

SC19

Cementing and Mounting Technologies for Optics

Stefan Mattle
Leica AG

Thursday, 28-Jul-1994
8:30 am to 12:30 pm
Room: 13

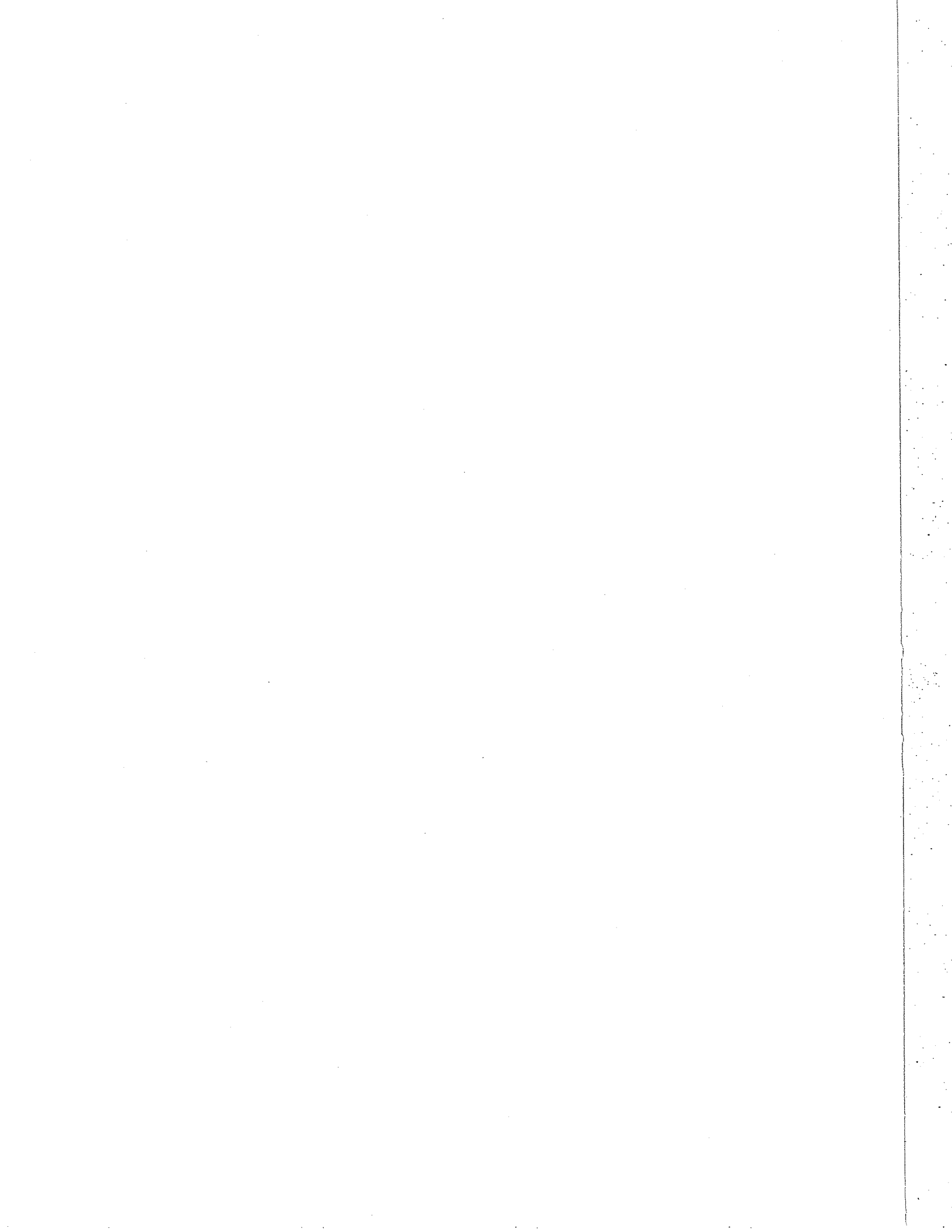
Bob Parks

106A

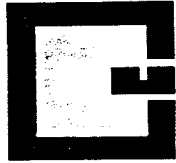


SPIE's International Symposium on
**Optics, Imaging,
and Instrumentation**

24-29 July 1994
San Diego Convention Center
and Marriott Hotel & Marina
San Diego, California USA



The Continuing



Education Unit®

Continuing Education Units (CEU) Available for SPIE Short Courses

Implementation Date: Beginning with its 1994 San Diego Symposium, SPIE will offer Continuing Education Units (CEU) for all of its short courses.



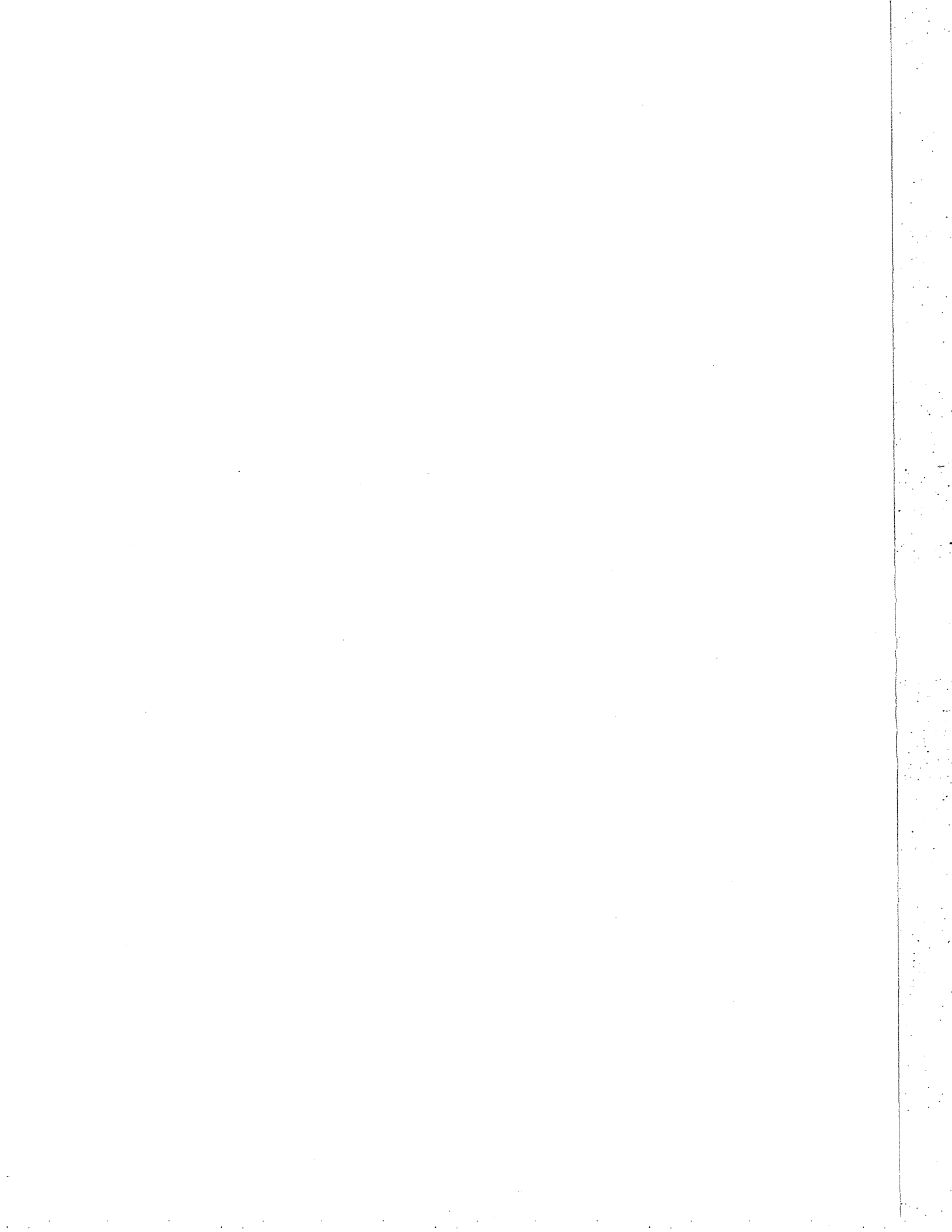
Standards: SPIE is an approved User Member of IACET, The International Association of Continuing Education and Training and has agreed to follow the standards that have been set by this organization. The mission of IACET is to promote and advance quality continuing education and training. SPIE, like other User Members, is committed to developing educational experiences which have a clear purpose, result from careful planning, are taught by qualified instructors and which are routinely evaluated. A copy of IACET's guidelines are available from SPIE upon request.

Definition of CEU: Continuing Education Units (CEUs) were created as a way to document noncredit work in specifically developed activities for adult learners in a variety of disciplines. One CEU is defined as 10 contact hours of participation in an organized continuing education experience. One full-day course equals .65 CEU (deducting scheduled break and lunch times). A half-day course equals .35 CEU (deducting one-half hour break).

Requirements for CEU Award: Students must be present for the entire short course, must complete the evaluation form provided, and must return the form to SPIE within 30 days of the course presentation.

Certificate of Attendance: SPIE will prepare and send a personalized Certificate of Attendance listing the title and date of course, CEUs earned, and student name for each student requesting CEUs and fulfilling the requirements listed above.

Permanent Records: SPIE will maintain a permanent record of all CEUs earned for each student. These records will be available upon request to the student only. To obtain a copy of your records call SPIE's Education Services Department at 206/676-3290.



