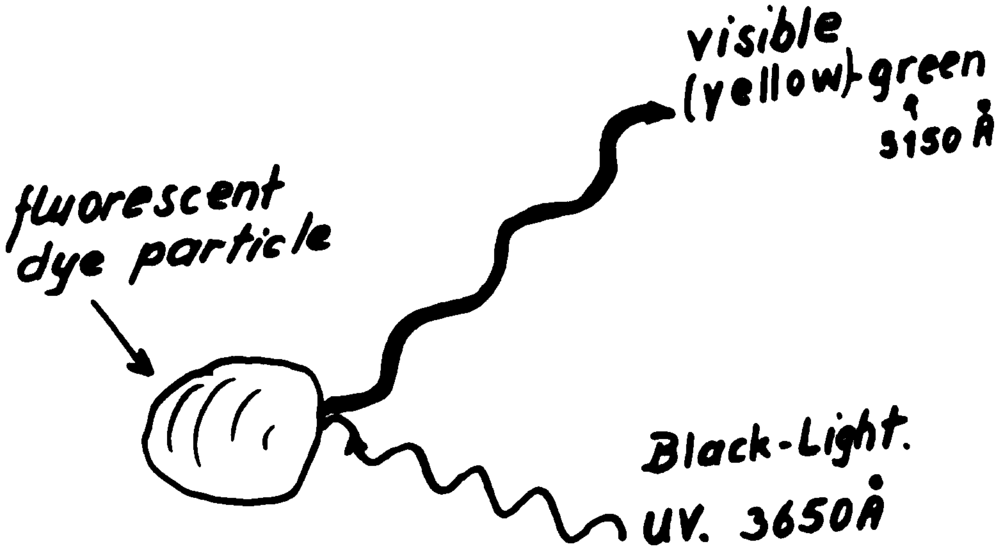
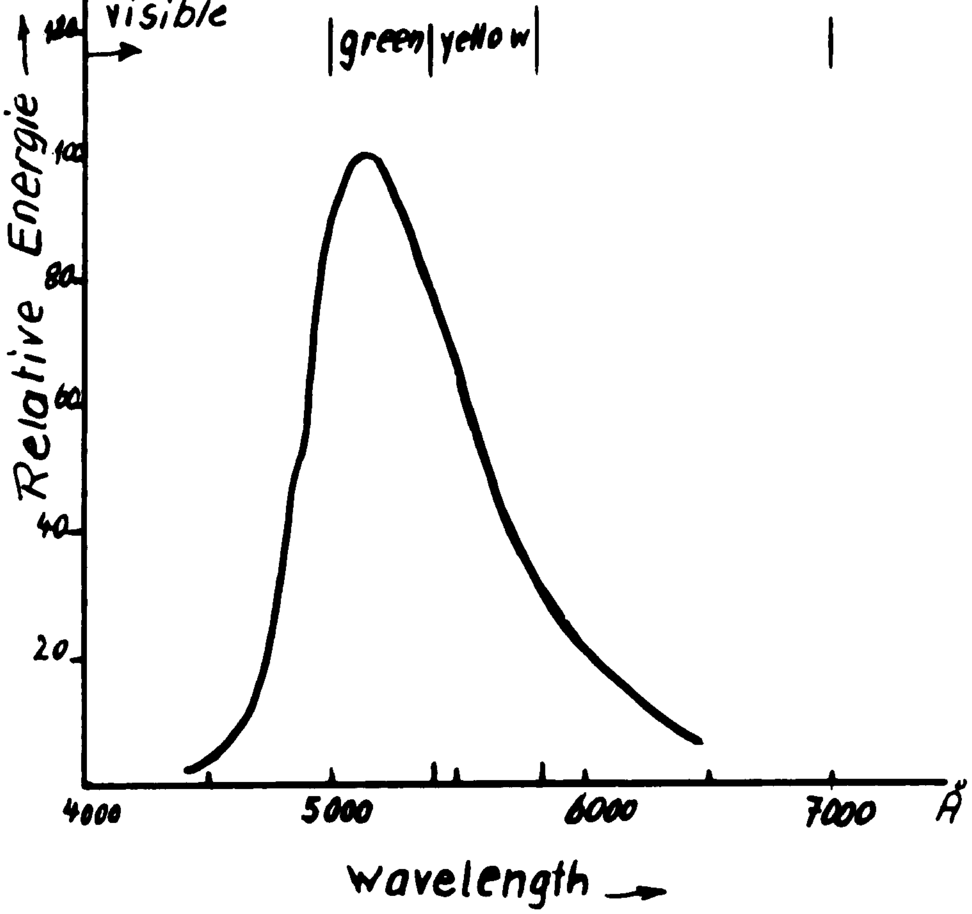


Fig. 9

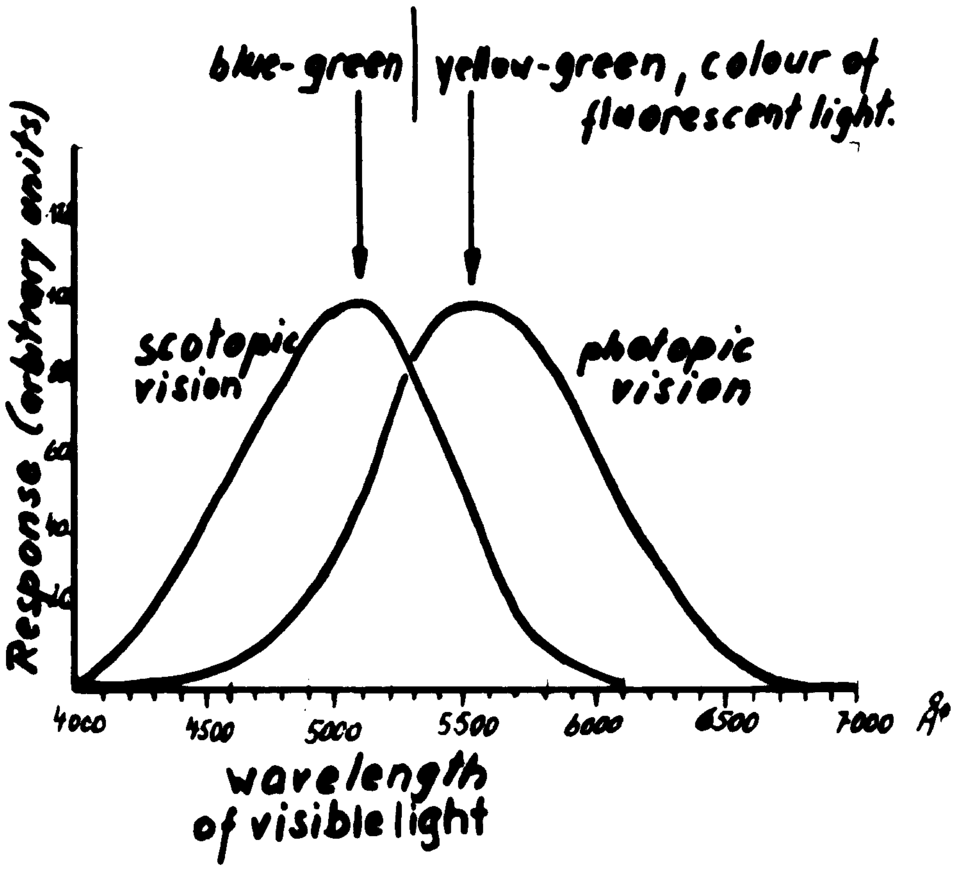
Emission spectrum of yellow-green fluorescent dye



excited with black-light of 3650 Å (365 nm)

Fig. 10

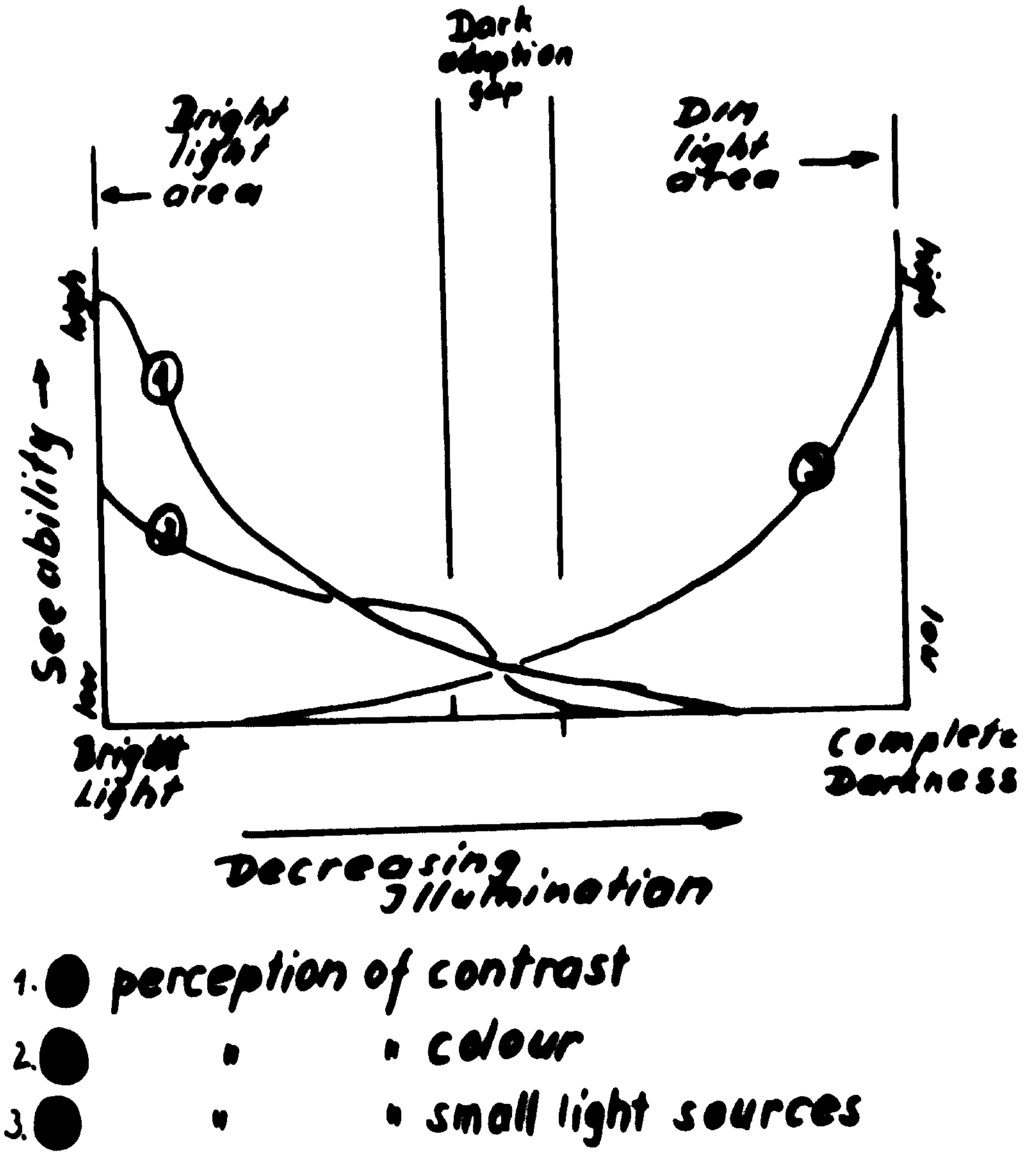
Colour response of the human eye



P.O.P.

Fig. 11

Perception of light by the human eye
(Schematic)



F. D. F.

Fig. 12

small lights has a maximum (curve 3). The possibility to observe small fluorescent indications increases because the eye is drawn to any source of light on a dark background. Also, because of the halation effect light sources appear larger than they are.

Conclusions for penetrant testing.

Use bright light for the red-white method. Red attracts the eye as we know from traffic lights where the stop sign is red. Using fluorescent methods work in very dim light (almost complete darkness). Very small cracks can be found only in complete darkness (1 um and less). Never forget the time required for the human eye to adapt in the dark. The minimum is 5 minutes. Very fine cracks can be found only after 20 minutes. (These times are flexible, depending on the individual).

1.4. Modern light equipment for PT.

The intensity of black light lamps decreases during use and from time to time it is necessary to measure the lamp's radiation intensity. (Fig. 13).

The transmission curve of a black light glass filter and the response curve of the sensitivity of a photo-voltaic cell show that it is possible to measure this with a standard light meter consisting of photo-voltaic cells and a micro-ammeter, using a special filter.

Black ray ultraviolet meters for long wave UV radiation with UV-resistant silicon photodiodes and a dye-correcting filter measurement of UV light is possible in the radiation range from 365 nm to 400 nm. With multiplier masks they measurement areas can be changed (e.g. from 0 to 2500 µW/cm^2 and from 0 to 10000 uW/cm^2). The deviation of modern measuring tools is about ± 2.5%.

Problem: What is the minimum candle power required on the test piece?

In the German Standard DIN 54152, part 1 (see English translation in annex III) paragraph 4.6.2.1 states that a minimum candle power of 70 lx is required (measured according to ISO-3059).

Paragraph 4.6.2.2 states that dye penetrants (red-white) in artificial light require a minimum of 500 lx.

This corresponds to the candle power of an 80 Watt vacuum tube lamp at a distance of 1 m.

Problem: At what distance do normal 100 W and 400 W black light lamps give this candle power?

(Fig. 15).