Handouts

for the

**SPIE SHORT COURSES
OPTOMECHANICAL
ENGINEERING**

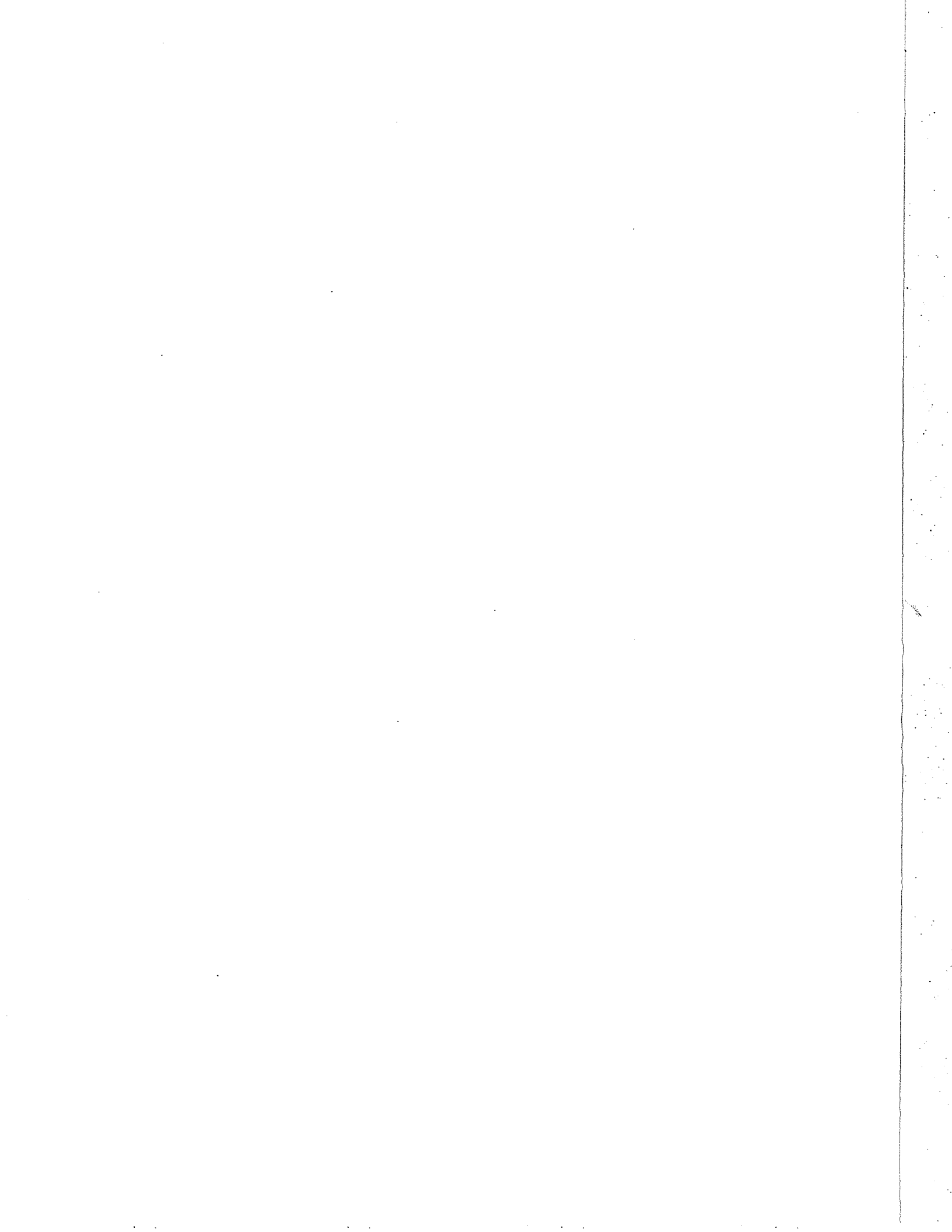
A study in

**CEMENTING AND MOUNTING
TECHNOLOGIES**

by

Leica AG, CH-9435 Heerbrugg

SPIE's International Symposium



Presentation of CEMOT

1. Introduction

- Leica
- Cemot
- Mounting and Cementing Technology

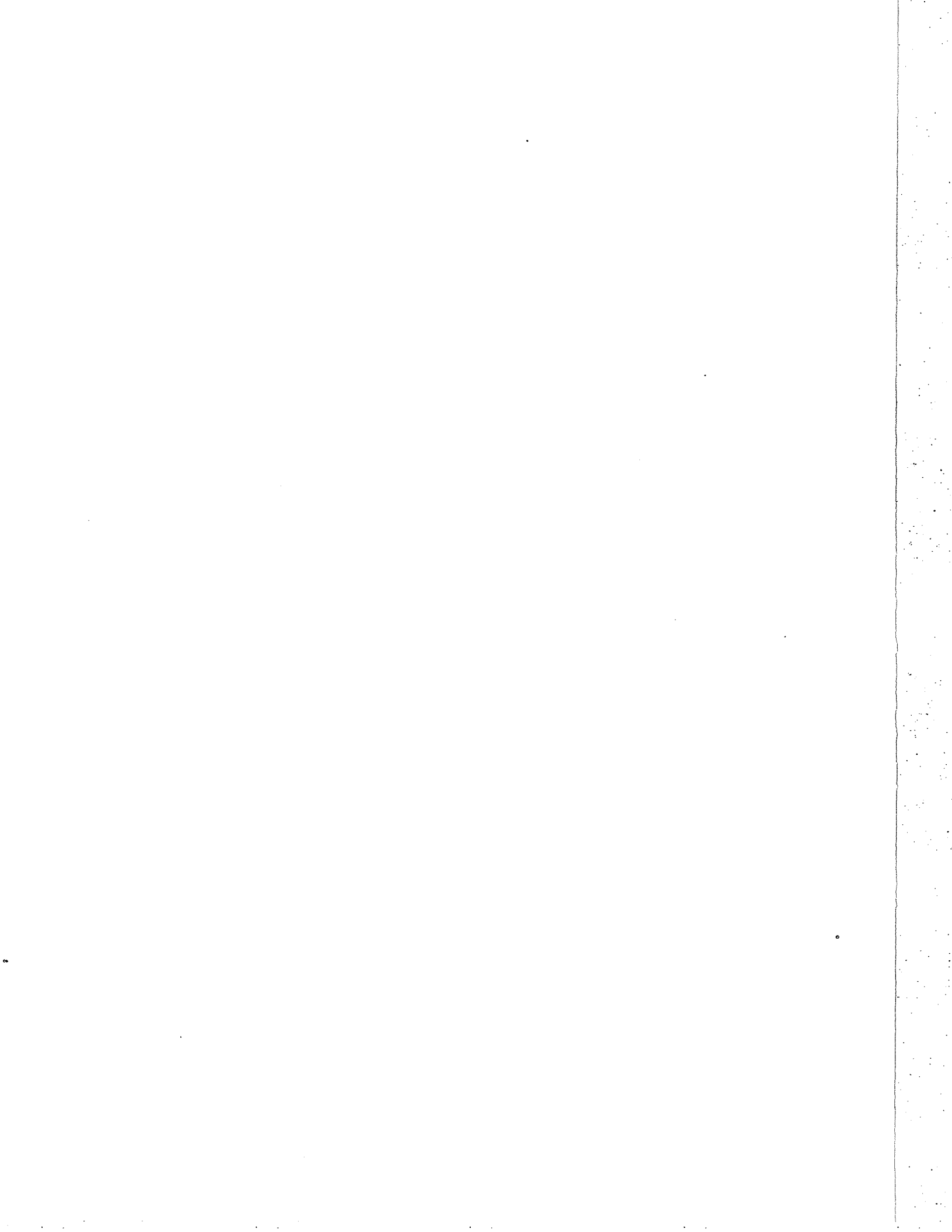
2. Material Selection

3. Material Data Catalogue

4. Properties of Adhesives

5. Environmental Testing of Selected Materials and Elements

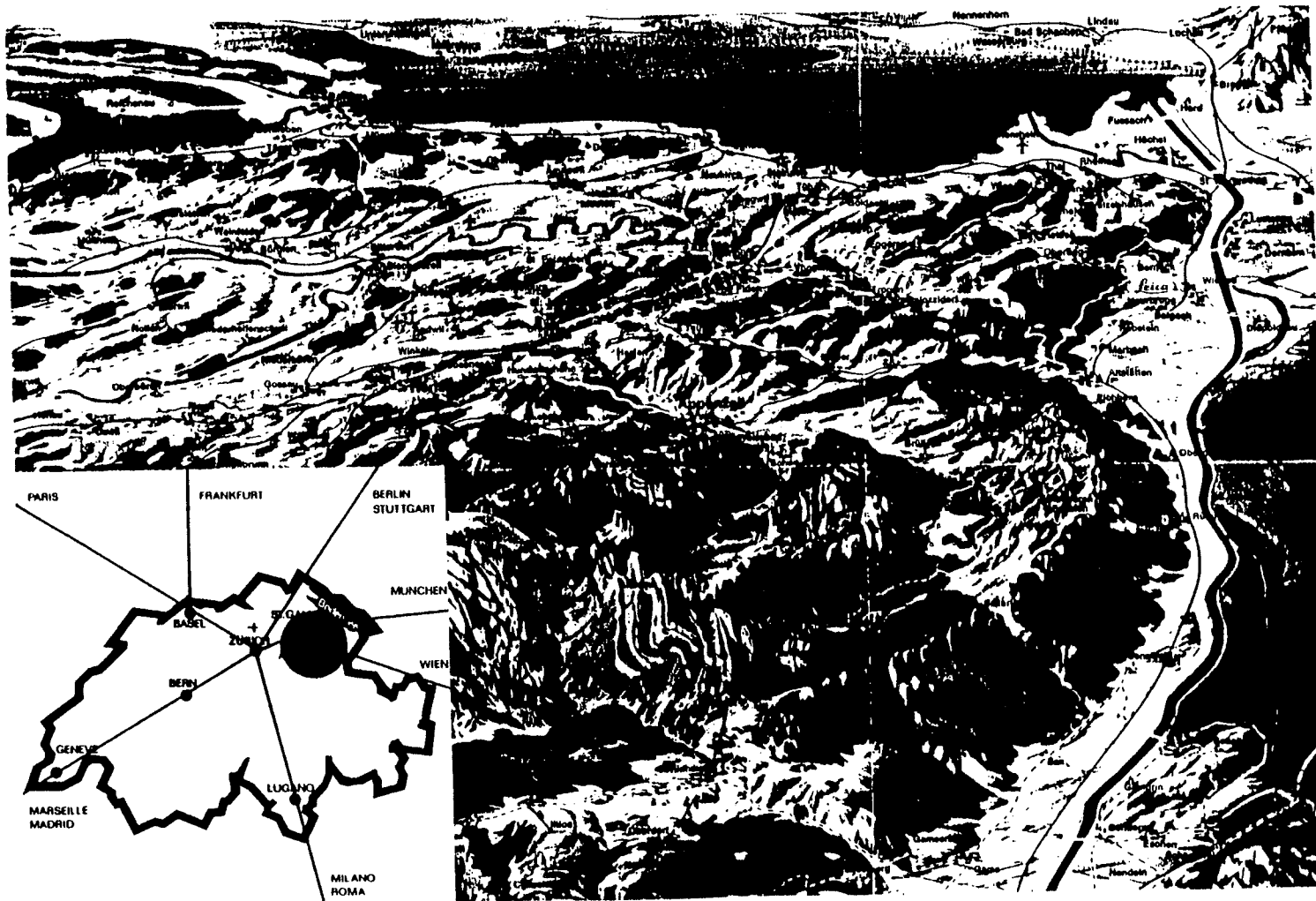
6. Discussion



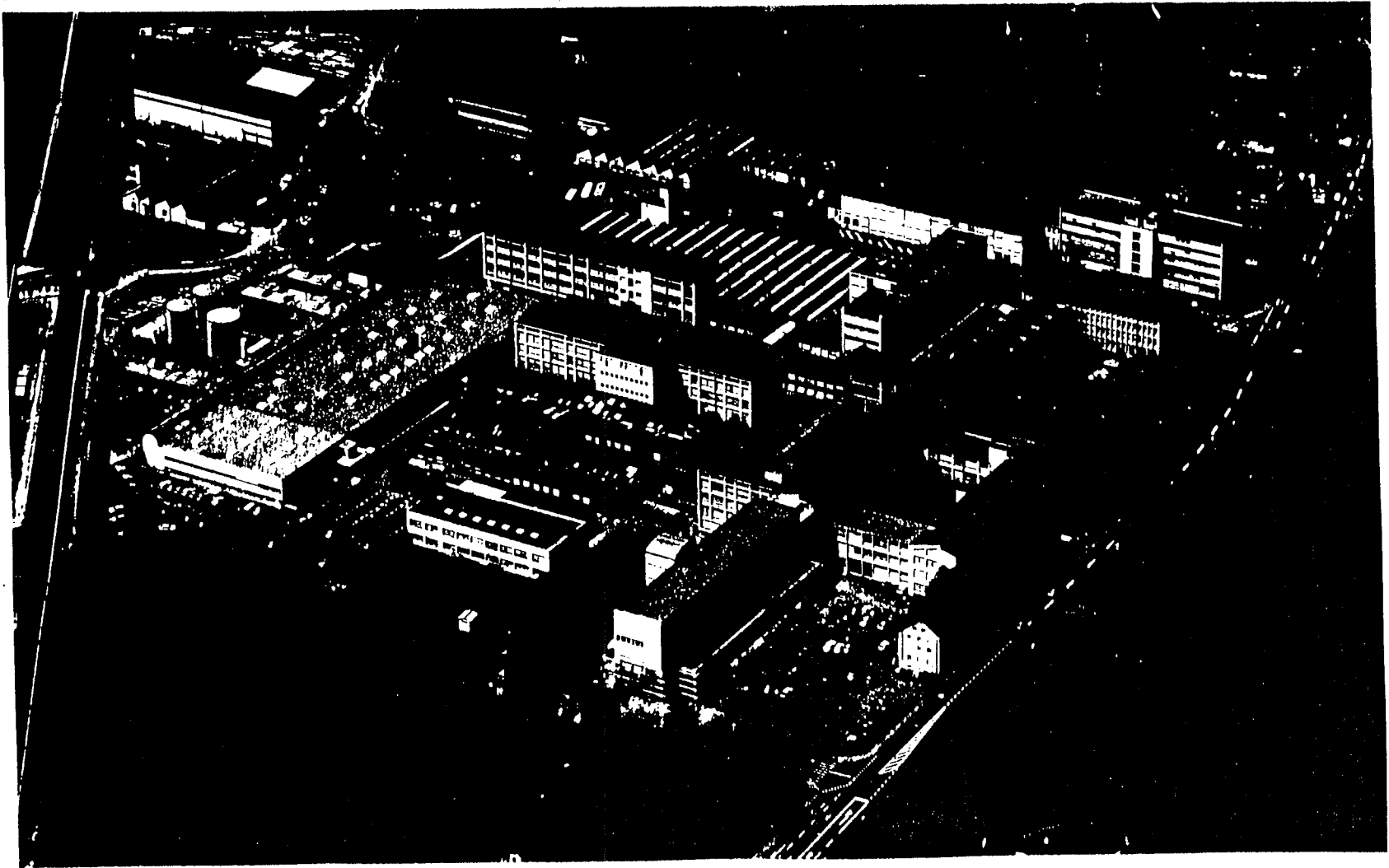
Seven world-famous brands under one roof



Our location



Leica AG, Switzerland

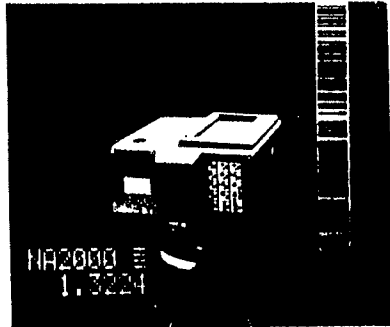


P. 5

2.1.3 - X.92

Leica

Product groups, Leica AG



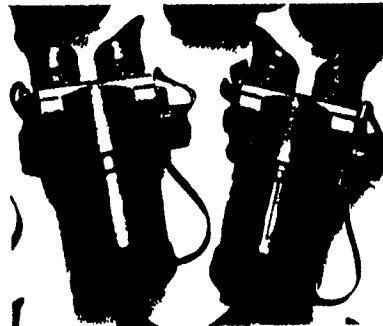
Geodesy

- *Optoelectronic theodolites and total stations*
- *Electronic distancers*
- *Data acquisition and software*
- *Levels and plummets*



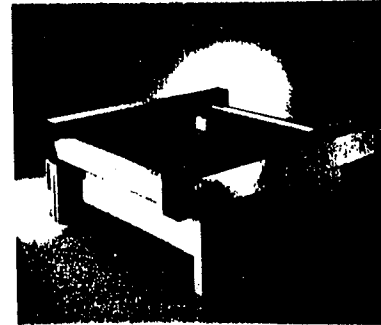
Microscopy

- *Stereomicroscopes*
- *Operating microscopes*
- *Macrosopes*
- *Photomicrographic systems*



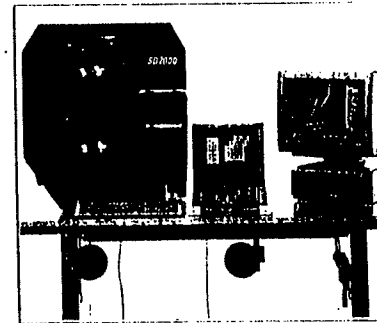
Special products

- *Optoelectronic sensors, sub-assemblies and instruments*
- *Night-vision devices*
- *Military survey stations*
- *Aerial cameras*
- *Photographic interpretation systems*



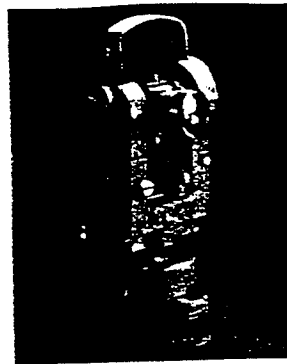
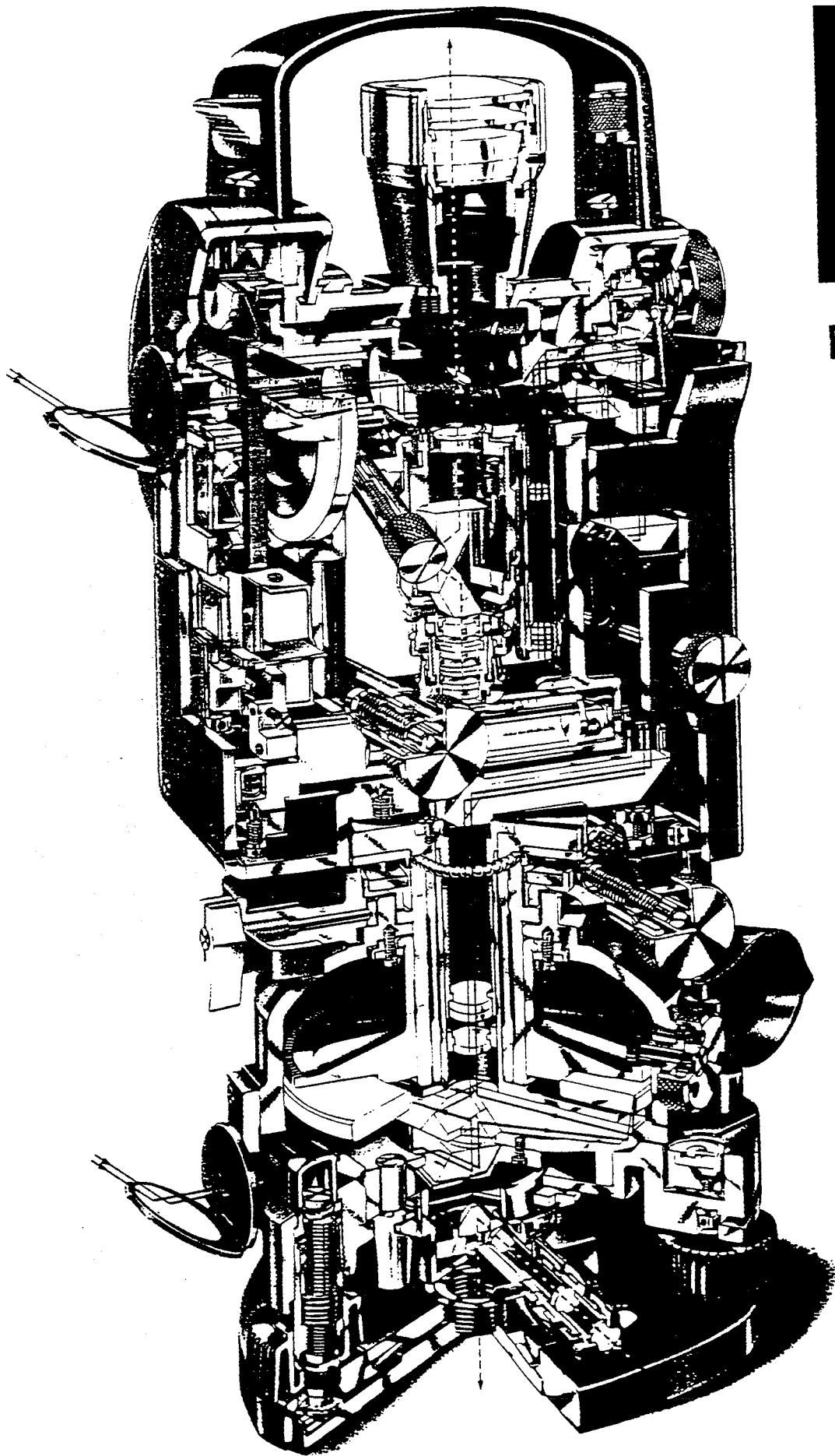
Plotters

- *Precision cutter/plotters*
- *Laser plotters*



Photogrammetry and metrology (Unterentfelden)

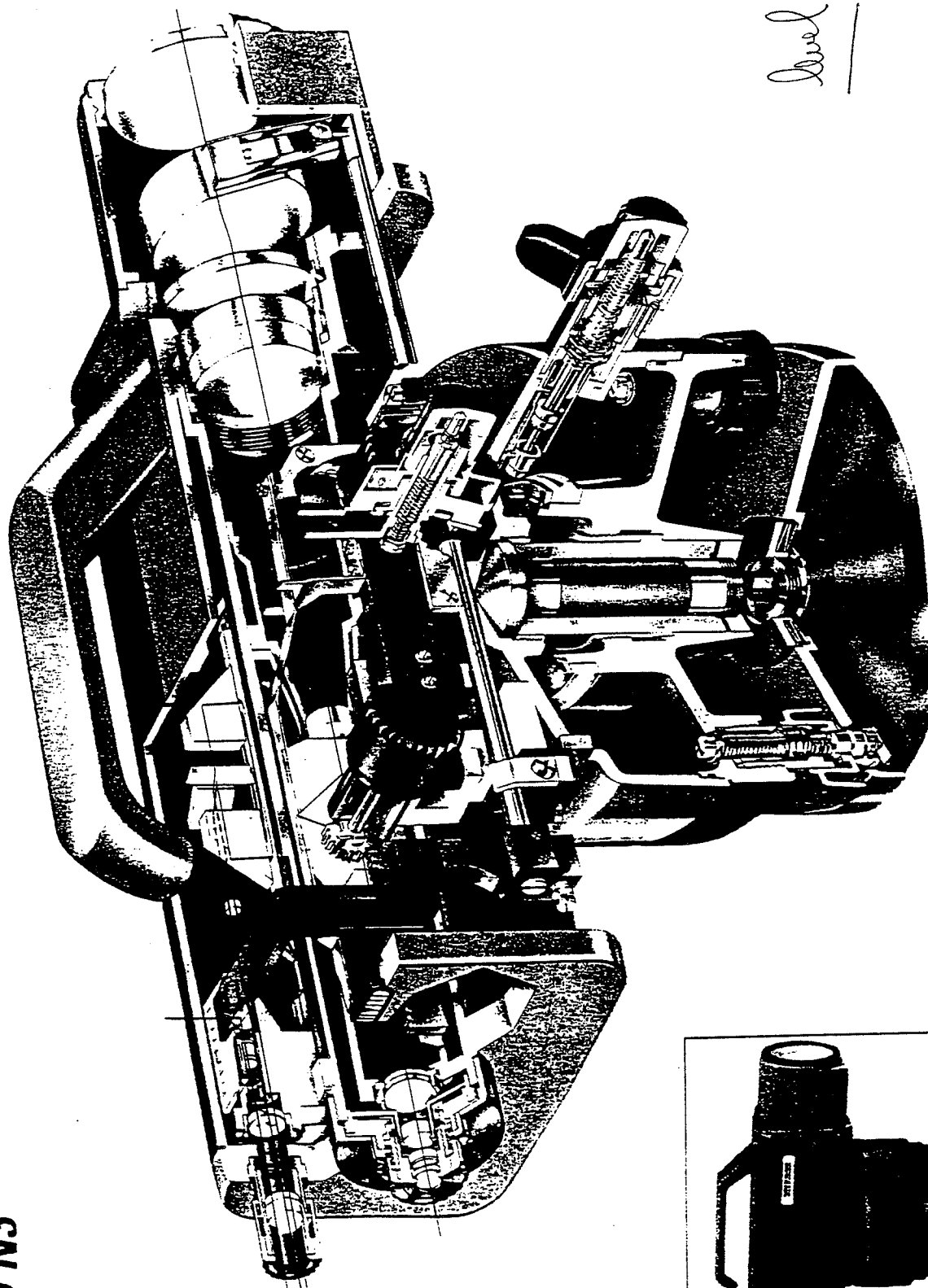
- *Digital and analytical photogrammetry systems*
- *Modular land information systems*
- *Civilian monitoring systems*
- *Automated measuring systems*



WILD T2

Leica

level



WILD N3



WILD BIG2

Night-vision goggles

Image intensifier tube

Rotary switch
'OFF ON. IR'

Locking pin
pressure
for 'R position'

Drive sleeve
(diatric setting)

Main objective
distance setting

IR indicator

Infrared light source
LED

Lens protecting cap
(with diopter for
daylight use)

Clamping
screw for face mask

Eyeieces

Neck cord

Eye-base
adjustment drive

Battery

Housing

Night vision

Leica

CEMOT

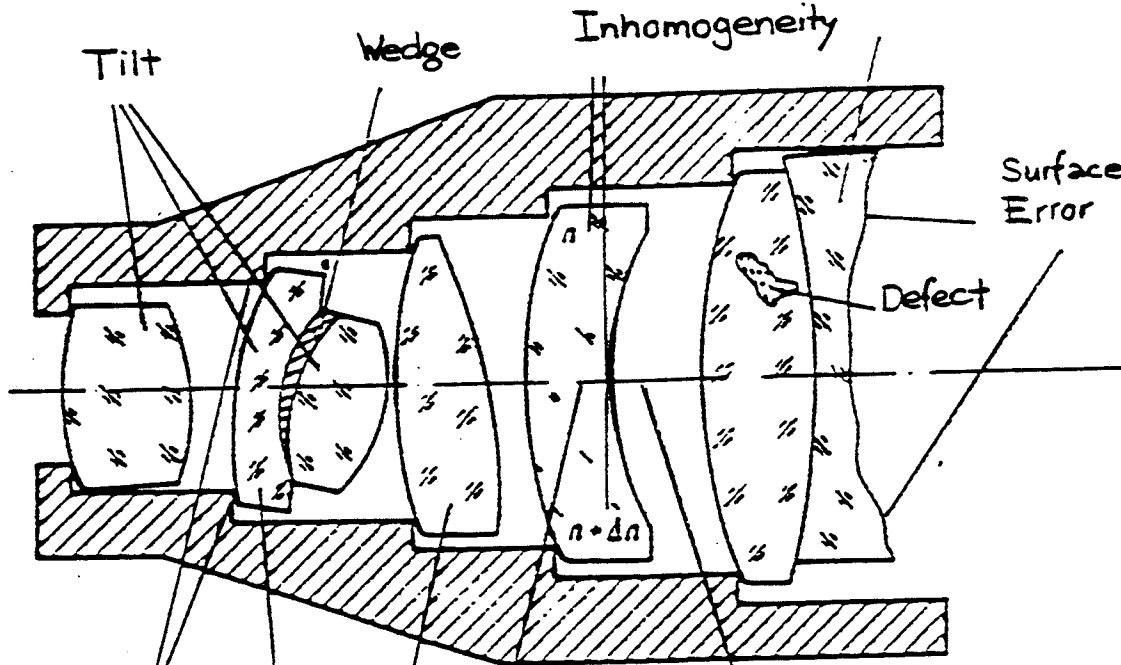
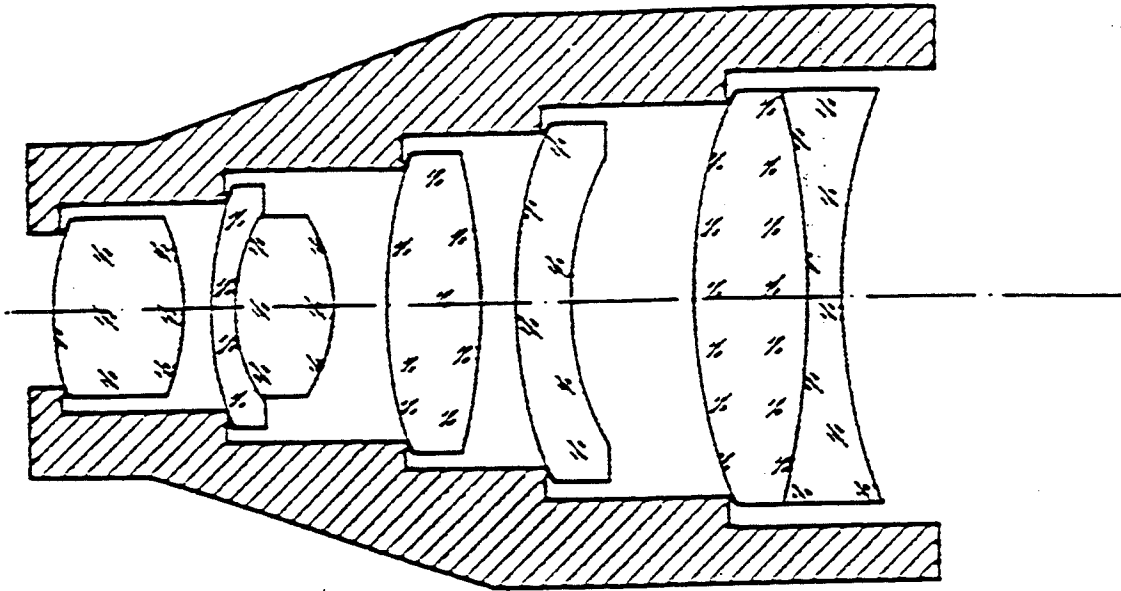
Study of

Cementing and Mounting

Technologies for Laser

Communication Optics

Errors in Optical Systems



Transmission loss
Veiling glare.