Transmission curve of black-light filter glass and response curve of photo-voltaic cell:

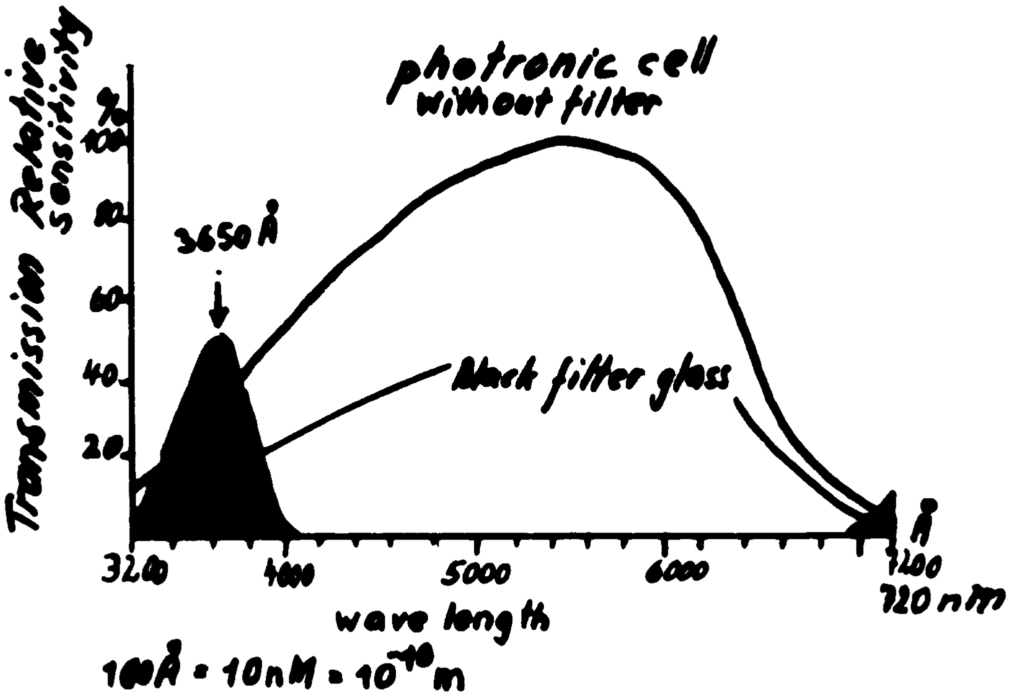
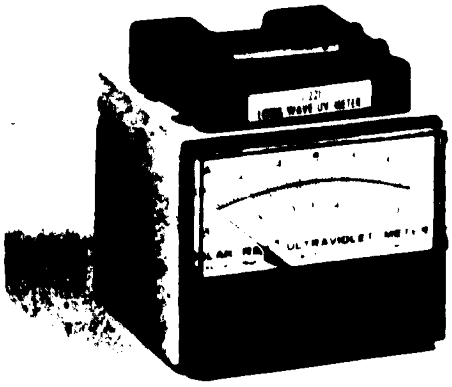


Fig. 13



Black-Ray -

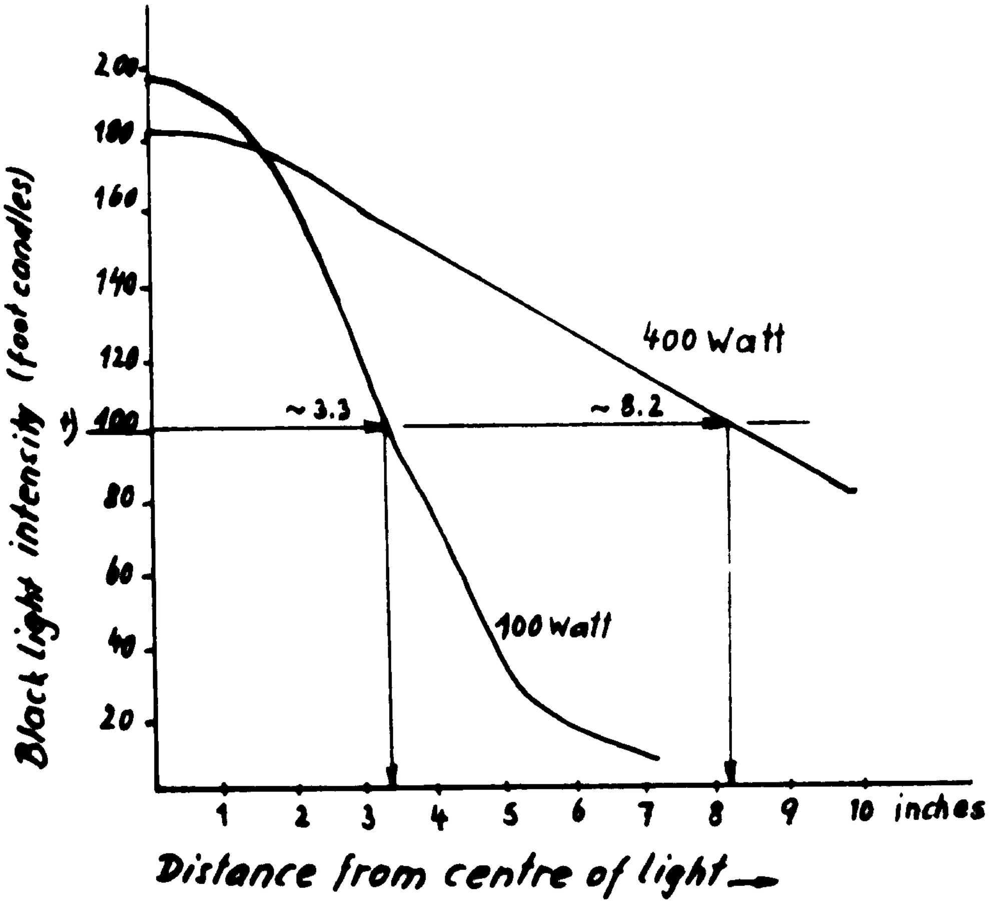
Ultraviolet - Meter

Long wave UV-Meter

$\mu W/cm^2 \times 100$

Fig. 14.

Distribution of black light from 100 Watt and 400 Watt lamps in a distance of 15 inches (38 cm) from the work-table.



*) minimum of black-light intensity at the point of inspection: (white light excludet!) 100 foot candles (double at centre)

1" = 2.5399978 cm

3.3 × 2.54 ≈ 8,4 cm

8.2 × 2.54 ≈ 20.8 cm

100 Watt lamp: circle of ≈ 17 cm

400 Watt lamp: circle of ≈ 42 cm

in a distance of = 38 cm from the lamp

Fig. 15

The relation between black light intensity (foot candles $\mu W/cm^2$) and distance from a light-centre whows that the 100 W-UV-lar has 500 $\mu W/cm^2$ at a distance of 11 cm from the light centre. A 400 W lamp has a candle power of 500 $\mu W/cm^2$ at a distance of 30 cm from the light centre. (Fig. 16).

A 100 W-UV-lamp has 500 $\mu W/cm^2$ on the periphery of a circle with a diameter of 20 cm at a distance of about 40 cm from the light source. At the centre of this circle there is a light intensity of about 1600 $\mu W/cm^2$ (200 f.c.).

The corresponding data for the 400 W-UV-lamp is:

At a distance of 40 cm, circle of 55 cm diameter; 1500 $\mu W/cm^2$ in the centre. As a consequence, when working with new UV-lamps, one should work with a portable 100 W-UV-lamp at a maximum distance of 40 cm and inspect only an area of 20 cm diameter.

The corresponding data for the 400 W lamp is: distance of 40 cm, 55 cm diameter.

Fig. 17 is the conversion-curve from foot candles to the new unit $\mu W/cm^2$. Because the output of black light intensity of lamps decreases during their lifetime to 25% of that of a new lamp, it is necessary to check them periodically.

Problem: How to measure the transmitted fluorescent light intensity?

We have already described how to measure UV-light directly.(Fig.18 The radiation of a fluorescent screen can also be measured with photo-voltaic cells. The fluorescent screen can be made of poly-styrol-bound fluorescent dye on a plate covered with a limp polyester film. The data d_1, d_2, r_1, and r_2 must be standardised. Measurements are not possible in daylight. With multiplier masks we can measure a wide range of intensity.

Last but not least it is absolutely necessary that the inspector has the best visual faculties especially for seeing isochromatic light. Pay attention also to the above-mentioned properties of the human eye. The best distance for the inspection of fine cracks is reading distance.

Problem: The heat from lamps bothers the operator.

(Fig. 19).

We pass electrical energy (100%) to a fluorescent or quartz lamp. Nearly 23% of this is used to heat the electrodes, about 25% of the heat from discharges in the ray tube and about 30% of the heat UV-radiation becomes infrared heat radiation.

Result: 78% of the input of electrical energy becomes heat.

(Fig. 20).

Distribution of black-light.

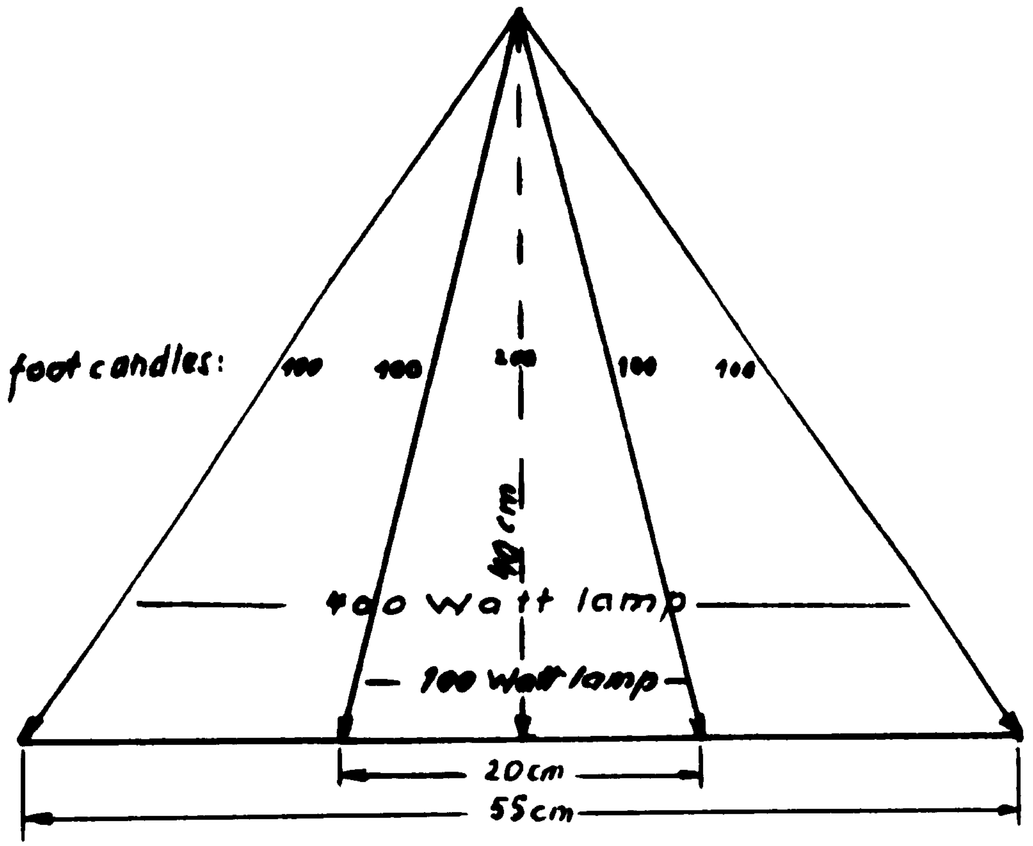
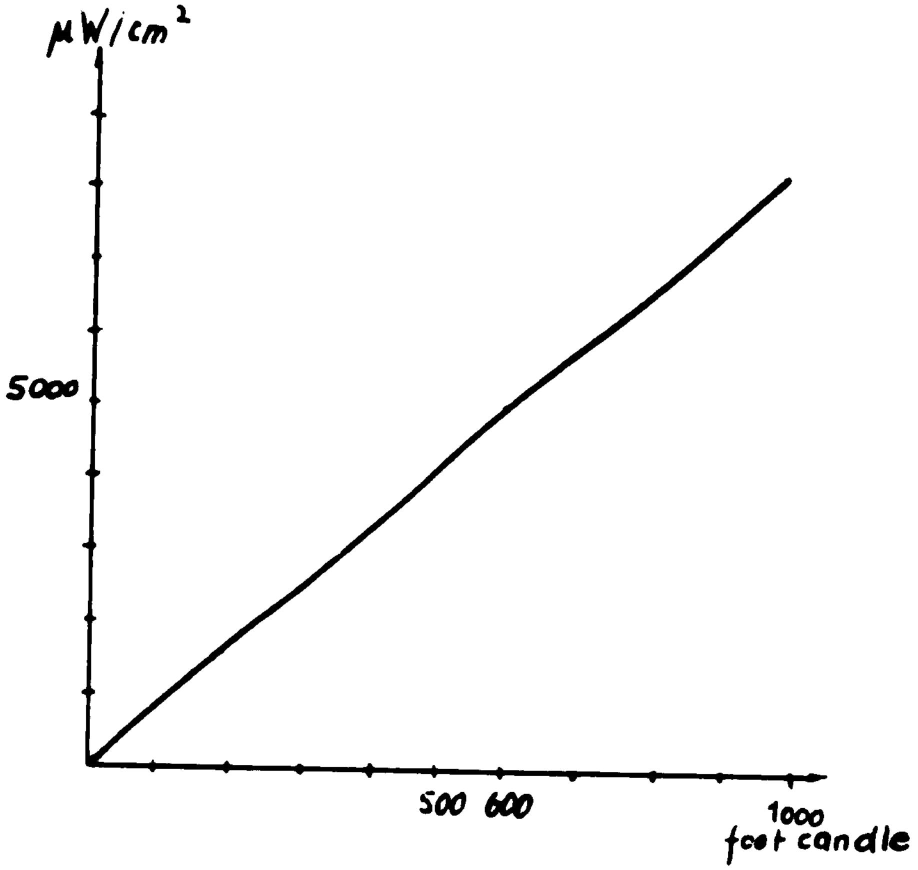


Fig. 16

Conversion curve

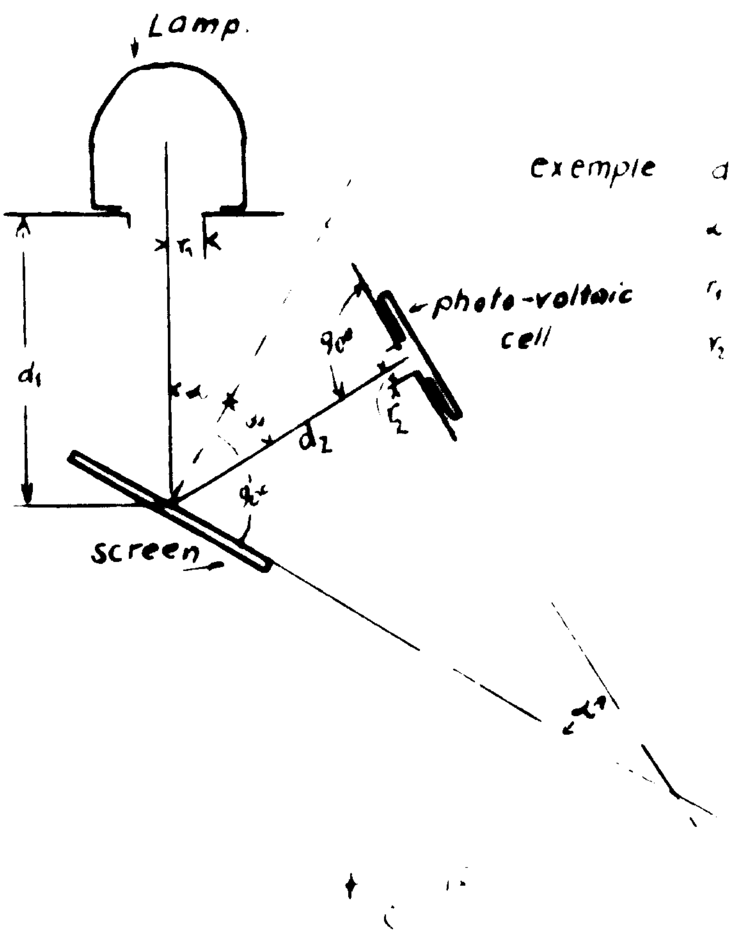
foot candle – $\mu W/cm^2$



$100\,\mu W/cm^2 = 12$ footcandle

Fig. 17

Indirect measuring tool for UV-light.