2. DEFINITIONS

Reported from document Requirement specification for mounting/cementing technologies for space optics. ESA XA89/141/RC, Issue 1, 12.6.89

- OPTICAL CEMENT *fine cement*
Optical cement is an highly transparent adhesive used to bond two optical elements at their optical effective surfaces. The cement forms part of the optical path.

- CEMENTED OPTICAL ELEMENT
A cemented optical element consists of at least two components bonded together with optical cement in glass-to-glass contact.

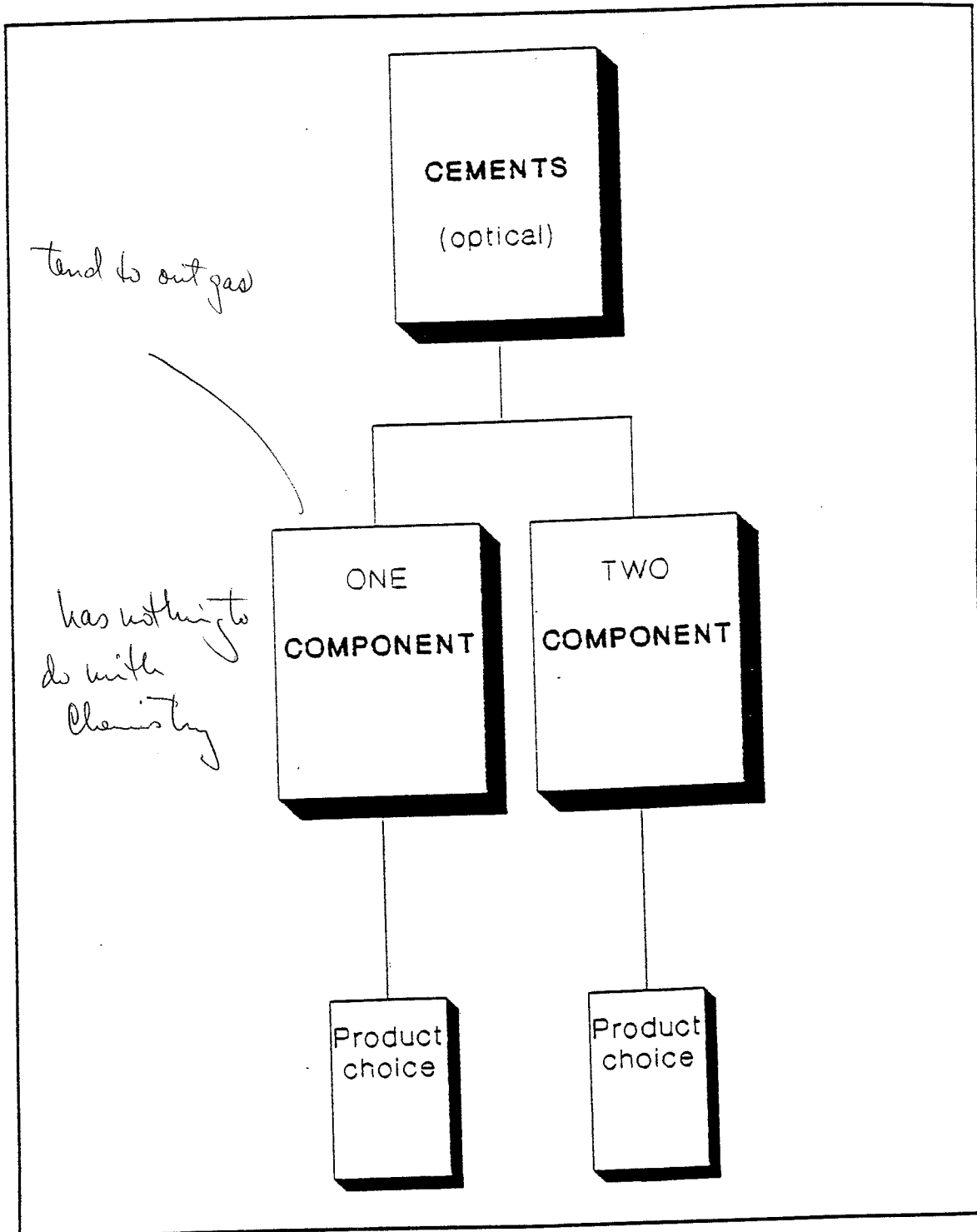
adhesion not too important large area, protected

- MOUNTED OPTICAL ELEMENT
A mounted optical element is an optical component, either cemented or not, which is fixed in a holder consisting of metal, ceramic, plastic or similar. This element forms part of a larger assembly in higher integration status.

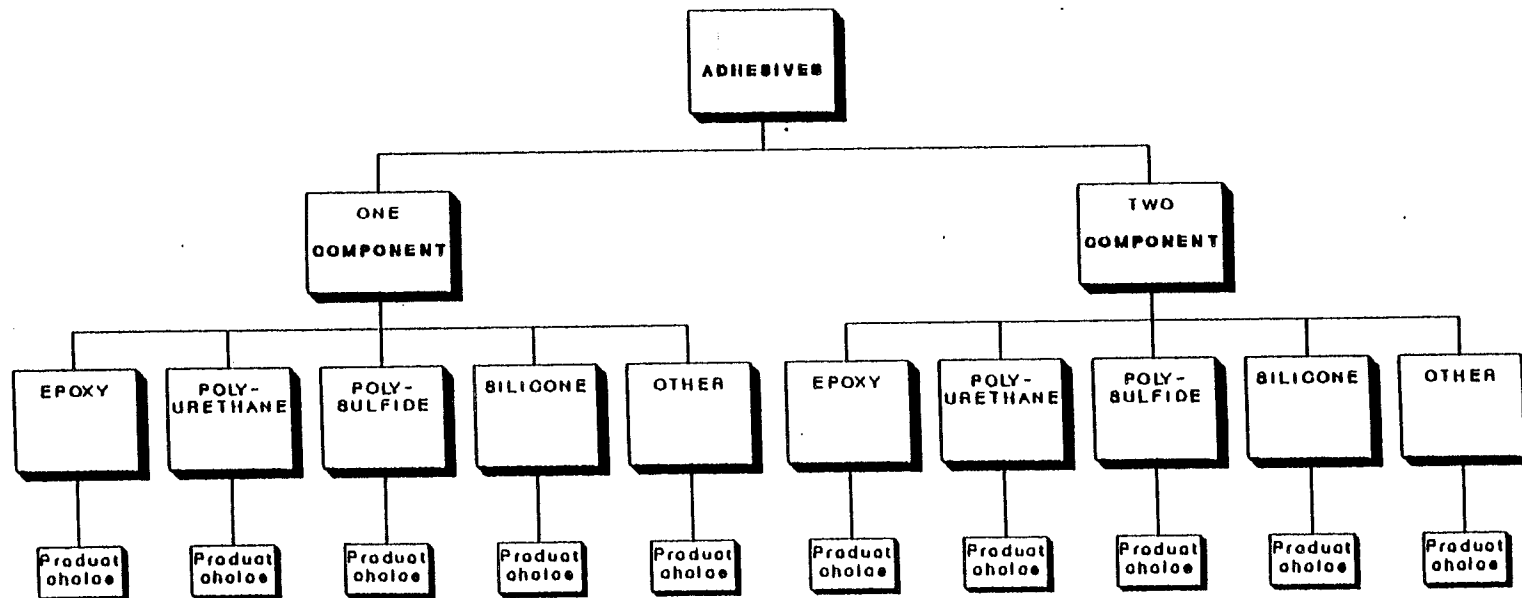
uses adhesive where adhesion is important

Small area, exposed to environment

Selected Cements and Adhesive for Testing



Selected Cements and Adhesive for Testing



Evaluation Criteria of the Adhesives and Cements

did survey of suppliers got ~ 300 responses

—in-house experience on adhesives for optical mounting and cementing

—know properties of the adhesives like:

hardness

mechanical strength

level of qualification (e.g. MIL) ⁵⁹²⁰ ~~5192~~

—application

curing condition

limited by component to ~ 80°C

viscosity

higher for prototype
lower for production

—reliability of the supplier

no gas permeability measurements

Material Data Catalogue

Evaluation Criteria of the Adhesives and Cements

Selected Cements and Adhesives for Testing

Material Data Sheet of the Cements

Material Data Sheet of the Adhesives

Selected Cements and Adhesive for Testing

SELECTED CEMENTS AND ADHESIVES FOR TESTING

← glass to glass

1. CEMENTS

1.1 ONE COMPONENT

<u>TRADE NAME</u>	<u>MANUFACTURER</u>
Delo-Photobond 310	Delo K.-Chemie GmbH & Co KG, BRD
Delo-Photobond 330	Delo K.-Chemie GmbH & Co KG, BRD
Gupalon UV 4532	Gusselit GmbH & Co, BRD
Lens-Bond UV 71	Summers Laboratories, Cot.-Div., USA
Lens-Bond UV 74	Summers Laboratories, Cot.-Div., USA
NCA 61	Norland Products Inc. NJ, USA
NCA 65	Norland Products Inc. NJ, USA
NCA 81	Norland Products Inc. NJ, USA
Vitralit 1731	3M Adhesive, Coat.and Seal. Div. USA
Vitralit 2000	3M Adhesive, Coat.and Seal. Div. USA
Vitralit 7104	3M Adhesive, Coat.and Seal. Div. USA

Selected Cements and Adhesive for Testing

1.2 TWO COMPONENT

<u>TRADE NAME</u>	<u>MANUFACTURER</u>
Araldite CY221 + HY2966	Ciba-Geigy AG, Basel, CH
Araldite XW396 + XW397	Ciba-Geigy AG, Basel, CH
Eccobond Z4	Grace, Emerson & Cuming, USA
Epo-Tek 301	Epoxy Technology Inc. USA
Epo-Tek 302-3	Epoxy Technology Inc. USA
Epo-Tek 305	Epoxy Technology Inc. USA
Epo-Tek 314	Epoxy Technology Inc. USA
Lens-Bond C59	Summers Laboratories, Opt.-Div., USA
Lens-Bond F65	Summers Laboratories, Opt.-Div., USA
Lens-Bond M62	Summers Laboratories, Opt.-Div., USA
Lens-Bond R33-74	Summers Laboratories, Opt.-Div., USA
Stycast 1266 A-B	Grace, Emerson & Cuming, USA

1.3 SILICONE

<u>TRADE NAME</u>	<u>MANUFACTURER</u>
Rhodorsil-RTV 141	Phone-Poulenc chimie fine, F

do not use because it causes problems in other areas - coatings and adhesions with other adhesives

Selected Cements and Adhesive for Testing

← glass to mount

2. ADHESIVES

2.1 ONE COMPONENT

2.1.1 EPOXYS

<u>TRADE NAME</u>	<u>MANUFACTURER</u>
Eccobond 927-10E	Grace, Emerson & Cuming, USA
Eupalon Mono 3531	Gusselit GmbH & Co. BRD
Insul-Bond Epoxy 14	Transene Company, Inc. USA
Vitralit 1550	3M Adhesive, Coat. and Seal. Div. USA
Vitralit 1722	3M Adhesive, Coat. and Seal. Div. USA

2.1.2 POLYURETHANE

<u>TRADE NAME</u>	<u>MANUFACTURER</u>
Bostik 2634	Bostik GmbH, Ennart Chemical Grp. CH
Gomastit 800	Merz + Benteli AG, CH
Sikaflex 360HC	Sika AG, Industrie Division, CH

Selected Cements and Adhesive for Testing

2.1.4 SILICONE

others release acid - causes corrosion

TRADE NAME

MANUFACTURER

Dow Corning 3145 RTV

Dow Corning Europe, Brussel, B

releases just alcohol

2.1.5 OTHER TYPE

TRADE NAME

MANUFACTURER

Delo-Photobond 440

Delo K.-Chemie GmbH & Co KG, BRD

Vitralit 6129VT

3M Adhesive, Coat. and Seal. Div. USA

Vitralit 6102

3M Adhesive, Coat. and Seal. Div. USA

2.2 TWO COMPONENT

2.2.1 EPOXYS

Good bond

TRADE NAME

MANUFACTURER

Araldite AV138M - HV998

Ciba-Geigy AG, Basel, CH

Araldite AW106 - HV953U

Ciba-Geigy AG, Basel, CH

Araldite AW136N - HY994

Ciba-Geigy AG, Basel, CH

Araldite AY103 - HY953F

Ciba-Geigy AG, Basel, CH

Araldite AY103 - HY956

Ciba-Geigy AG, Basel, CH

Araldite CY221-30TX - HY2966

Leica Heerbrugg AG, Heerbrugg, CH

Selected Cements and Adhesive for Testing

<u>TRADE NAME</u>	<u>MANUFACTURER</u>
Armstrong A-12	Armstrong Products Co. Inc., USA
Armstrong A-12-T	Armstrong Products Co. Inc., USA
Eccobond 45 - Catalyst 15	Grace, Emerson & Cuming, USA
Epicote 828 - Epicure V125	Deutsche Shell Chemis, Eschborn, FRG
Epo-Tek H74	Epoxy Technology, Inc. USA
Gupalon Normal	Gusselit GmbH & Co, FRD
Hysol 11C	Hysol Division The Dexter Corp. USA
Hysol 0151	Hysol Division The Dexter Corp. USA
Hysol EA 932 NA	Hysol Division The Dexter Corp. USA
Hysol EA 9394	Hysol Division The Dexter Corp. USA
Hysol ES 4412	Hysol Division The Dexter Corp. USA
Koeradox 438	Kömmerring Chemische Fabrik KG, FRD
Milbond Part A + B	Summers Laboratories, Opt.-Div., USA
Scotch Weld 1614 B/A	3M Adhesive, Coat. and Seal. Div. USA
Scotch Weld 2216 B/A	3M Adhesive, Coat. and Seal. Div. USA
Stycast 2057 + Catalyst 9	Grace, Emerson & Cuming, USA
Thermodit S1005 Part A+B	Raychem Limited Thermodit Europe, GB

Problem with humidity ^{on} surface

2.2.2 POLYURETHANE *reduces adhesion*

<u>TRADE NAME</u>	<u>MANUFACTURER</u>
Uralite 3132	Hexel Corp., Chemical Products, USA

gives up with time

Test Program for Optical Cements

1.
Cements

for glass to glass - so opt. properties

Optical Properties

- Refraction Index
- Spectral Dispersion
- Spectral Transmission
- Fluorescence
- UV Resistance
- Ion. Rad. Resistance

but not as used
given in liquid state same

often poorly documented

important in space

P. 22

Mechanical Properties

- Hardness
- Tension/Bending Test

did not measure shrinkage because hard to measure (really want to know deformation of cement element)

Thermal Properties

- Therm. Exp. Coeff.
- Softening
- Outgassing

varies with temperature

Chemical Properties

- Solvent Resistance
- Toxicity
- Fungus Resistance

Test Program for Mounting Adhesives

2.
Adhesives

glass to mount

**Mechanical
Properties**

Hardness

Tension/Bending
Test

**Thermal
Properties**

Therm.Exp.Coeff.

Softening

Outgasing

**Chemical
Properties**

Solvent
Resistance

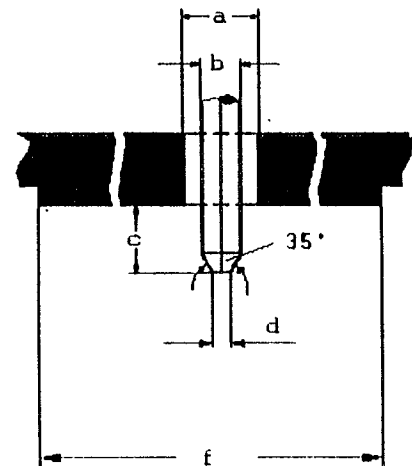
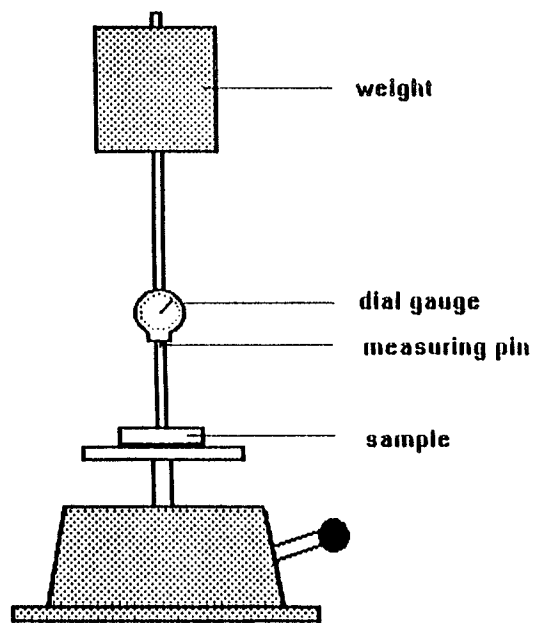
Toxicity

Fungus
Resistance

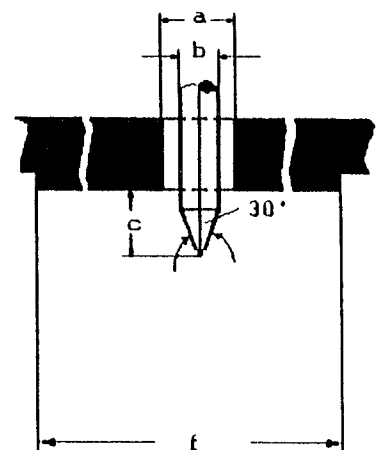
*← important but
difficult to measure*

Hardness - Procedure

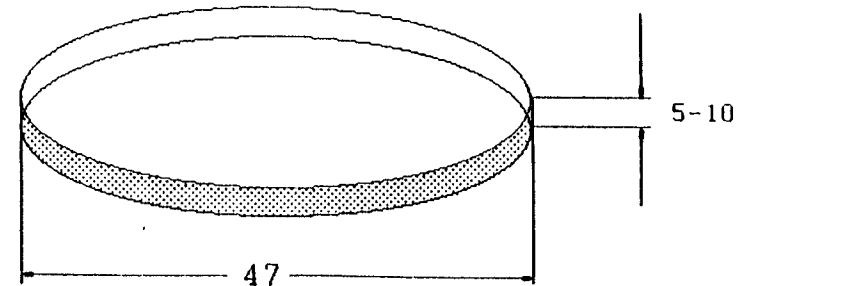
*depends on plasticity
because depends on time*