exemple $d_1 = d_2 = 40\,cm$

$\alpha = 30°$

$r_1 = 10\,cm$

$r_2 = 2\,cm$

Radiation of a fluorescent-lamp and a quartz-lamp:

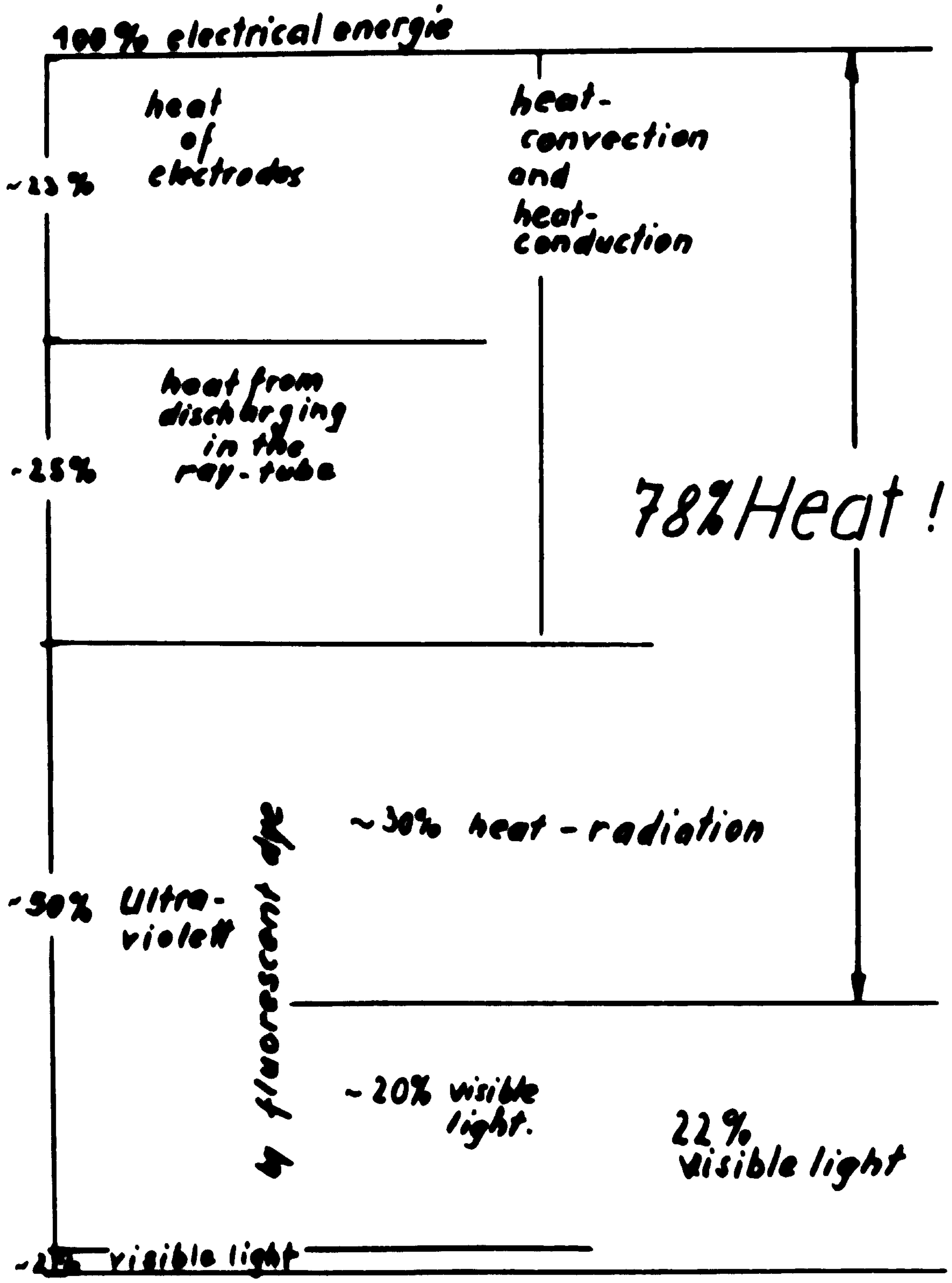
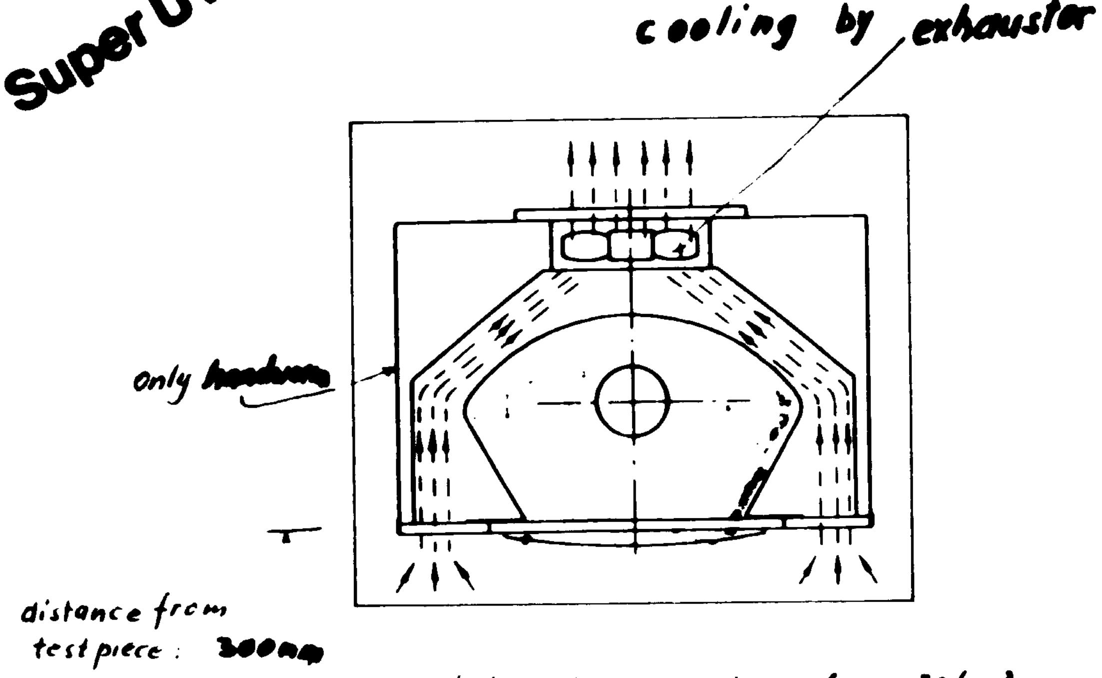


Fig. 19

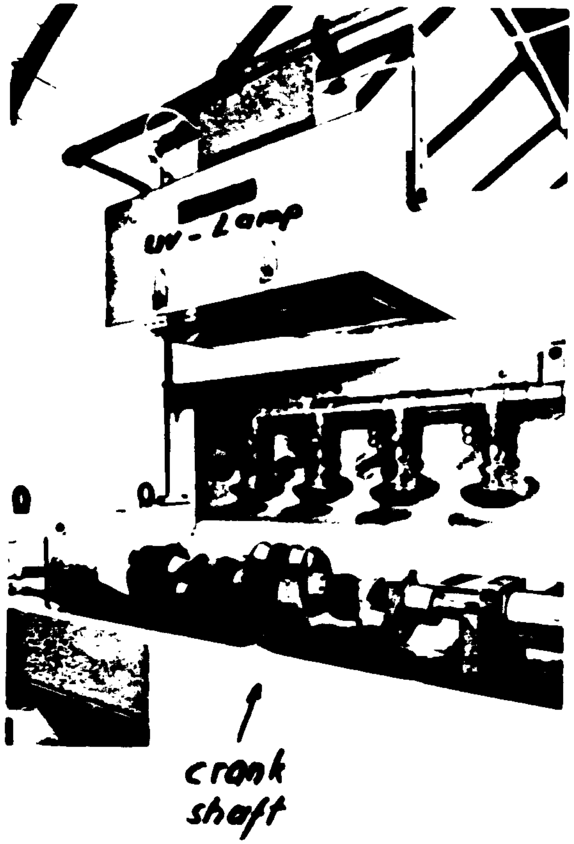
Fig. 20

Super UV Special Lamp 400 W



intensity of radiation: 4200μW/cm²

Fig. 20.



Therefore it was a good idea to cool the big stationary 400 Watt lamps with an air fan. Lamps of this kind have an intensity of radiation up to 4200 $\mu W/cm^2$ at a distance of 30 cm from the object to be tested and the surface of the lamp is handwarm.

Problem: How to make colour-photos of PT-indications?

The best colour photos of PT-indications are obtained by underexposing the part and the background with white light and exposing well the faults in black light. Therefore it is necessary to make a series of exposures in black and also white light in order to find the best exposure times.

These exposures cannot be made at the same time because it is necessary to place a special filter over the lens when working with black light. A light meter measurement is necessary if we wish to take more photos of different parts. Different photo floods of 400 W and spot lights of 100 W arranged in different distances and angles have to be used to find the best positions for the best illumination.

The photographic documentation of defects can be made by colour reversal film ASA50

1.5. Special PT-system with radioactive Isotopes.

The radioactivity from isotopes is sometimes used for PT e.g., an alcoholic solution of 10% CsCl with the radioactive isotope Caesium-137. After dipping or spraying (caution!), the surface should be cleaned by using dry methods. An γ-ray paper or film in a black wrapping placed on the area to be tested gets radiation from the defects which are filled with radioactive material. After a certain exposure time the developed film will show a copy of the defects. This is also a document. Cracks of less than 1 μm wide can be found.

Cleaning with the same solvent after inspection must be done very carefully, because the radioactive material must be removed out of the defects or the contaminated, non-recoverable parts must be preserved in a storage area. The half-life of Cs-137 is 33 years, which is long.

It would be better to use isotopes with a shorter half-life, but the problem is that they must be soluble in a usable solvent.

2. Visits to steel works and machine factories

2.1. Advice on practical applications of DPF techniques.

One factory in the food-industry had a filling plant for different juices and Coca Cola. The filling plant was manufactured of stainless steel (18/8) welded in several places by hand and machine. (Fig. 21). The welds were porous and leaking but the leaks were very small. Coca Cola passed through the pipe pores so slowly that it was impossible to see where the leaks

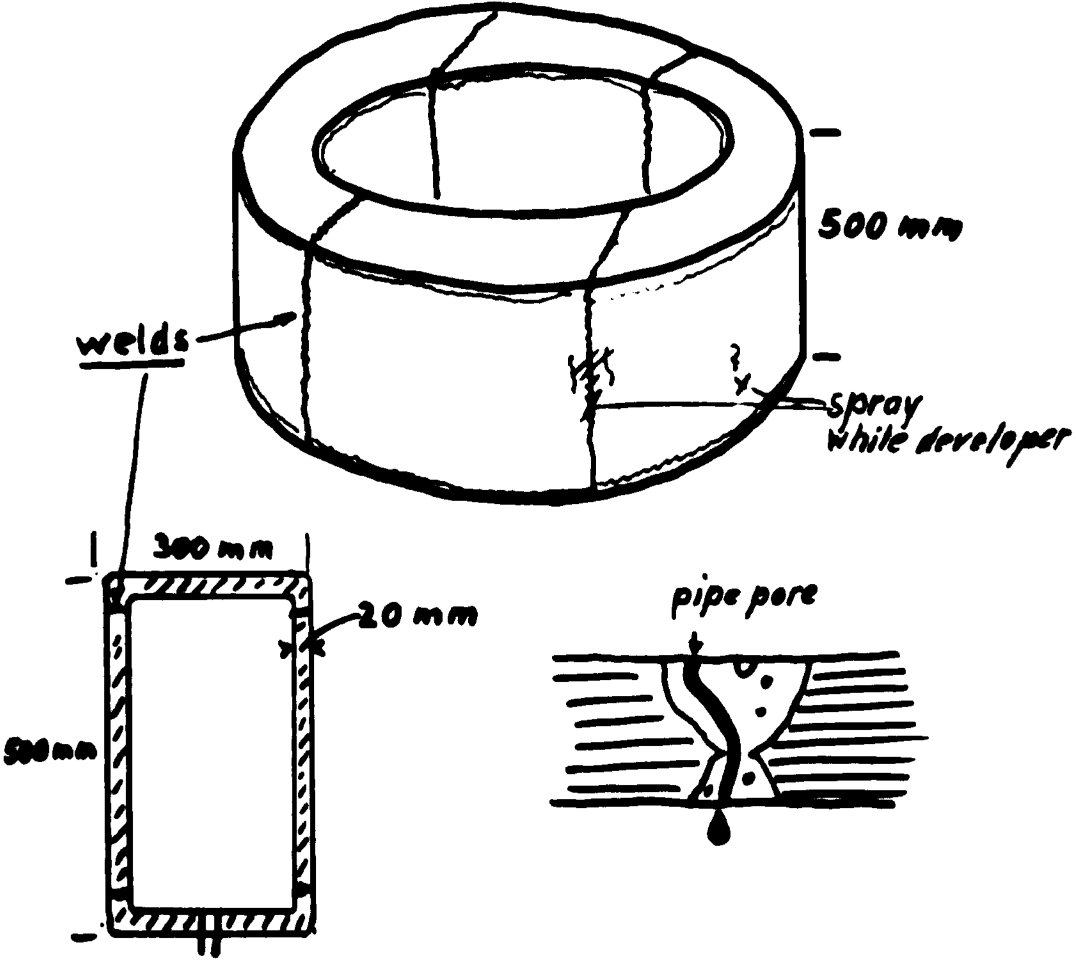
Coca-Cola

or

Cherry-juice

for Penetrant.

feed device for bottles



compare with „list of requirements of liquid penetrant."

stainless-steel: 18/8

drying of electrodes or powder

Fig. 21

were, but the surface was always soiled. This is against the food and sanitary rules because microbes come into these leaks and sufficient cleaning was impossible. To find all the leaks I proposed a good cleaning of the outside of the filling plant and spraying the welded areas with a good wet developer. Coca Cola would be a good penetrant or, if a better contrast should be needed, the test should be made at the time when cherry juice was bottled. After a certain time the finest defect gives a good visible indication. If marked the defects could be repaired by welding during the next shut-down of the plant. Coca Cola seems to be a good penetrant, cherry juice too!

Another firm wished to test porous austenitic fittings, especially valves and other connections and housings, by PT. But in this case PT is a dirty method. The cleaning after testing is very time-consuming and expensive. Gas leak testing with water and a detergent was a better practical solution and, if compressed air were used, no cleaning after testing and inspection is necessary. Leaks will be indicated by bubbles. After a certain time also very small leaks can be found.

To investigate defects in the motor industry, PT was supposed to be used. The complicated cast motor parts were dipped into the penetrant bath, but the factory only looked for fine cracks in the region of the small steel strips cast in the aluminium alloy of the motor block. Defects of this kind were found during the use of these motors. Therefore it was not profitable to test the whole part. It was sufficient to spray only the area of the parts with probable cracks with an FP and after removing the excess of FP on the surface by dry paper the finest cracks could be seen in a darkroom after adapting the eyes, without any developing.

A cheaper method more quickly done!

In another case of defects in big cast parts of cantilevers, PT produced big plane indications characteristic of big pores. Magnetic Particle Testing on the contrary, showed exact indications of cracks without interference from the big pores. This is a good example of the combined use of different NDT methods which is completely effective.

Another firm had to test painted steel constructions. It seemed to be very difficult to find cracks under the paint of big steel parts. The paint was not soluble in solvents, but the coat of paint could be removed by burning down and cleaning the surface. The remaining burnt paint in the pores and cracks did not make the PT more difficult because the porous remainder of the paint in the surface defects was retaining the penetrant during removal of the excess penetrant from the surface. After developing, the defects were very clearly visible using the simple RW method.

2.2. Discussion of results and economic controls in production.

Often (especially in the construction of nuclear power plants) all NDT testing methods are required for one single part and this implies high costs. It is necessary therefore to make manufacturers, employers and supervisers also aware of the economic aspects of testing, although security should be the first consideration. Easy, cheap testing methods like PT are requested although other NDT methods used on the same part can find the same defects. On the other hand, PT often could be used instead of more expensive and time-consuming NDT methods, if the latter do not give substantial benefits. The few cases in 2.1. give examples of economic testing without any loss of security. This theme was explained clearly and repeatedly to the people in the factories visited.

2.3. Facilities for the elimination and avoidance of harmful Defects.

NDT tests and also destructive tests are necessary to clear up faults in industrial products, to avoid these faults in the future and get the best quality and economic results in production. One of the firms visited showed us many machines, [illegible] some for hardness testing developed and manufactured by themselves. During the whole production different NDT and DT tests are made and all results are marked in a check list. The quality of all the welded parts was the best. They worked with German DIN but they also take orders according to ASTM etc. The testing machines in the laboratory came from different European countries, both East and West, and also from the USA. They have developed an ink for PT but there are not sufficient test pieces to compare the intensity with that of established firms in Europe and the USA. In part 3 of this report the efforts we made in INEND to find standards for PT materials are discussed as are PT performance and PT test pieces.

It was often stated that it was very expensive to work with small spray boxes for penetrants, solvents and developers. They had to test a large number of parts and I pointed out that they also had to work with an ozone-destroying carrier gas and contaminated themselves and the environment. This can be avoided by modern spray guns using compressed air from 6 up to 15 atm. They have a content of 1 l or smaller and are replenishable. A more convenient equipment is composed of a turbine blower, a universal electric current motor and a dust-proof spray gun.

This transportable equipment can work in all places where electric current exists, but all of these spraying instruments produce some dust. This means a health hazard and a loss of money! Electrostatic guns are developed especially for this purpose and their advantages are that they give an equal thickness of liquid or solid test material on the surface of parts to be tested, small use and short execution times. The disadvantage is that this equipment is more stationary.

2.4. Security rules/symbols and danger signs.

The toxicity of all materials used for penetrant testing is a special problem. In the Federal Republic of Germany there is a regulation from 1971 called "Regulations concerning dangerous substances. This has to be obeyed since 1 January 1972. There are for instance limits for using benzol, tetrachlorcarbon and pentachlorethylene. People who work with substances with a content of more than 1% of the above-mentioned dangerous substances have to be examined by a medical officer of health every half year. In former times it was believed that milk would offer protection against damage to health from radiation and from dangerous liquids and gases, but this is not so because the fats in milk are soluble in chlorhydrocarbon and that causes an accelerated and elevated absorption of the toxin. Also by the inhalation of these toxic gases with tobacco-smoke toxic products of dissociation of chlorhydrocarbon can be produced. Manufacturers of penetrants and other materials for PT now try to use less dangerous substances to protect the health of operators. Typical substances used are trichlorethylen, perchlorethylen, methylchloroform, methylenchlorid and dichlorethylen. The manufacturers of dangerous products are obliged to put prescribed and standard symbols and signs on bottles, cans, containers, packages, etc., with a defined size, with the visible symbols for danger printed in black on a yellow-orange background so that operators are always aware of danger. For Argentina I believe it could be important to mention that this rule was the result of many years of work of a committee for dangerous substances, founded by the Secretary of State for Work and Social Order. The members of this committee are:

3 representatives of manufacturers of dangerous materials,
1 representative of trade factories of dangerous materials,
3 representatives of factories working with dangerous materials,
1 representative of NORM Committee (DIN),
1 representative employer association.
1 representative industry association,
2 representatives trade union,
2 representatives science,
4 representatives protection of workers administrative body and two medical men from industry.

It is necessary for all interested commercial or social corporations to particioate in committees of this kind.

3. Standards for penetrant testing

Standardization concerning PT can be divided into three sections:

A. Testing of samples of a PT system under the authority of the State. State registered, the manufacturer receiving a certificate.

B. Testing of products made by the manufacturer and comparison with the results of the state-registered sample.

C. Routine controls by the user of PT materials.

3.1. Standardization of materials used in PT.

In the German DIN 54152, part 2, January 1977, we find the following tests to ascertain the quality of PT materials:

1. Sensitivity test of penetrant systems.
2. Testing of penetrants:

2.1. Tests for physical and chemical properties:
2.1.1. Density.
2.1.2. Viscosity.
2.1.3. Surface tension.
2.1.4. Flash point.
2.1.5. Water content.
2.1.6. Halogen content.
2.1.7. Sulphur content.
2.1.8. Free acid content.
2.1.9. Free base content.
2.2. Technical evaluation tests:
2.2.1. Dye quality by spectrophotometer.
2.2.2. Stability of red dye in halogen vapour lamp.
2.2.3. Stability of fluorescent dye in halogen vapour lamp.
2.2.4. Stability of fluorescent dye under black light.
2.2.5. Stability of red dye to elevated temperature.
2.2.6. Stability of fluorescent dye to elevated temperatures.
2.2.7. Stability of red dye to subzero temperatures.
2.2.8. Stability of fluorescent dye to subzero temperatures.
2.2.9. Resistance against change of temperature.
2.2.10. Tolerance of waterwash penetrants to contamination with water.
2.2.11. Water washability of post-emulsification penetrants.
2.2.12. Storage ability in open cases.
2.2.13. Storage ability in closed containers.
2.2.14. Water contamination test.

3. Testing of intermediate cleaners (removers).

3.1. (1-7) Solvents (tests: 2.1.1; 2.1.4; 2.2.11; 2.1.6; 2.1.7; 2.1.8; 2.1.9).
3.1. (1-6) Emulsifiers (2.1.1; 2.1.2; 2.1.6 to 2.1.9).
3.2.7. Capacity for absorbing water and penetrants.
3.3. Storage ability in closed original containers (after storing: 2.1.1; 2.1.2; from 2.1.6 to 2.1.9; 3.1.7).

4. <u>Testing of developers:</u>

4.1. Dry developer:

4.1.1. Density of grains.

4.1.2. Grain size distribution.

4.1.3. Grain form.

4.1.4. Specific surface.

4.2. Wet developers:

4.2.1. Density of grains of dry substance.

4.2.2. Grain size distribution of dry substance.

4.2.3. Grain form of dry substance.

4.2.4. Specific surface of dry substance.

4.2.5. Density of carrying liquid.

4.2.6. Flash point of carrying liquid.

4.2.7. Part of dry substance.

4.2.8. Deposit volume.

4.2.9. Corrosion test.

4.2.10. Contaminating.

4.2.11. Storage ability in closed containers.

5. <u>Testing of solvents:</u>

5.1. Molecular weight (chemical formula).

5.2. Density.

5.3. Viscosity.

5.4. Surface tension.

5.5. Flash point.

5.6. Boiling point.

5.7. Ignitable limits of gaseous solvent in air.

5.8. Security rules satisfied.

5.9. Degrees of dangerous substances satisfied (toxicity).

All these single tests must also be standardized.

For testing samples of products made by manufacturers of PT materials by the national institute, all the tests described are used. The tests made by the manufacturer can be reduced to these tests, which are absolutely necessary to determine the quality as for the sample tested by the national institute. The user of PT material can make the same tests of the manufacturer with stored materials. He must test the intensity of the penetrant system used in short periods of time, perhaps every morning. For this it is essential to have a test piece specifically for this purpose. Such a test piece was developed and is described later.

3.2. Standards for the performance of PTS.

Before developing standards for the performance of PT, it is necessary to define the different PTS as described in 1.2. The most expensive system is not always the best. Many experiments and much consideration are often necessary to find the most economical PTS.

The standard for the performance of PTS therefore can only define how to perform the different steps. The German DIN 54152 allows the possibility of 30 standard procedures using only 3 letters. For each step the exact performance is defined and at the end there is an example of a blank form for a test report. An English translation of part 1 of this standard is given in annex III. It is not an official translation. Figure 2 is a scheme outlining all the possibilities for the performance of DIN 54152.

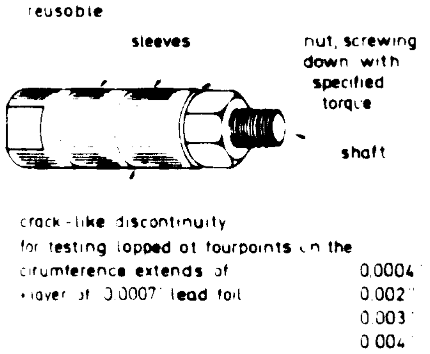
Behind the scheme there is an underlying consideration. The operating inspector found parts with defects, but the rejection and acceptance of parts should be permitted only by persons who know exactly the conditions of service of the machine parts, perhaps assisted by an experienced national supervisor.

A portion of the rejected pieces may be repaired and later accepted. The rest must be discussed with the manufacturer to find the cause of the damage and to avoid this in future. The user of these parts may also make a claim against the manufacturer.

3.3. Development and production of PT pieces.

3.3.1. Discussion of standard test pieces.

Standards for testing the intensity of PTS are indispensable and have existed for a long time, but there is no single test piece for all methods. The intensity of a PTS depends on many factors, e.g., on the material to be tested. Many different test pieces are proposed: The United States Navy test block consists of a bolt and two sleeves. Between the lapped sides of the sleeves at four points on the circumference are extends of 0.0004" (0.01 mm), 0.0002" (0.05 mm), (0.05 mm), 0.003" (0.08 mm) and 0.004" (0.1 mm). The nut of the bolt can be screwed down with a specified torque.



A test block made by this method with a controlled width has not the roughness of natural cracks

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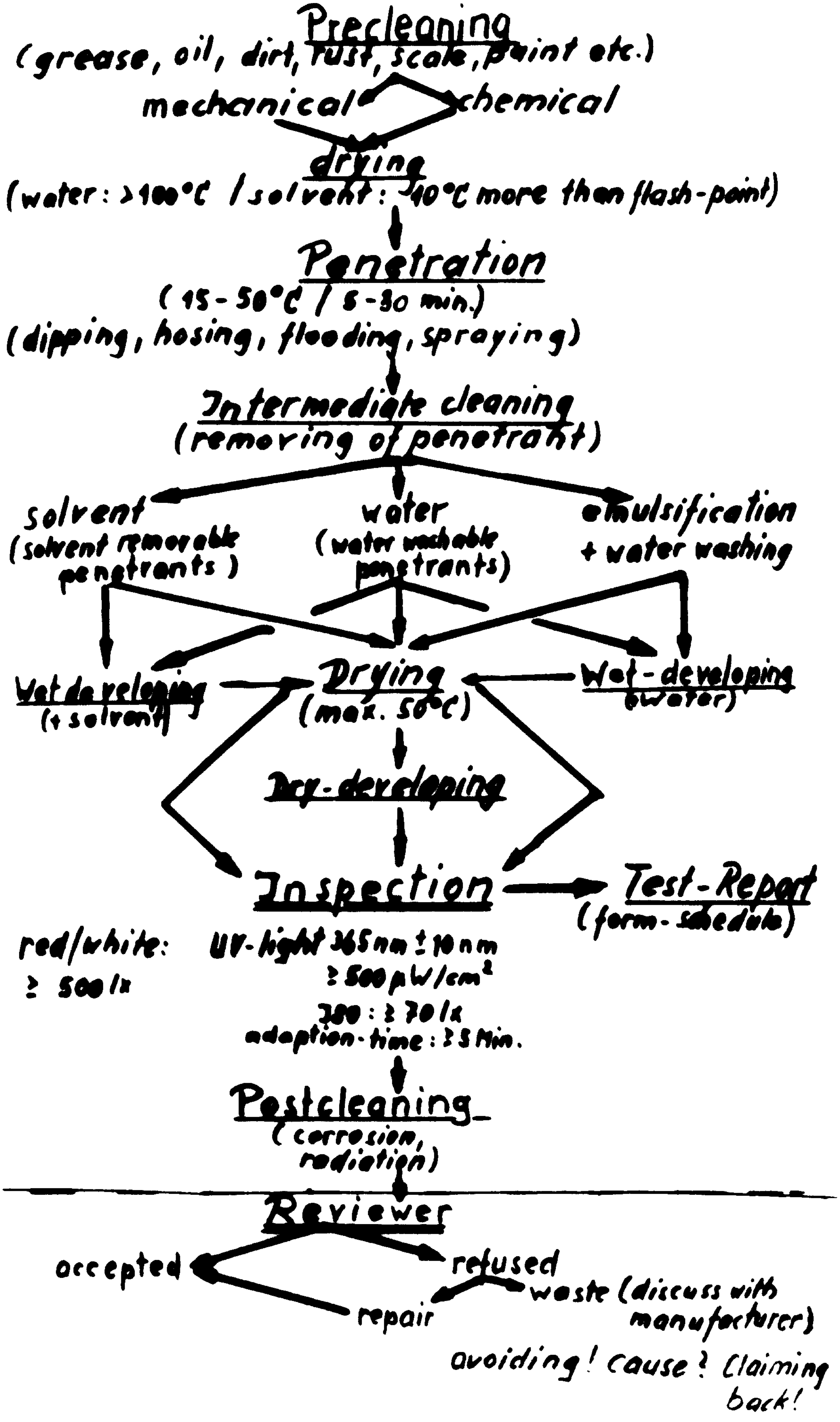
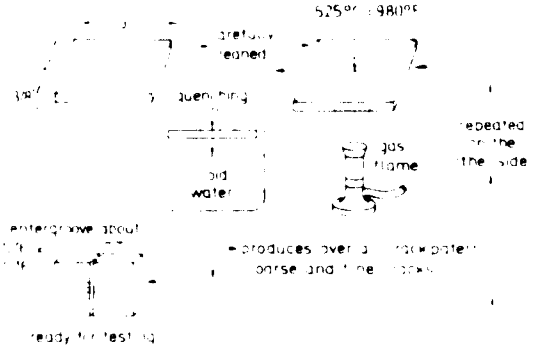
Source: (R.W. Miller, Welding Journal, Jan., 1958 p. 30).