Shore A



Shore D



Sample plate for optical cements and adhesives

The equipment for measuring Shore A and D

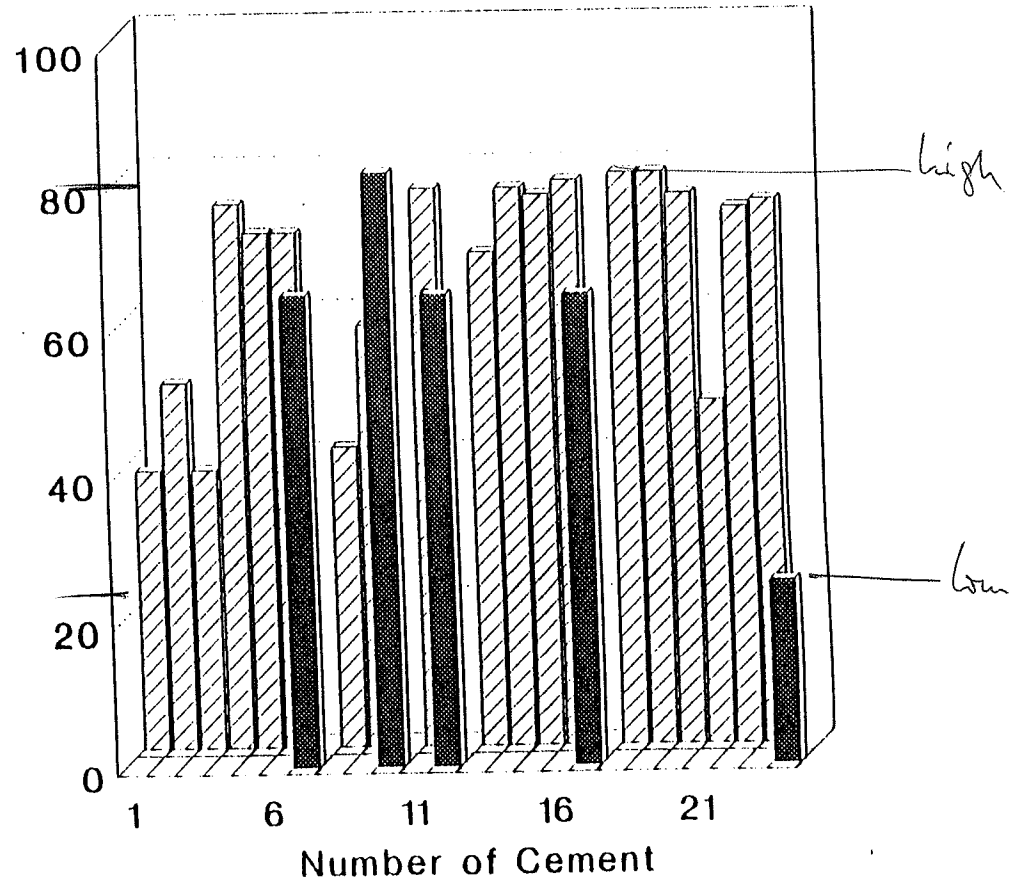
measure at room temperature

in production, thickness of cement layer
not controlled

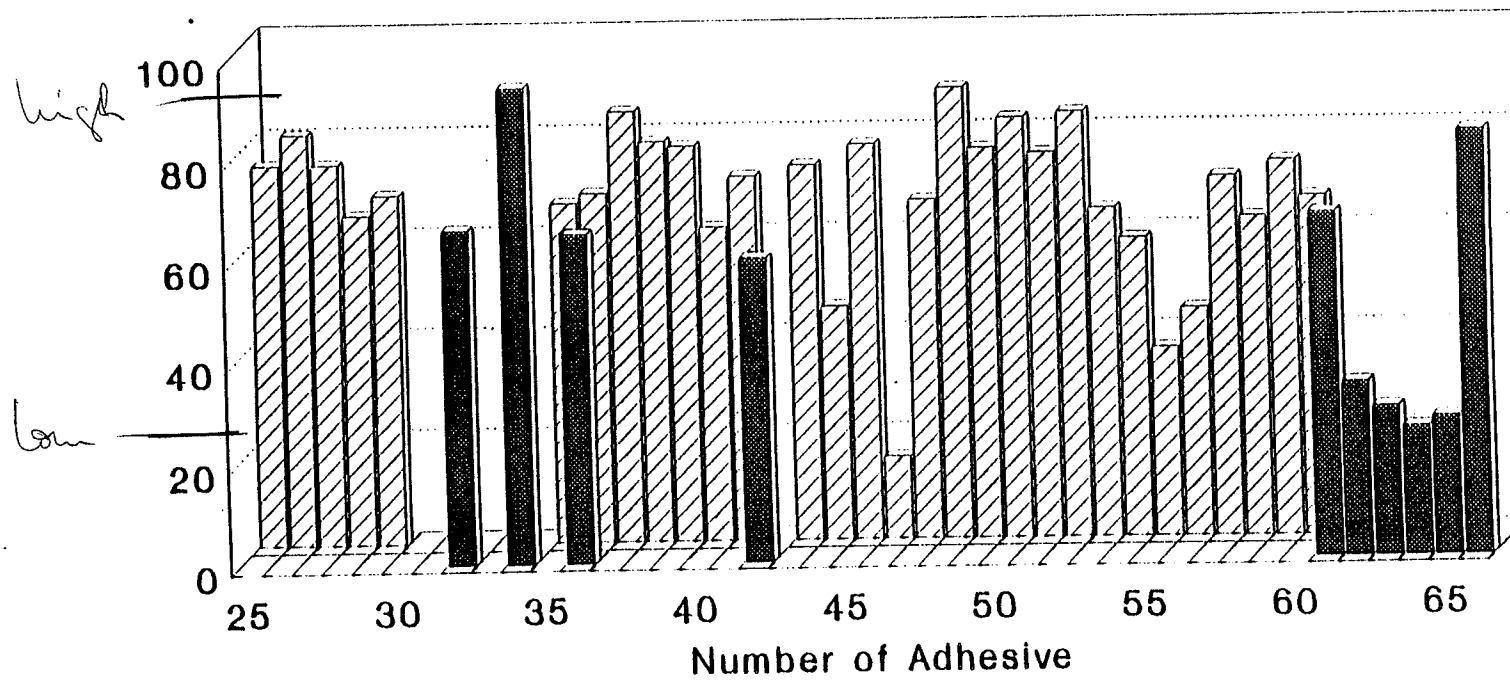
Hardness - Results for the Cements

May not be absolute
but all measured under
same conditions

Mechan. Properties
▨ Hardness Shore D
■ Hardness Shore A



Hardness - Results for the Adhesives



Mechan. Properties

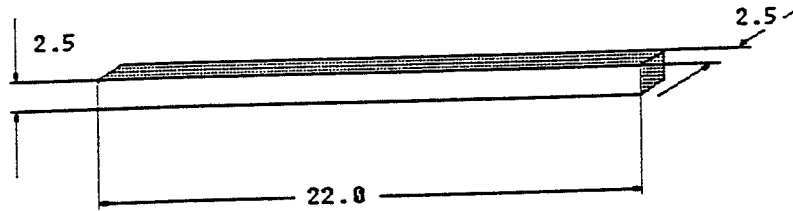
■ Hardness Shore A

▨ Hardness Shore D

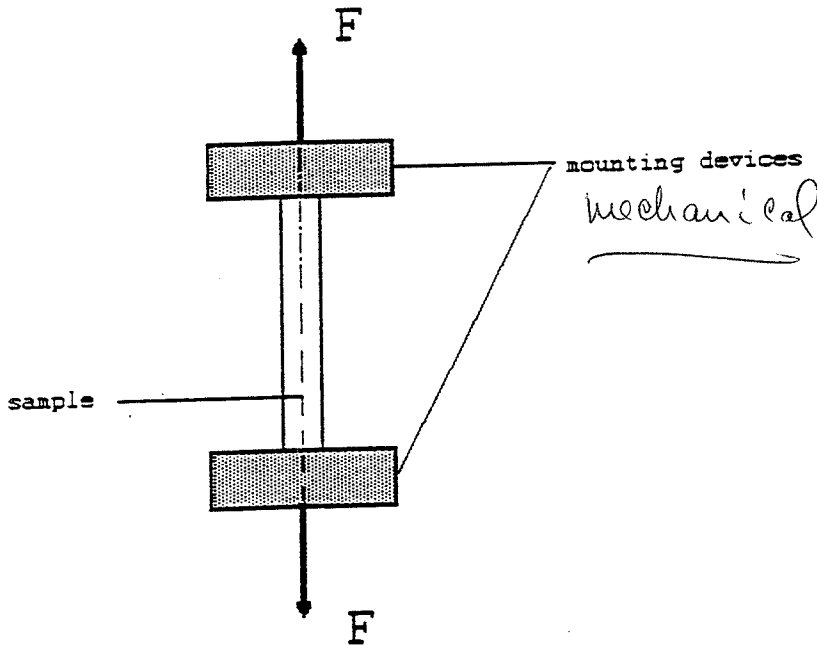
for soft

for hard ones

Tension/Bending - Procedure

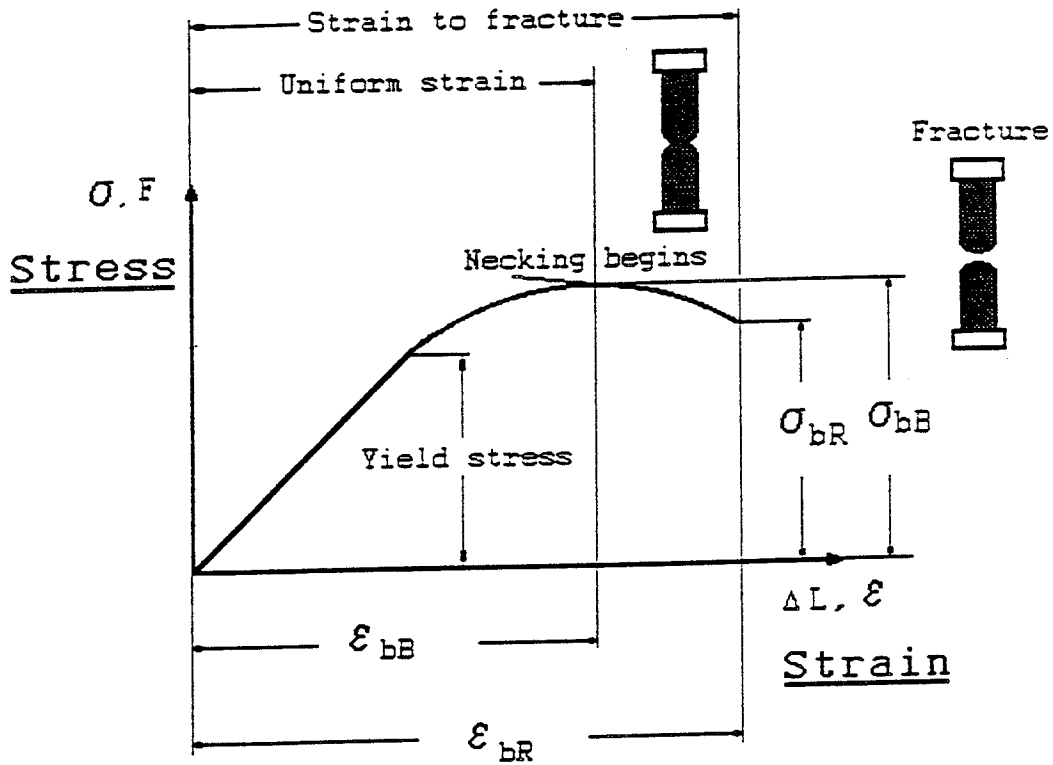


The shape of the sticks for the tension and bending test



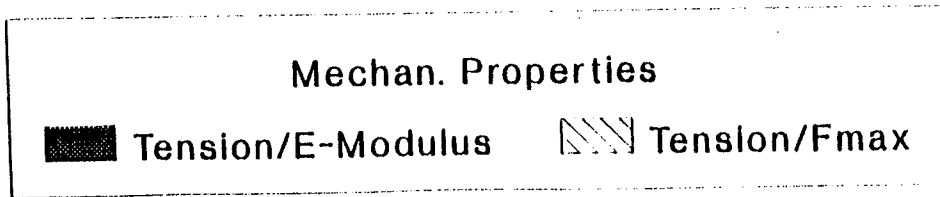
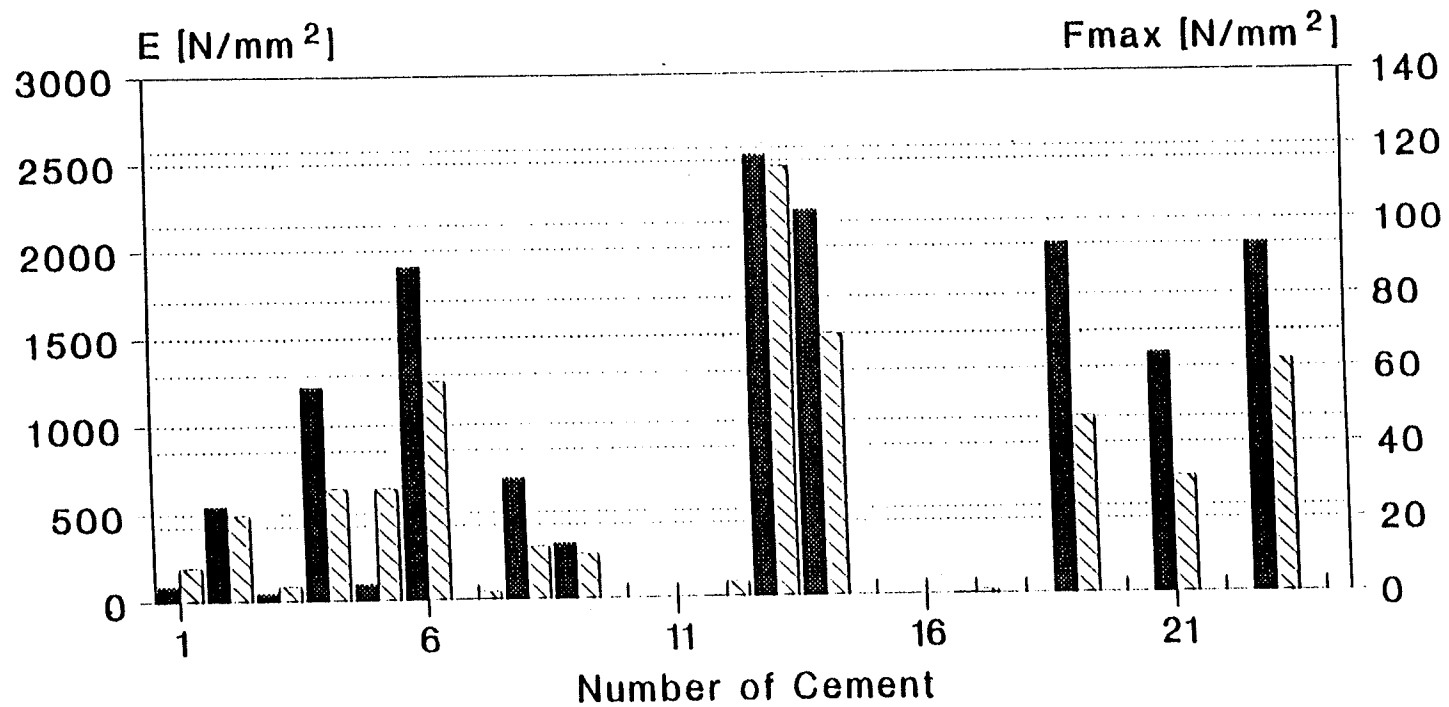
schematic of the force induction at the sample during a tension test

Selected Cements and Adhesive for Testing



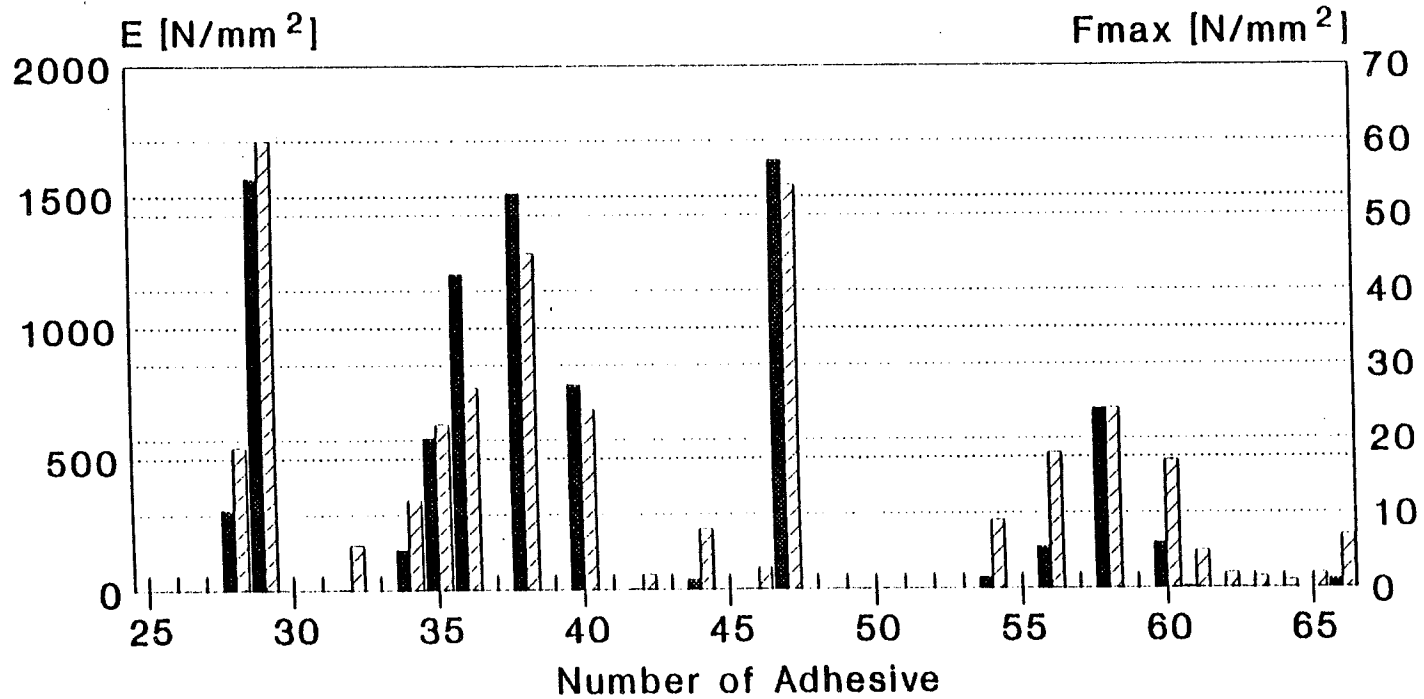
The stress-strain-Diagram of a tension experiment (H.E. Boyer, T.L. Gall; Metals Handbook Desk Edition American Society for Metals, Metals Park Ohio, 1985).