DIN 54152 (Draft December 1976)

Performance:

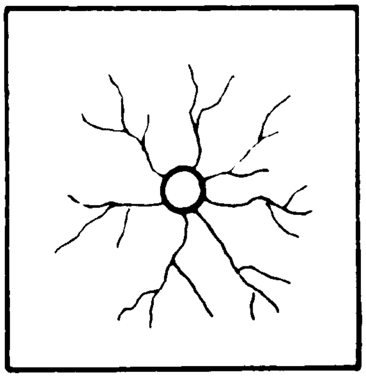


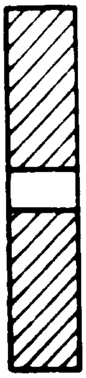
but it produces crack-like discontinuities usable for comparing different charges of PTS.



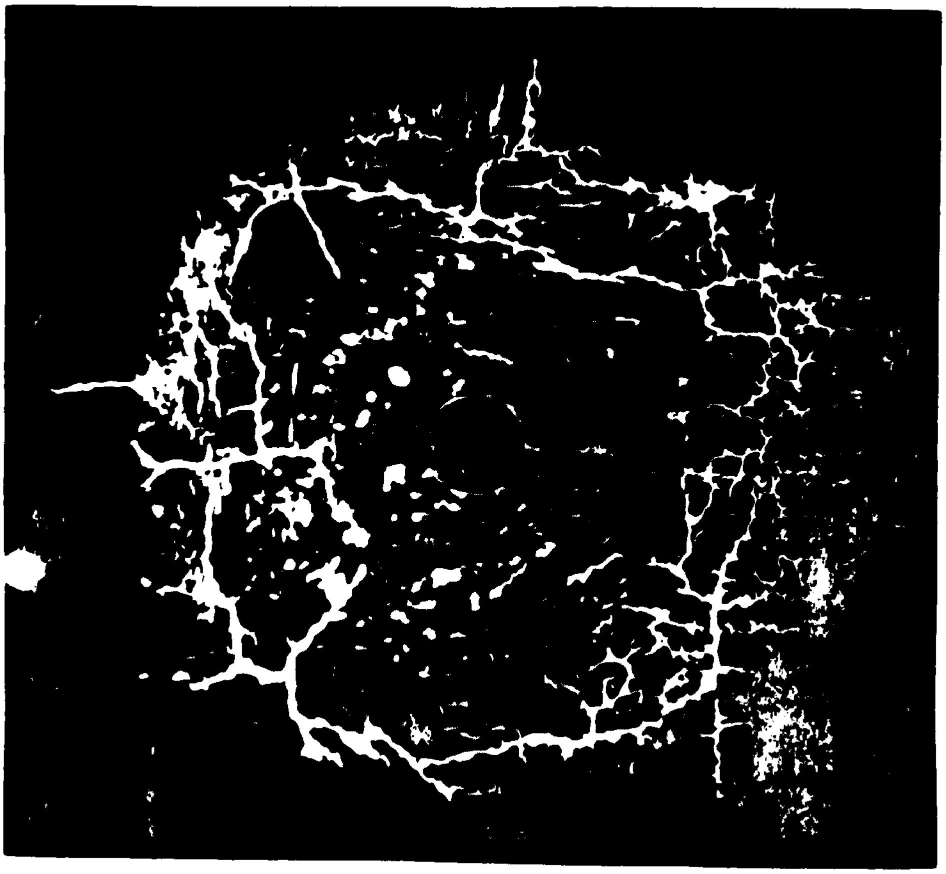
developed by Magnaflux Corporation

Another test specimen developed by the Magnaflux Corporation is the aluminium alloy type 2024-T-3 test block, easy to produce and quite cheap. The schedule for producing cracks is: An aluminium alloy plate of 3" x 2" x 3/8" is heated by a gas flame up to 525°C (980°F). When this temperature has been reached in the middle, the plate is quenched in cold water from the heated flat side. This procedure has to be repeated on the other side of the plate. A centre groove about 1/16" x 1/16" gives the possibility to test one PTS on one half and to compare with another PTS on the other half. Coarse and fine cracks should be produced; if not the procedure is repeated. After careful cleaning, re-use is sometimes possible. Different test blocks of this kind do not produce cracks with uniform depth and width, but they have a wide range of cracks, both in width and depth. It is also possible to take other aluminium alloys with other quenching temperatures for this purpose.





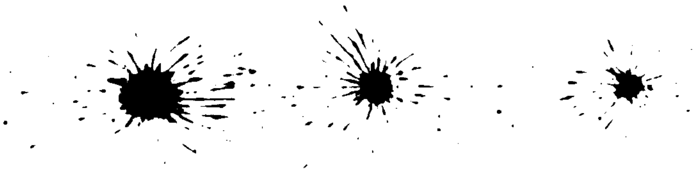
A test block of AlMg5 developed in the Federal Republic of Germany (LFT 6350-601) has nearly the same dimensions. It has an extra boring of 6 mm diameter in the centre of the plane, promoting the development of cracks. It is heated by laying it on a copper plate using borax as the flux between copper and aluminium. As 540°C sheet must be quenched in cold water from the heated flat side. Then the other side also should be heated and quenched by the same method. After quencning a good cleaning with water and emery paper (granulation 150) is necessary.



The distribution of these hardness cracks (enlarged 2 x) is shown in the illustration opposite.

The test block should be cut in two before testing. This test piece is also used for testing PTS at elevated temperatures. These penetrants are needed to test hot seams during welding, e.g., for testing the root. The test pieces described so far have variable and unknown depths. By means of a cantilever bending tool for cracked test strips (see Fig. [illegible]), it is possible to produce cracks of growing width and always the same depth. By using a cylinder for bending, the width of the cracks is uniform.

Test strips (see Fig. 4) of about 50 mm x 100 mm, up to 2 mm thick, chromium-plated iron or other metals are bent in this way. The hard chromium plate is variable but always easy to measure. (Fig. 5). Using different steels or other metals we can produce many variations of bent chromium-plated test strips by using cantilever bending or radial bending (with or without rebending) with different or uniform widths but always with defined depth (see illustration).



Another variation of chromium-plated test pieces with stress cracks is produced by making a Brinel hardness test on the surface with different weights. The indications of the fine cracks seen are made by FPTM.

Bending tool for test strips (cracked) for cantilever bending:

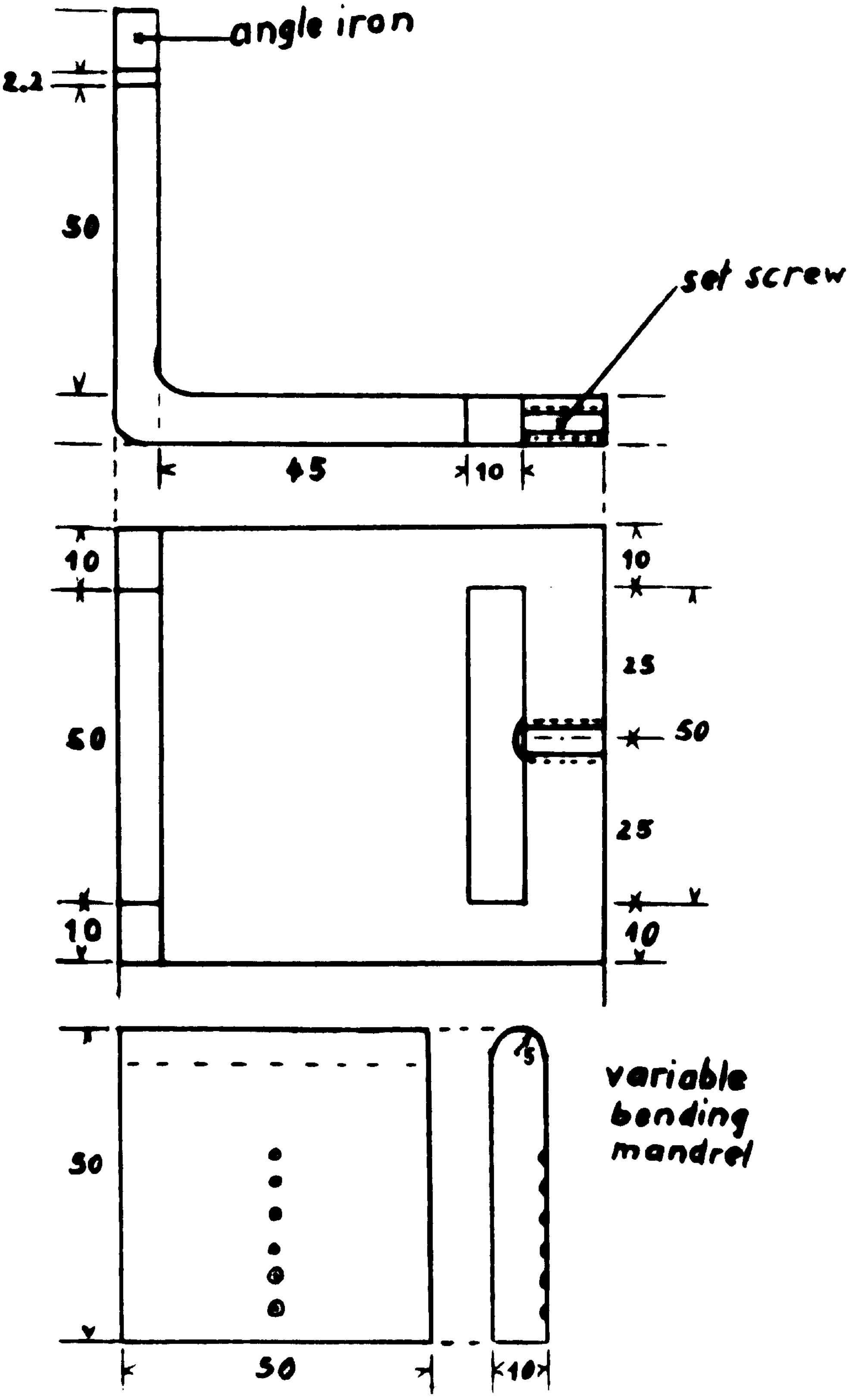
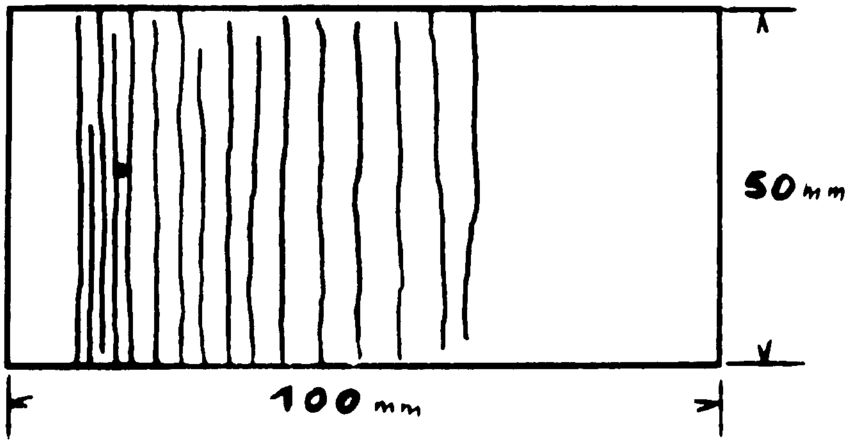


Figure 4

Cracked test strips:

cantilever bending



thickness up to 2 mm

radial bend

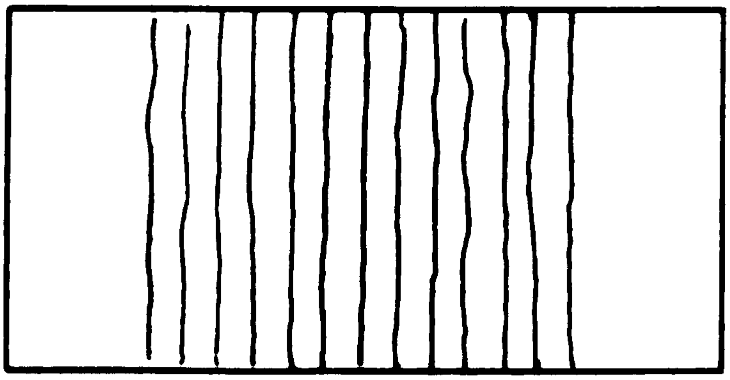
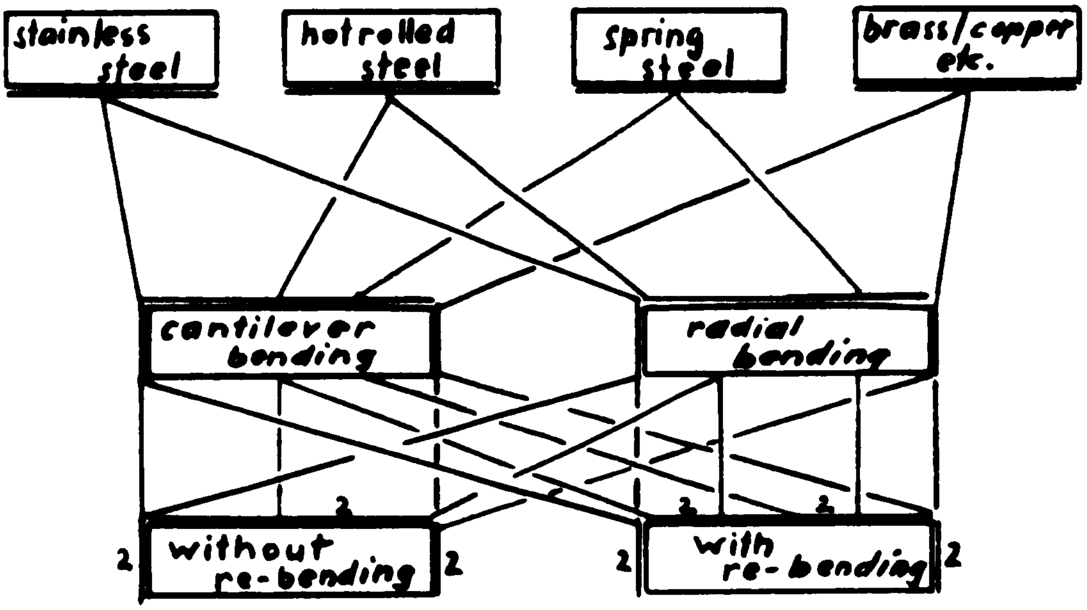


Figure [illegible]

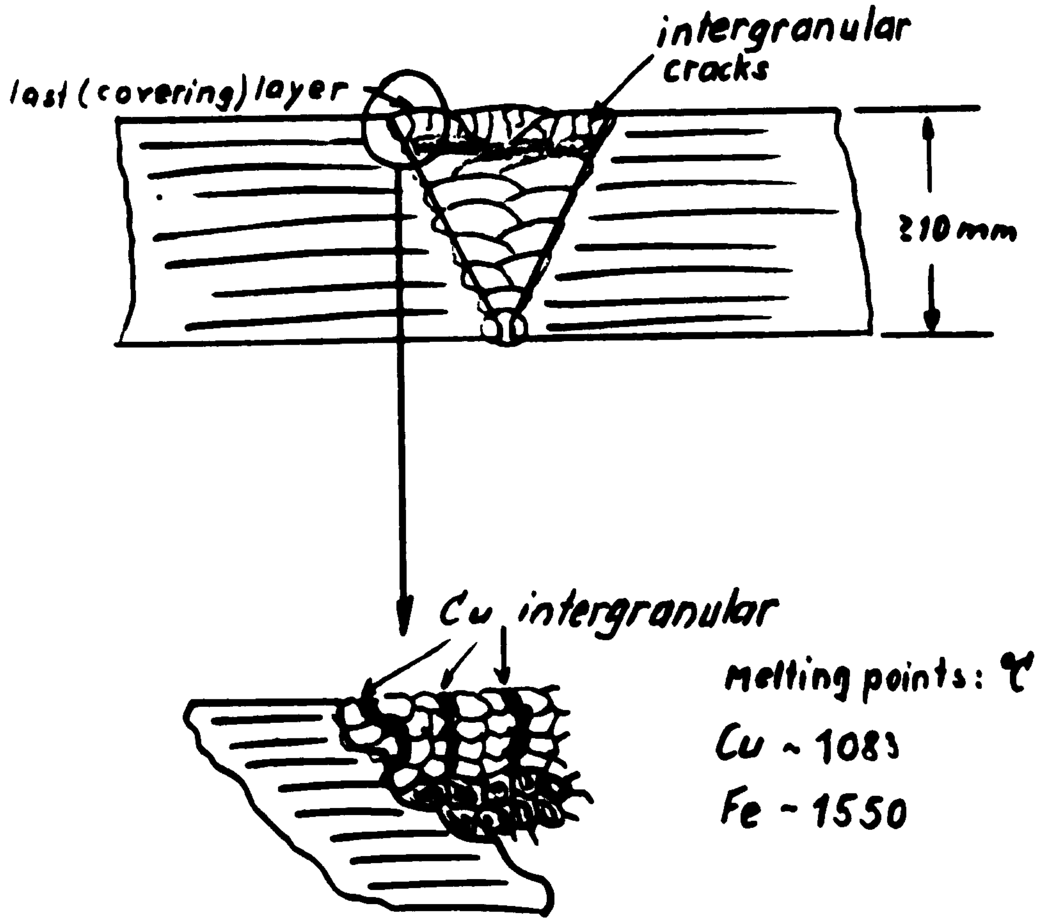
Variations of bended test strips: chrom plated



material:	Variations:
stainless steel	4
hot rolled steel	4
spring steel	2
brass, copper etc.	4
	14

3.3.2. Developing and producing a new test piece.

An article found in the German literature proposed making welded test pieces with cracks (see opposite photo), but the width and visibility of these cracks were not sufficient in our opinion. We tried to find a method to produce very fine cracks which are nearly invisible. Intergranular cracks caused by copper between the microscopical fine grains of an austenitic steel weld seam are fine enough



Production method:

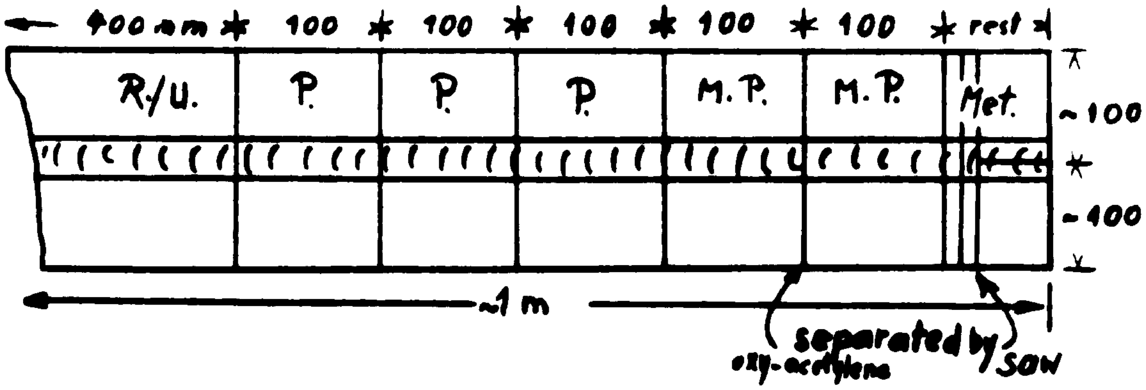
A stainless or mild steel sheet of any thickness is welded without the last layer (see sketch on previous page). The preliminary layer is then melted by autogenous heating and welded again by the addition of a copper wire. The last layer is welded with an austenitic electrode (we used electrodes for steel 304L and 316L). While cooling, very fine cracks appear in all directions.

The photo does not show all the existing cracks. They are made visible by PEFPT.

The production of this welded test piece with these kinds of cracks is possible only in a welding plant. It is very easily reproducible.

Comparing NDT and DT tests of PT test weld.

We welded several 20 mm plates, in parts as shown in Fig for X-ray, ultrasonic, penetrant, metallographic and magnetic testing.



R = radiography; U = ultrasonics; P - penetrant;
Met. = metallography; MP = magnetic particle.

Figure 26

This gives a good possibility to compare the indications of the cracks produced by these different NDT and DT methods. The radiograph of such cracks is shown in Fig. [illegible].

At the end of my mission the different comparison studies had not been finished. A report will be given later.

3.4. Training of NDT personnel.

PT must be performed by personnel having a qualification for testing. A translation of a German Draft of DIN 54160 (Annex IV shows the requirements for testing personnel of two levels and the necessary training and experience required to guarantee the best results in production testing. The German Society for Nondestructive Testing (Deutsche Gesellschaft für Zerstörungsfreie Prüfung e.V.)(= DGZfP), has for a long time given courses for the training and qualification of NDT personnel. The course programme from August 1978 to June 1979 of DGZfP also contains courses for penetrant testing. In 12 educational centres, 75 lecturers teach 61 courses in non-destructive testing.

3.5. Comments on Organisations.

German DIN for example, are made by working committees DIN 54152 of FNM (Fachnormenausschuss Materialprüfung). The result of this careful preparation up to international drafts of standards as ISO/DIS 3452 "Non-destructive testing penetrant inspection - General Principles" and ISO/DIS 3879 "Welded Joints - Recommended Practice for Liquid Penetrant Testing". Personnel for penetrant testing must be qualified. The DIN 54160 on this subject is made also by a committee of FNM. The committees are established by all interested organisations and firms. In 2.4 another committee is discussed and this is the best example of cooperation to obtain standards. In order to compare existing and developing organisations in Argentina, reference was made to the German Society for Welding Techniques (DVS = Deutscher Verband für Schweisstechnik) with its professional schools for welding and Research Institutes (SLV = Schweisstechnische Lehr- und Versuchsanstalt).

In particular, the organisation and abilities of SLV - Duisburg were discussed. This is an Institute with a staff of 131 persons, 6000 participants in courses per year for welders and welding engineers. One Institute of this kind in Bueros Aires, for instance INEND, could perform all the training of welding and NDT personnel at all levels and also work for Argentine industry on a service basis.

4. "INEND Informa".

During the period of my stay in Argentina the first and second editions of "INEND Informa" were printed in April 1978. It gives information on the activities of INEND, technological information and indications of publications on NDT. The editorial staff were Ing. H. Espejo, Director of INEND; Dr. C. K. Beswick, UNDP Project Adviser, and the editors, Dra. S. V. Tanis and Ing. J. N. Báez.

5. Practical hints in penetrant testing.

1) Clear fluorescent indications of fine cracks by blowing sometimes only a small amount of micro-crystal powder with an angle of 45° over the surface.

2) Rough surface - use dry developer.
Smooth/polished surface - use wet developer.

3) Intermediate cleaning (removal of penetrant) of fluorescent penetrant always in black light.

4) Eye-adaption in black light: 5 minutes.

5) Wet only those parts of work pieces with penetrant etc., where defects are dangerous and expected.

6) Fluorescent indications inspected before developing often give a better information of the width of cracks than after developing.

7) Only the cleanest work in all steps of penetrant testing avoids bad errors.

8) Read and observe the manufacturer's indications of all means for penetrant testing.

9) Use long-stored means only after testing their necessary quality.

10) Use short removal and emulsification times but long developing times.

11) Small limited areas of penetrated parts are often cleaned better with cloths or paper than with water or solvents.

12) Do not add detergents to the washing water, otherwise penetrant will be removed from the defects.

13) Do not use oil-contaminated compressed air for drying.

14) Time and temperature of all steps must be proved and always controlled.

15) Fresh air must always be added to hot air driers.
Infrared lamps must not be used for drying.

16) Exact attention should be paid to all standards (norms) concerning penetrant testing.

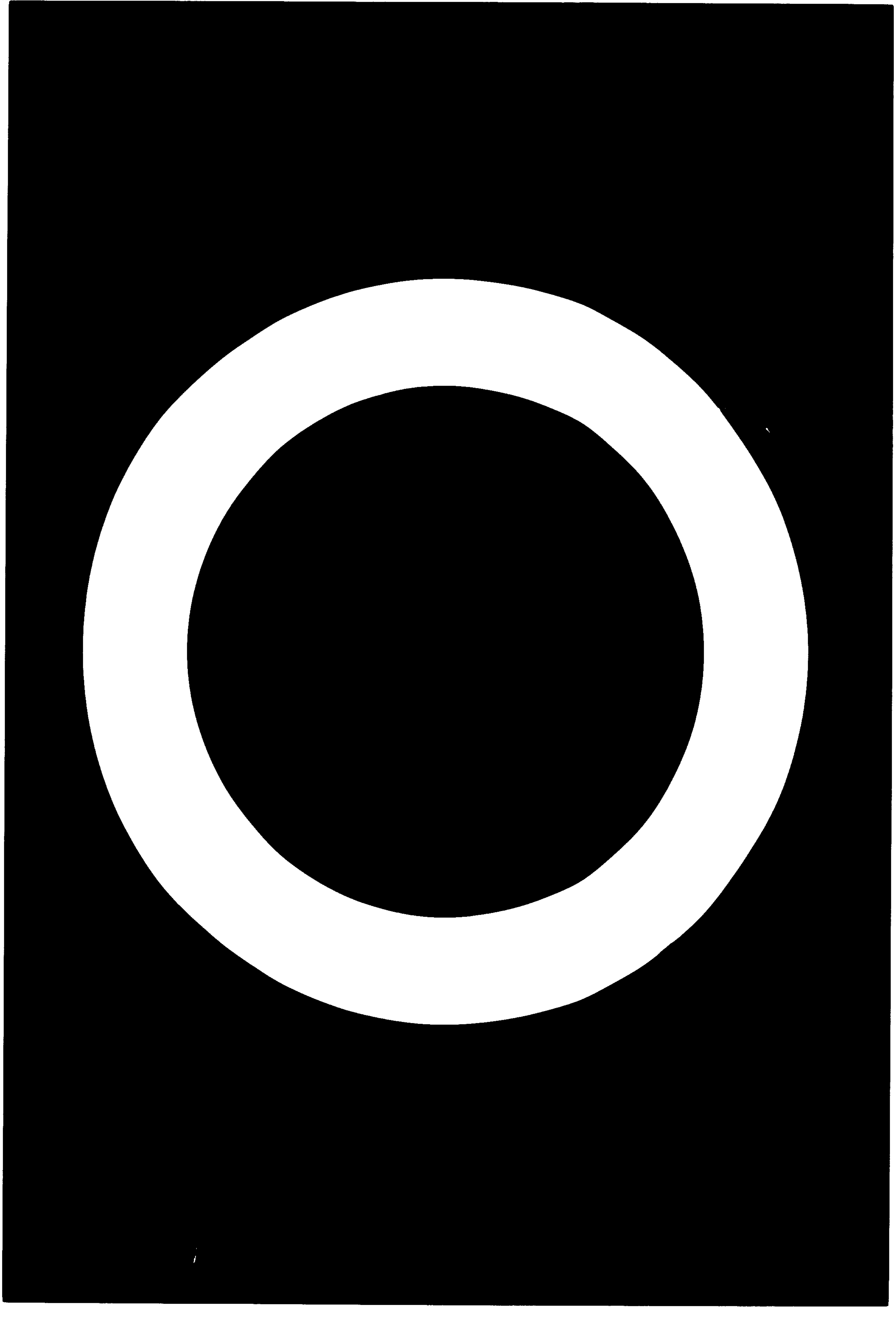
17) Use the testing directions and check-lists of your office.

18) Control all testing means in the prescribed time interval.

19) Clean prescribed test pieces should always be used to control the penetrant systems.

20) Respect the security rules.

21) Judge of its usability only if you know the exact use of a tested part.