Mechanical Properties of the Cements Tension Test



use in part at for Adhesives because may be used toward limit

Mechanical Properties of the Adhesives Tension Test



Mechan. Properties

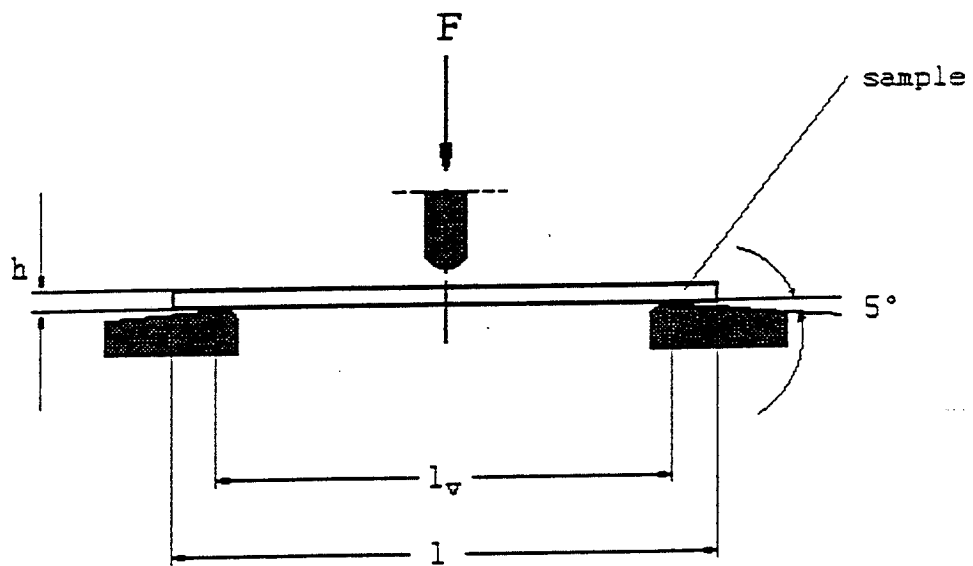


Tension/E-Modulus



Tension/Fmax

Selected Cements and Adhesive for Testing

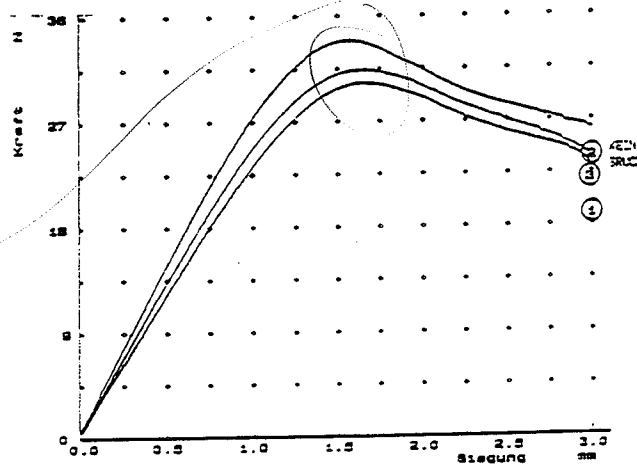


Schematic presentation of the bending-test

Prüfung : Biegeversuch FTL-Nr. : 902987
 Bezeichnung : NOA 61
 Art.-Nr. : 431508
 Material : Cement
 Datensatz TRS: 8: 90298702
 Prüfer : T.Nussebaumer

PARAMETER :
 Prüfkraft :
 Vorkraft F_v : 0.1 N
 Prüfungsgeschwindigkeit : 8 mm/min
 Stützweite l_v : 20 mm
 Beginn Sekantenmodul l₁ : 0.2 mm
 Ende Sekantenmodul l₂ : 0.8 mm

n	Dicke mm	Breite mm	Maximalkraft N	Durchbiegung mm	F _{max} N/mm ²	E-Modul N/mm ²
1	2.28	2.30	33.9	0.97	85.0	1573.8
2	2.22	2.28	31.4	0.97	83.8	1508.1
3	2.23	2.24	30.3	1.08	81.8	1483.2



n	Dicke mm	Breite mm	Maximalkraft N	Durchbiegung mm	F _{max} N/mm ²	E-Modul N/mm ²
STATISTIK : n = 3						
X	2.24	2.27	31.9	0.98	83.8	1508.1
S	0.03	0.03	1.8	0.02	1.7	85.5
V	1.43	1.34	5.78	1.82	2.08	3.40

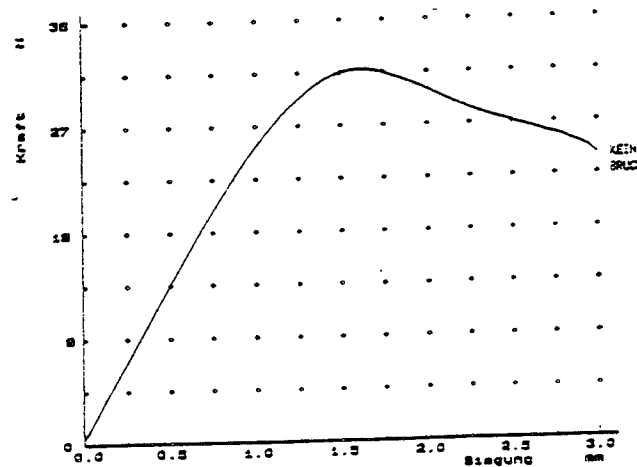
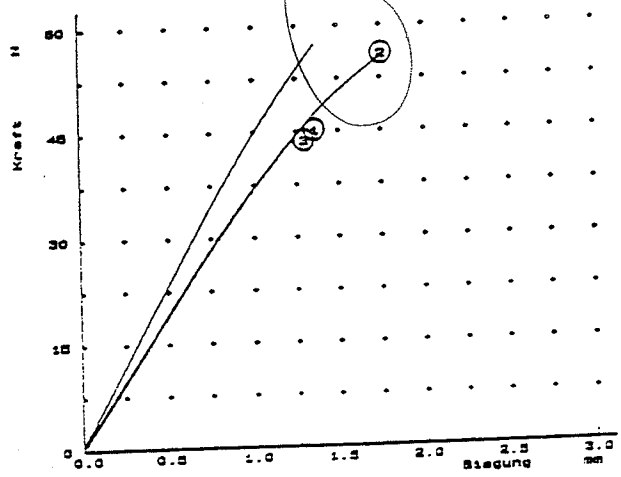


Fig.7.3.3.1.11 Stress and strain diagram of the cement No.6
 NOA 61 (Bend Test)

Prüfung : Biegeversuch FTL-Nr. : 902178
 Bezeichnung : EPO-TEK 314
 Art.-Nr. :
 Material : Cement
 Datensatz TRS : 90217801
 Prüfer : T.Nussebaumer

PARAMETER :
 Prüfart :
 Vorkraft F v : 0.1 N
 Prüfgeschwindigkeit : 200 mm/min
 Stützweite l v : 200 mm
 Beginn Sekantenmodul "1" : 0.2 mm
 Ende Sekantenmodul "1" : 0.8 mm

n	Dicke mm	Breite mm	Maximalkraft N	Durchbiegung mm	Bruchkraft N	Bruchdehnung %	F _{max} N/mm ²	E-Modul N/mm ²
1	2.23	2.38	57.5	1.28	57.5	4.84	126.4	3023.8
2	2.22	2.24	53.7	1.30	53.7	5.98	151.5	3038.0
3	2.22	2.24	46.1	1.24	46.1	4.38	126.4	3043.4



rigid

n	Dicke mm	Breite mm	Maximalkraft N	Durchbiegung mm	Bruchkraft N	Bruchdehnung %	F _{max} N/mm ²	E-Modul N/mm ²
STATISTIK : n = 3								
X	2.22	2.28	53.1	1.34	53.1	4.88	126.4	3038.4
S X	0.01	0.25	6.1	0.14	6.1	0.84	14.0	10.3
Y	0.25	10.84	11.31	10.41	11.31	15.88	10.37	0.34

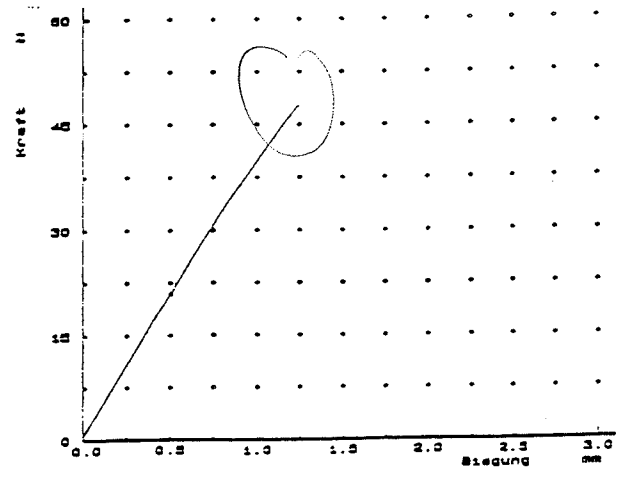
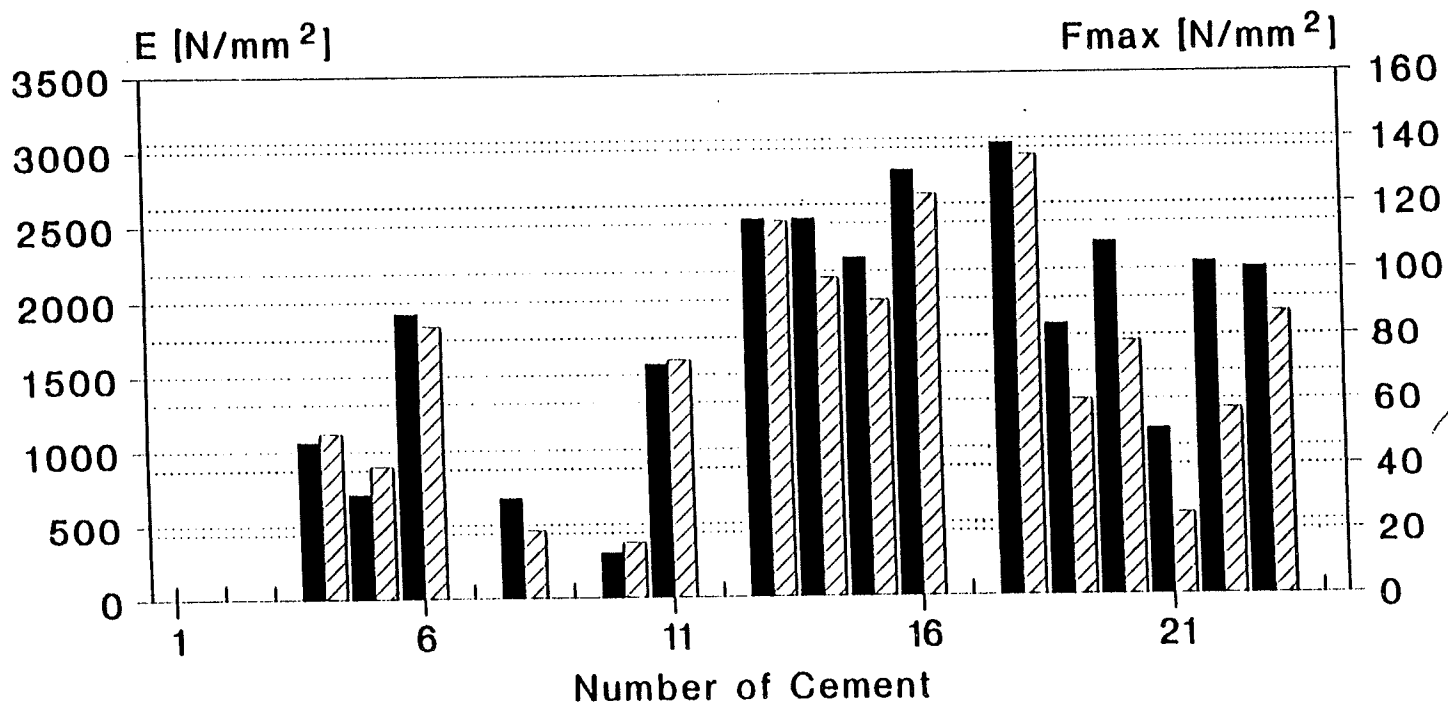
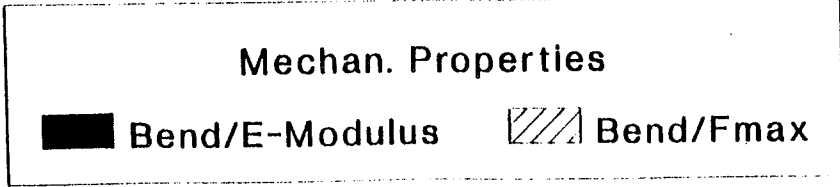


Fig.7.3.3.1.13 Stress and strain diagram of the cement No.18
 EPO-TEK 314 (Bend Test)