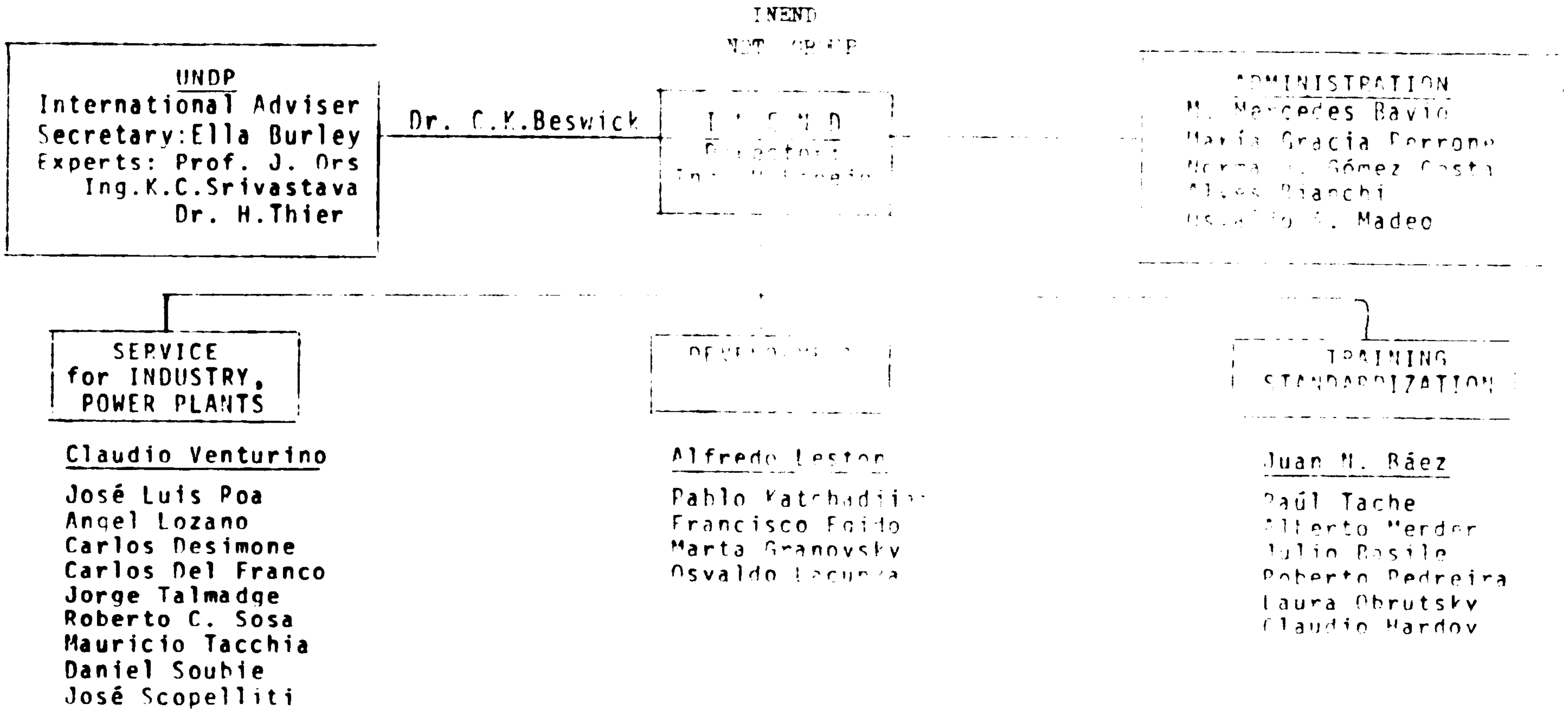


Annex I

[illegible]

INEND

[illegible]



Annex II

JOB DESCRIPTION

DU/ARG/71/537/11-26/31.3.D.

POST TITLE:	Expert in Non-Destructive Testing Applications of Dye Penetrant Methods for the Inspection of Materials such as Metals, Plastics, Ceramics, etc.
DURATION:	Three months.
DATE REQUIRED	April 1978.
DUTY STATION:	Buenos Aires; with travel within the country.
DUTIES:	The expert will be attached to the Constituyentes Atomic Centre of the Comisión Nacional de Energía Atómica (CNEA) and will be responsible to the Project Director within the activities of the Non-Destructive Testing Institute. Specifically, the expert will be expected to: 1. Assist and advise on practical applications of dye penetrant techniques on a range of materials and components as required within the Institute's testing programme. 2. Advise on and guide work programme directed at developing standards of quality assessment, their application and evaluation for dye penetrant methods. The expert will also be expected to prepare a final report, setting out the findings of his mission and his recommendations to the Government on further action which might be taken.
QUALIFICATIONS:	Specialist in dye penetrant techniques with experience in applying these techniques to a wide range of materials. Experience in formulating and guiding development programmes an advantage.
LANGUAGE:	English or Spanish.

BACKGROUND INFORMATION:

The United Nations Development Programme Project ARG/71/537 is working with the NDT Department of CNEA in establishing a National Institute for NDT and quality control.

An important field of activity lies in the introduction of the latest quality control techniques for manufacturing industries. In particular the application of NDT for the economic control of production and the elimination of harmful defects is a major requirement.

The NDT Laboratory at the Constituyentes Centre is equipped with a range of NDT facilities for X- and Gamma-radiography, ultrasonic testing, magnetic particle and penetrant inspection, eddy current testing, etc., as well as supporting mechanical and electronic workshops and metallurgical equipment.

Annex III

TRANSLATION OF STANDARD DIN 54152, PART 1, OF THE FEDERAL REPUBLIC OF GERMANY

The following parts of this standard are projected:

Part 2 - Testing Properties.
Part 3 - Control-piece (test piece).

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1. Aim and scope.

Penetrant testing serves to detect flaws, e.g., cracks, laps, folds, pores and lack of fusion, with openings to the surface.

It can be used for all materials except those which are attacked by the penetrant's properties.

This standard contains neither rates of assessment which refer to any object nor declarations about the qualification of single testing systems.

2. Principles of procedure.

Penetrant operation depends on the capillary effect of defects on suitable penetrants. The usual testing procedure is to work in accordance with the following steps:

a) Precleaning process (see section 4.1).
b) Penetrating process (see section 4.2).
c) Intermediate cleaning process (see section 4.3).
d) Drying process (see section 4.4).
e) Developing process (see section 4.5).
f) Inspection (see section 4.6).
g) Postcleaning (see section 4.7).

The effectiveness of the procedure depends, among other things, on the physical properties of the testing materials, on the structure of the surface of parts to be tested, and the kind of flaws, as also on the testing temperature and the time of influence.

3. Classification and Nomenclature.

In penetrant procedures different testing systems can be used. *

3.1. Classification and nomenclature of test properties.

---

* A testing system implies a combination of the following testing materials: penetrant, intermediate cleaner and developer.

Test Properties					
Penetrant		Intermediate cleaner		Developer	
Identification	Designation	Identification	Designation	Identification	Designation
A	Fluorescent penetrant	A	Solvent, liquid phase	A	Dry Developer
B	Dye-penetrant	B	solvent, vapor phase	B	wet developer
C	Fluorescent dye-penetrant	C	Water		
		D	water & solvent		
		E	emulsifier & water		

3.2. Nomenclature of the testing systems.

The system of penetrant procedure to be used will be specified with a short sign, which is composed of the following identification letters for the testing properties:

1. Identification letter: penetrant.
2. Identification letter: intermediate cleaner.
3. Identification letter: developer.

E.g., Notation of a testing system of fluorescent penetrant, with water as intermediate cleaner and with dry developer (short-sign ACA):

Penetrating process ACA DIN 54152.

Note: Because penetrant, intermediate cleaner and developer must harmonise, testing systems with the same short-sign must not have the same sensitivity.

4. Performance.

4.1. Precleaning.

Precleaning will ensure that the surface to be tested is free from residues and that the penetrant can enter the faults. Therefore, disunions, e.g., scale, rust, oil, grease, dye-paint or electro-plated coatings, have to be carefully removed by mechanical or chemical means. Both methods should be used.

4.1.1. Mechanical Precleaning.

Scale, slag, rust, for example, can be suitably removed by brushing with a wire brush, by rubbing, grinding, and in special cases also by radiation or similar methods. In each case care must be taken not to close the defects by precleaning. If that occurs, a subsequent pickling is necessary.

4.1.2. Chemical Precleaning.

Oil or grease residues may be removed by suitable solvents; in single cases, e.g., in the case of coatings, pickling of the pieces to be tested is necessary. After pickling the parts must be neutralised and carefully rinsed.

4.1.3. Drying.

After precleaning the parts to be tested must be carefully dried, so that neither water nor solvent remains in the defects.

4.2. Penetrant Process.

4.2.1. Application of the Penetrant.

The penetrant may be applied to the part to be tested in various ways, e.g., by spraying, painting or rinsing. Moreover, dipping into the penetrant is allowed. Care must be taken to wet the whole surface.

4.2.2. Testing Temperature.

Testing temperature is usually from 15 to 50°C.

A testing temperature lower than 5°C must be avoided.

When testing between 5° and 15°C proceed according to item 4.2.3.

For temperatures above 50°C qualified testing procedures must be used.

4.2.3. Penetrating Time.

A suitable penetrating time depends on the properties of the penetrant, on testing temperature, on the material of the part to be tested and on the defects to be detected. It is usually between 5 and 30 minutes.

For testing between 5° and 15°C, the penetrating time usually has to be doubled.

In no case must the penetrant be allowed to dry up during the penetrant process.

4.3. Intermediate Cleaning.

Excess of penetrant adhering to the surface must be removed completely, so that the penetrant which is located in the defects is preserved.

The kind of intermediate cleaning depends on the penetrant used.

4.3.1. Penetrants removable by solvents.

Solvents used must harmonise with the penetrant.

To avoid removing penetrants from defects, spray with water or wipe off excess penetrant with a non-fuzzing cloth or cleaning rag, when cleaning by solvents.

4.3.2. Water washablepenetrants.

The penetrant will be removed by rinsing or spraying with water. Strong spraying is forbidden. Warm water may be used, at a temperature not higher than 40°C. The intermediate cleaning may also be carried out by suitable washing equipment. Water washable penetrants can generally be removed by solvents. In these cases proceed according to section 4.3.1.

4.3.3. Post-emulsifiable Penetrants.

To remove the penetrant from the surface it must first be made water-soluble with an emulsifier. This may be done by rinsing or dipping. Painting should be avoided. The time of influence of the emulsifier has to be fixed so that the excess of penetrant can be removed from the surface by the annexed washing process. The emulsifying time must not be exceeded. Post-emulsification washing must be done in accordance with section 4.3.2.

4.3.4. Control of Intermediate Cleaning.

During intermediate cleaning the surface to be tested must be tested for residues, e.g., in the use of fluorescent penetrants by aid of black light during intermediate cleaning.

4.4. Drying Process.

After removing excess penetrant, the surface must be dried quickly. This may be done as follows:

a) With a clean and dry cloth.

b) By normal evaporation at ambient temperature.
c) By drying at an elevated temperature (max. 50°C).
d) By drying with forced circulated air.
e) By combining procedures a) to d).

A procedure must be followed so that the penetrant is prevented from drying within the defect. The drying process must not be carried out if a wet developer with water is used as a carrier liquid.

4.5. Developing Process.

The developer draws the penetrant that has remained in the defects to the surface, producing clearly visible indications of defects. The developer has to be coated equally and as lightly as possible, but the base must be just covered.

The preceding step of the testing process must be immediately followed by application of the developer.

4.5.1. Dry Developer.

A dry developer will be used for testing parts when using fluorescent penetrants. The developer has to be applied by spraying equally on the testing surface.

4.5.2. Wet Developer.

As a carrier, water, alcohol or other chemical solvents are used. Before application the penetrant liquid has to be thoroughly mixed.

Wet developer can be applied by spraying or dipping the part to be tested. Applying the penetrant by pencil should be avoided if possible.

4.5.3. Developing Time.

In principle, the developing time should correspond to the penetrating time. In exceptional cases the developing time can be extended.

4.6. Inspection.

4.6.1. Performance.

At the end of the developing time the surface under test will be inspected all over for defects (Inspection).

Aids to visual testing, such as a magnifying glass or contrast-improving spectacles, are permitted.

Defects are shown up either in colours or by fluorescent spots or lines which appear during the developing time.

The diameter, extent and intensity of faulty areas, is not usually a measure of the dimension and depth of the defect.

In certain cases, i.e., when defects of different sizes have to be identified, a preliminary sight-test should be made after applying the developer. In this way a better interpretation of defects will be possible.

If an unequivocal evaluation of the indications of defects is not possible, the whole testing process, beginning with the precleaning, must be repeated. Should it be necessary to choose testing conditions which are more convenient, it is not permissible to change from fluorescent to dye penetrant and vice versa.

4.6.2. Visibility Conditions.

4.6.2.1. Fluorescent Penetrants.

The surface to be tested must be inspected under black light, the maximum wave-lenths being within the wave-length region of 365 mm ± 10 mm.

The black light must have reached full intensity. At the surface under inspection the black light must have a candle power of a minimum of 500 $\mu W/cm^2$.

If measured in ISO3059, the candle power must reach a minimum of 70 lx.

The inspector requires a minimum of 5 minutes to adapt his eyes to light conditions in the testing region. The above instructions apply to inspection in darkrooms. In surroundings with other light conditions, a corresponding increase of radiation intensity on the surface to be inspected is required.

4.6.2.2. Dye Penetrant.

The surface to be inspected must be illuminated by daylight or artificial light to a minimum of 500 lx1). Reflexions must be avoided.

4.7. Postcleaning.

After inspection a post-cleaning of the tested part is necessary so that any residue of the testing material cannot interfere with its further use. If a developer with water as carrier liquid has been used, it is advisable to conduct the postcleaning immediately after inspection.

Immediately after the post-cleaning, the part should be dried and, if necessary, treated by corrosion protecting means.

5. Test Report.

A written report of the results of penetrant testing must be made. The test report must contain the following instructions.

Information on tested part:

- Sign.
- Dimensions.
- Material.
- Structure of surface.
- Method of testing.
- Extent of testing.
- Identification of testing system used in accordance with section 3.2. with name of producer and sign of product.
- Description of performance (in accordance with section 4).
- Deviation from testing instruction.
- Deviation from this standard.
- Description of defects determined.
- Place of testing, date of testing, name of inspector.
- Name and signature of liable inspector.

In the appendix is an example of a blank form for the test report.

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1) This corresponds to the candle power of an 80 Watt vacuum tube lamp at a distance of 1 m.

Page 4 Draft DIN 54 152 Part 1

APPENDIX

Example of a typical blank form for a test report.

Firm: Work-order

Division: Sub-order

Penetrant Process

Test Report...... Page.... By....

Project: Component:
Client: Factory N°
Order N° Client: Drawing N°

Test object: (other specification e.g.)

Dimensions welding plan Test series N°
welding seam sheet N°

Material:

ingot N° Part N°
Structure of surface: melt N° Model N°

Condition of heat treatment:

Test direction (e.g. specification, terms of delivery):

Test procedure: (other specifications e.g.
post-cleaning
Short sign of test system: preservation)
Producer:

Name of product:

Penetrant:
Intermediate cleaner:
Developer:

Performance

Test temperature: Intermediate cleaning:

Pre-cleaning: Emulsification time
Developing time

Penetration time

Deviation from the test procedure:

Deviations from DIN 54 152 Part 1:

Test result:	(e.g. Specification of Location of defect Type of defect Allocation of defects Extent of defects Number of defects Sketch)	
Test place:		
Test date:		
Name of operator:		
Evaluation according to test prescription	Allowable:	Not allowable
Remarks:		
Test division:		
Responsible tester:	Date:	Signature
Client/Expert:	Date:	Signature
Inspection Society:	Date:	Signature

EXPLANATION.

This standard draft was made by working committee DIF Surface Processes: (Chairman: Dr. Ing. H. A. Stelling, Hannover), of Fachnormen Ausschuss (FNM) (Standards Committee).

It results from the careful preparation of two international drafts of standards:

JSO/DIS 3452 "Non-destructive testing-penetrant inspection - General Principles":

and

JSO/DIS 3879 "Welded Joints - Recommended Practice for Liquid Penetrant Testing".

The Committee did not think it proper to have a special standard in addition to the general standard on penetrant testing for application to welded joints since the transferability of a general standard to welding joints is guaranteed. Therefore, the connotation of both the above-mentioned International Standard

Drafts is made on the basis of only one, the present DIN Standard Draft (degree of conformity D).

In principle an attempt was made to accept extensively the essential contents of the International Standard Draft in spite of necessary modifications to the text and factual content.

Modifications are deemed to be necessary in several points.

Annex IV

TRANSLATION OF DRAFT STANDARD CONCERNING THE REQUIREMENTS FOR TESTING PERSONNEL, FEDERAL REPUBLIC OF GERMANY

1. Scope, Content, Purpose

This standard establishes guidelines for the qualification of nondestructive testing personnel. It can be applied where standards or other codes require certified personnel for nondestructive testing.

Its application is intended to ensure that personnel for NDT is certified and qualified according to uniform guidelines.

The standard establishes:

- requirements for education, training and experience in NDT
- the examination of knowledge and skill as well as physical aptitude
- demonstration of the required qualification
- written certification by the employer of satisfactory qualification (certified)

2. Test Methods

Qualification within the framework of the present standard is applicable to each of the following methods:

Ultrasonic Testing	(U)
Radiographic Testing	(R)
Magnetic Particle Testing	(M)
Liquid Penetrant Testing	(P)
Eddy Current Testing	(E)

3. Levels of Qualification

There shall be three levels of qualification for NDT personnel.

For NDT personnel below Level 1, who meet already certain requirements, the term "NDT worker" shall be used. [1]

According to the importance of the tests to be carried out, the employer appoints persons for supervision who have the same or a higher level of qualification than the testing personnel to be supervised and who are familiar with the technical rules applicable to the specific test. They shall be responsible for the conduct of the nondestructive testing and the correct employment of the personnel qualified according to this standard.

---

1) Ref. "Guidelines for training, technical aptitude and examination for NDT workers" established by the German Society for Nondestructive Testing (DGZfP)
Can be obtained from the DGZfP, Unter den Eichen 87, 1000 Berlin 45

3.1 Level 1

An NDT Level 1 individual shall be qualified

- to properly perform specific calibrations, specific tests, and specific evaluations according to instructions and to record the results.

3.2 Level 2

An NDT Level 2 individual shall be qualified

- to set up and calibrate equipment
- to properly perform specific tests
- to evaluate results with respect to applicable codes, standards and specifications
- to limit the scope of the specific methods
- to guide and supervise NDT Level 1 personnel
- to prepare written instructions
- to organise simple testing procedures
- to organise and report additional nondestructive testing investigations

3.3 Level 3

An NDT Level 3 individual shall be capable to organise a comprehensive system of nondestructive tests; this includes:

- supervision of the proper performance of the test
- designation of test methods
- interpretation of codes, standards, and specifications
- designation of the particular test method and technique to be used
- evaluation of results in terms of existing codes, standards, and specifications
- assistance in the determination of acceptance criteria where none are otherwise available or applicable

He shall have sufficient practical background in applicable materials and fabrication and product technology. He shall be in general familiar with other NDT methods listed under section 2.

4. Background

4.1 Education

The general Level of education shall correspond to the primary school leaving certificate.

4.2 General Vocational Training

The general vocational training or practical knowledge acquired on the job shall correspond to the skilled workers certificate of a technical vocation.

5. Training and Experience in Nondestructive Testing

5.1 Duration of NDT Training and Experience

To be considered for certification the candidate shall satisfy one of the following criteria for the applicable NDT Level. Documented prior training and experience gained in positions and activities equivalent to those of Level 2 or Level 3 shall be considered as satisfying the criteria of par. 5.1.1 and 5.1.2.

5.1.1 Levels 1 and 2

Table 1 lists the minimum time for NDT training and experience for qualification of Levels 1 and 2.

Test Method	U		R		M		P		E	
Level	1	2	1	2	1	2	1	2	1	2
Training (hours)	80	100	80	100	16	16	[illegible]	16	48	2)
Experience (months)	3	9	3	9			[illegible]	2	1	2)

Table 1. Minimum times for qualification of Levels 1 and 2

A trainee for Level 1 shall work along with a qualified and certified individual.

For direct access to Level 2 times shall be aggregates of times indicated for Level 1 and Level 2.

The training time shall be divided to about 2/3 general and 1/3 specific discipline training.

If the candidate has additional experience in other disciplines for which qualification is not claimed, this experience can be taken into consideration. But for the discipline for which qualification is being claimed at least 50 per cent of the required experience must be documented.

If qualification is claimed in more than one of the six test methods, the required sum of experience can be reduced as follows:

- two test methods: reduction of the total time by 25 per cent
- **three test methods: reduction of the total bime by 1/3**
- four or more test methods: reduction of the total time by 50 per cent, but for each discipline at least 50 per cent of the experience time of the table.

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2) Minimum time to be fixed later

5.1.2 Level 3

To be considered for qualification of NDT Level 3 the candidate must satisfy one of the following criteria:

- at least 4 years of practical experience as a certified person of Level 2 in the applicable test method
- Completion of training with a passing grade as a technician and at least 2 years practical experience in a job corresponding to Level 2 of the applicable test method
- Completion with a passing grade of an engineering or comparable technological or scientific course and at least one year of practical experience in a job corresponding to Level 2 of the applicable test method.

When the individual is qualified for another test method the above requirements can be partially replaced by practical experience in another Level 2 test method listed in section [illegible]

5.2 Content of NDT Training

Personnel being considered for certification shall complete sufficient organised training to become thoroughly familiar with the principles and practices of the specified test method related to the level of certification desired and applicable to the practices to be used and the products to be tested. Knowledge and skills of each level (1, 2, and 3) for the specified test method shall be imparted to the trainees. For Level 3 additional general knowledge is required in all the other test methods mentioned above.

The division into general and specific experience should be made according to the following guidelines:

Experience, general:

general basic knowledge, methods, equipment, general rules (calibration, testing and safety regulations)

specific:

testing technique and application, product technology, codes relating to specific test method

Skills, general:

general practical training

specific:

product related testing techniques

Training programmes and catalogues with examination questions are in preparation.[3]

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[3] Prior to the publication of the amendments in preparation for this standard it is recommended to use the documents on Training and Qualification of NDT Personnel of the German Society for Nondestructive Testing (DGZfP), Unter den Eichen 87, 1000 Berlin 45, and the American Society for Nondestructive Testing, 3200 Riverside Drive, Columbus, Ohio 43221, US

Note: The general experience and skill can be acquired in the employers' firm as well as outside, specific experience and skills only within the employers' firm.

6. Examinations

In the physical and technical examination the candidate shall demonstrate his physical aptitude as well as his technical knowledge and skill. The following rules shall apply:

6.1 Physical Fitness Test

The physical fitness for the specified test method shall be verified if necessary.

Note: Visual acuity can be determined e.g. according to the "Guideline for the Determination of the Visual Aptitude of NDT Personnel for Magnetic Particle and Liquid Penetrant Testing" of the German Society for Nondestructive Testing (DGZfP).

6.2 Experience and Skills

The examinations shall be held separately for general and specific requirements. Details are in preparation.[4] Examinations for general experience and skill shall be conducted by an examination board. The examination board shall be composed as follows:

- Persons of NDT Level 1 can be examined by a representative of the training agency who must be a certified Level 3 individual for the specific discipline
- For Level 2 certification an additional certified Level 3 person for the respective NDT method who is familiar with the training and qualification of NDT personnel (e.g. appointed by the DGZfP) shall be member of the examination board. These two members of the examination board shall not come from the same agency. The chairman of the board shall be appointed by the training agency.
- For Level 3:
  a) a representative of the candidate's employer or from a related business
  b) a representative of another agency (e.g. appointed by the DGZfP) who trains and qualifies NDT personnel of Level 3.

  c) a representative from the Technical Supervisory Agencies of the Supervisory Autority.

All above members of the examination board must be certified Level 3 individuals for the respective method. At least one member must come from the industry. Other members in addition to the above mentioned members, who administer the examination, may be appointed.

The chairman is appointed by the training agency.
The composition of the examination board for the specific experience an skill is the responsibility of the employer.

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[4] See footnote 3.

7. Demonstration of Qualification

Documented:

a) physical aptitude

b) background

c) required training time

d) required practical experience

e) passed examination for general knowledge and skill

f) passed examination for specific knowledge and skill

Proof has to be submitted either through the respective certificates or by written statements.

8. Certification

If all documents required under 7 are submitted the employer can issue a certificate.

Certification shall be valid for a maximum of three years provided the service has not been interrupted for more than 1 year.
NDT personnel can be recertified once every three years in accordance with one of the following criteria:

a) Evidence of continuing service according to qualification

b) Re-examination: Type and scope of this examination shall be determined by the employer.

9. Transitional Regulation

After due documentation of technical knowledge, experience and training, an examination for level 1, 2, and 3 personnel can be waived. The employer has, however, to issue a certificate. Certification records shall be maintained on file and be made available if records are demanded. This regulation shall be in force for three years after this draft has become a standard.

Explanation

This draft standard has been established by WG 821 "Qualification and Training of NDT Personnel" (Chairman: Dr.-Ing. H. Schaper, Cologne) of TC Materials Testing.

The working group is conscious of the fact, that the structure and wording of this draft standard is not perfect due to necessary compromises of sometimes contradictory proposals. The WG has, however, decided to forgo another editorial revision in order to present to the experts as early as possible the factual content, where general agreement was reached.

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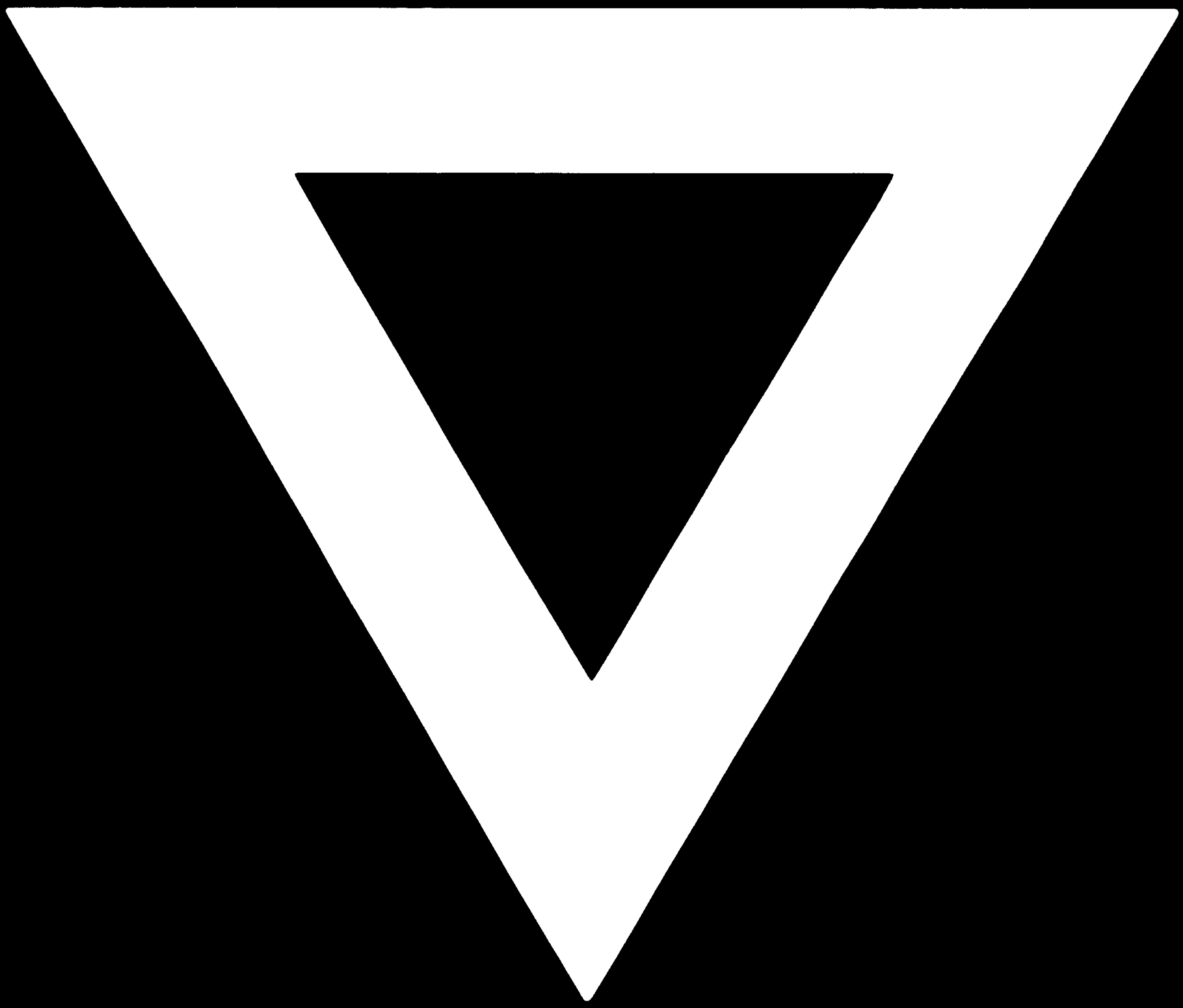

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