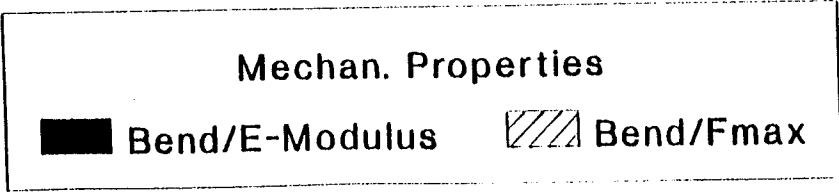
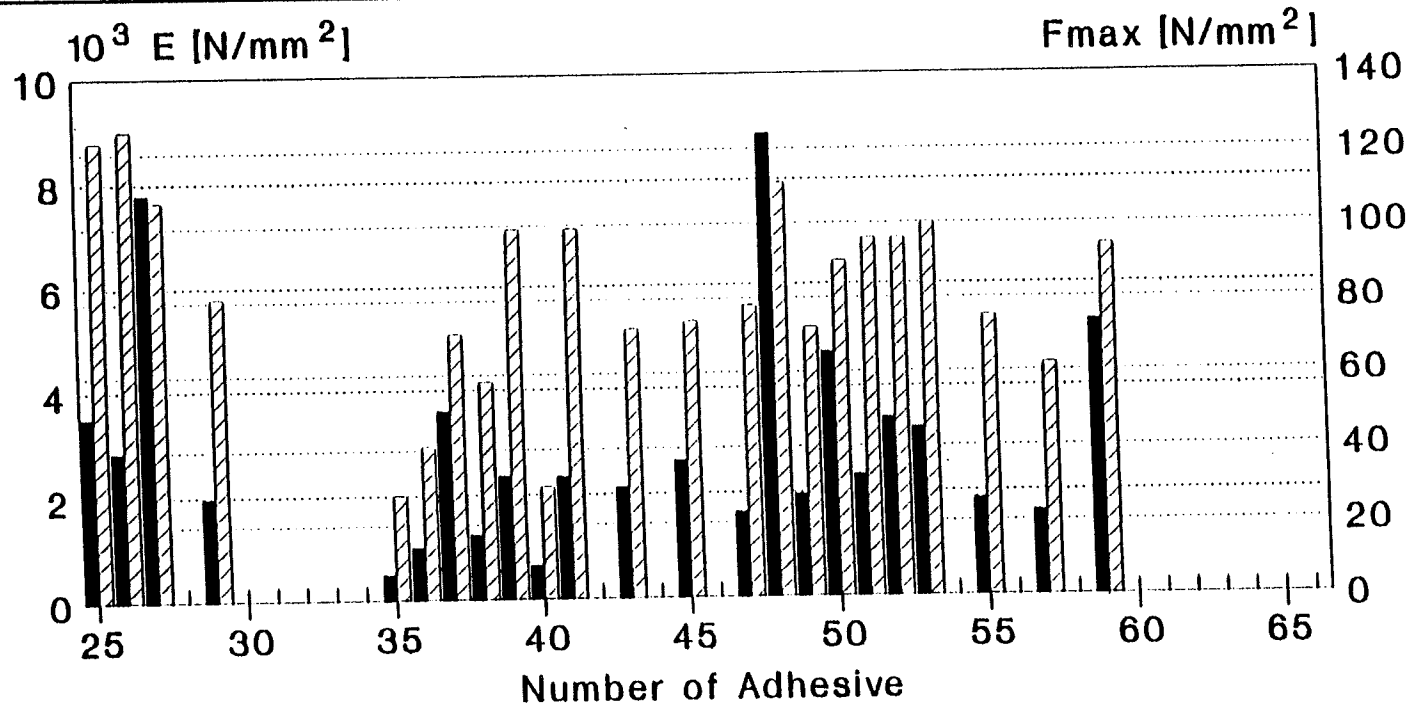
Mechanical Properties of the Cements Bend Test



*over 35 N/mm²
glass breaks first*



Mechanical Properties of the Adhesives Bend Test



Thermal Properties

Thermal Expansion Coefficient

Thermal Expansion Coefficient - Procedure

Thermal Expansion Coefficient - Results for the Cements

Thermal Expansion Coefficient - Results for the Adhesives

Softening

Softening - Procedure

Softening - Results for the Cements

Softening - Results for the Adhesives

Outgassing

Outgassing (TML Leica) - Procedure

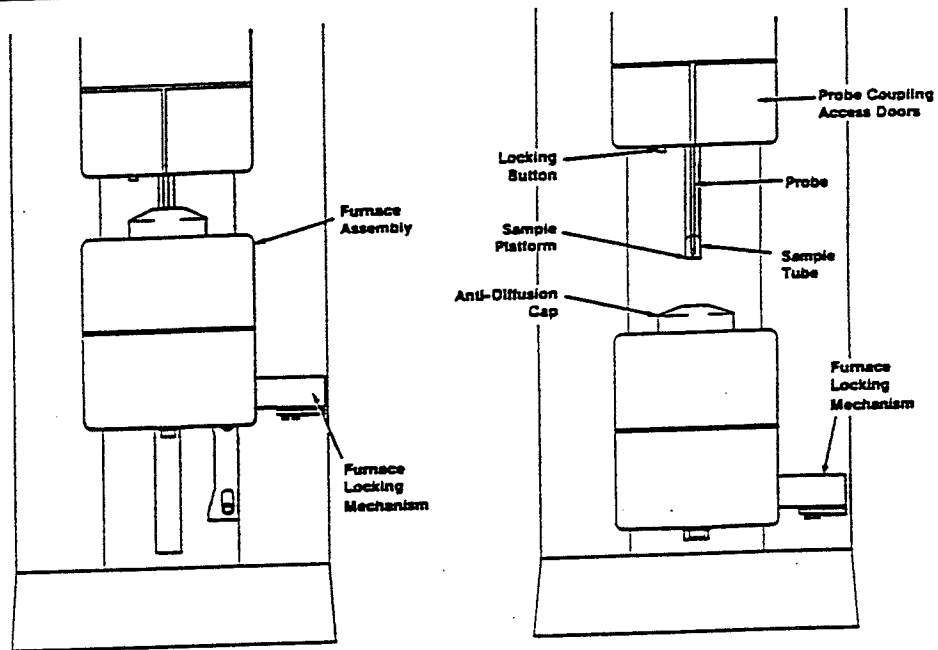
Outgassing (TML Leica) - Results for the Cements

Outgassing (TML Leica) - Results for the Adhesives

Outgassing - Results published in literature

Outgassing - Test of Selected Cements and Adhesives

Thermal Expansion Coefficient



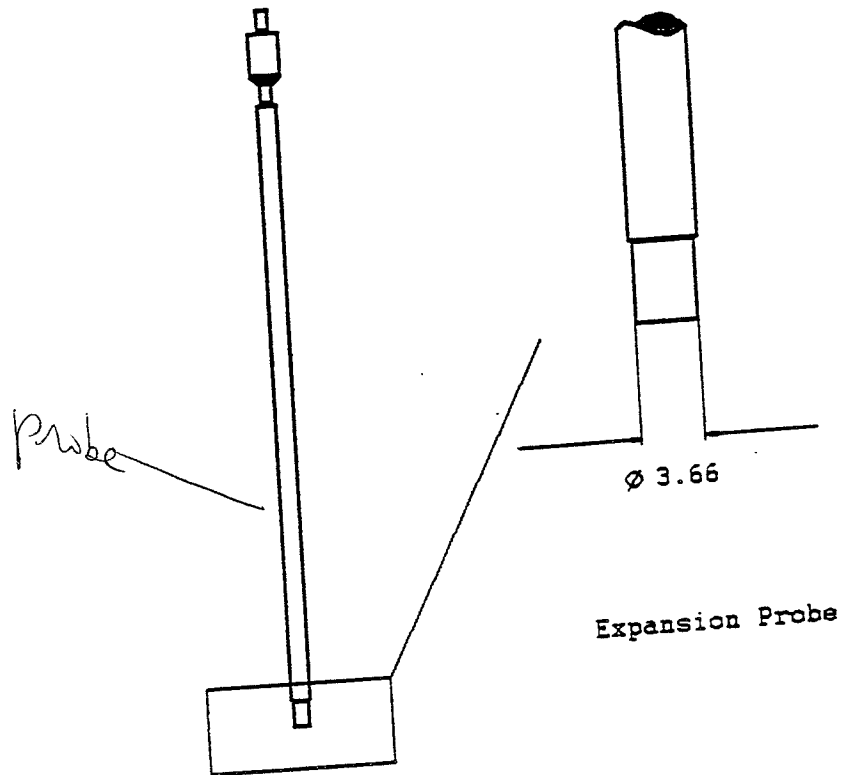
Perkin Elmer

SPECIFICATIONS

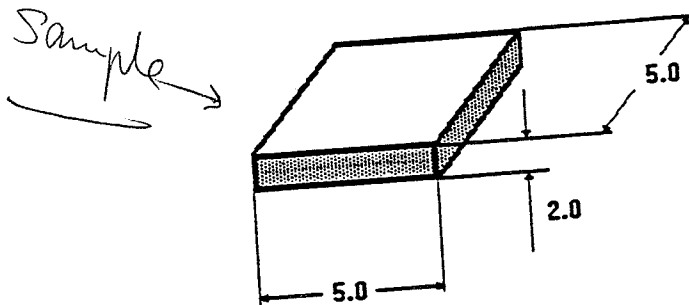
TMA 7 THERMOMECHANICAL ANALYZER

Sensitivity	0.4 $\mu\text{m}/\text{cm}$
Ordinate Linearity	$\pm 0.5\%$ to 1.9 cm (0.75 in)
Sample Size	0.75 cm (0.3 in.) diameter (maximum) 1.91 cm (0.75 in) height (maximum)
Computer Controlled Loading	130 grams raising to 270 grams lowering
Temperature Range	Standard unit allows operation from ambient to 1000°C. With optional accessories the range may be extended to -170°C.
Heating and Cooling Rates	0.1 to 100°C/min. in 0.1°C/min. increments.
Temperature Precision	$\pm 2^\circ\text{C}$
Sample Type	Solids, liquids, powders, films or fibers.
Atmosphere	Static or dynamic including nitrogen, argon, helium, carbon dioxide, air oxygen or other inert or active gases.
Temperature Sensors	Chromel-alumel thermocouple.
Probe Types	Expansion, Penetration, Compression, Flexure, Extension, Dilatometer.

Thermal Expansion Coefficient

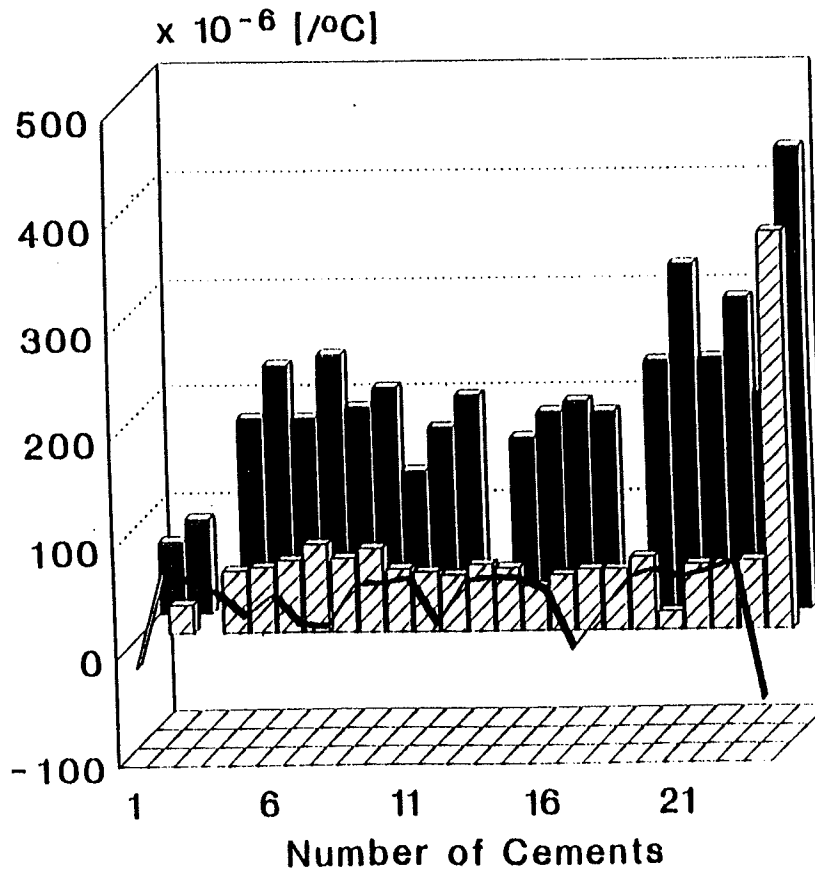


Sample probe for the expansion measurement



sample shape of cements and adhesive for the TMA examination.

Thermal Expansion Coefficient - Results for the Cements



Regions:

■ high Temperature

▨ low Temperature

■ Transition Temp.

above
35/century
pt.

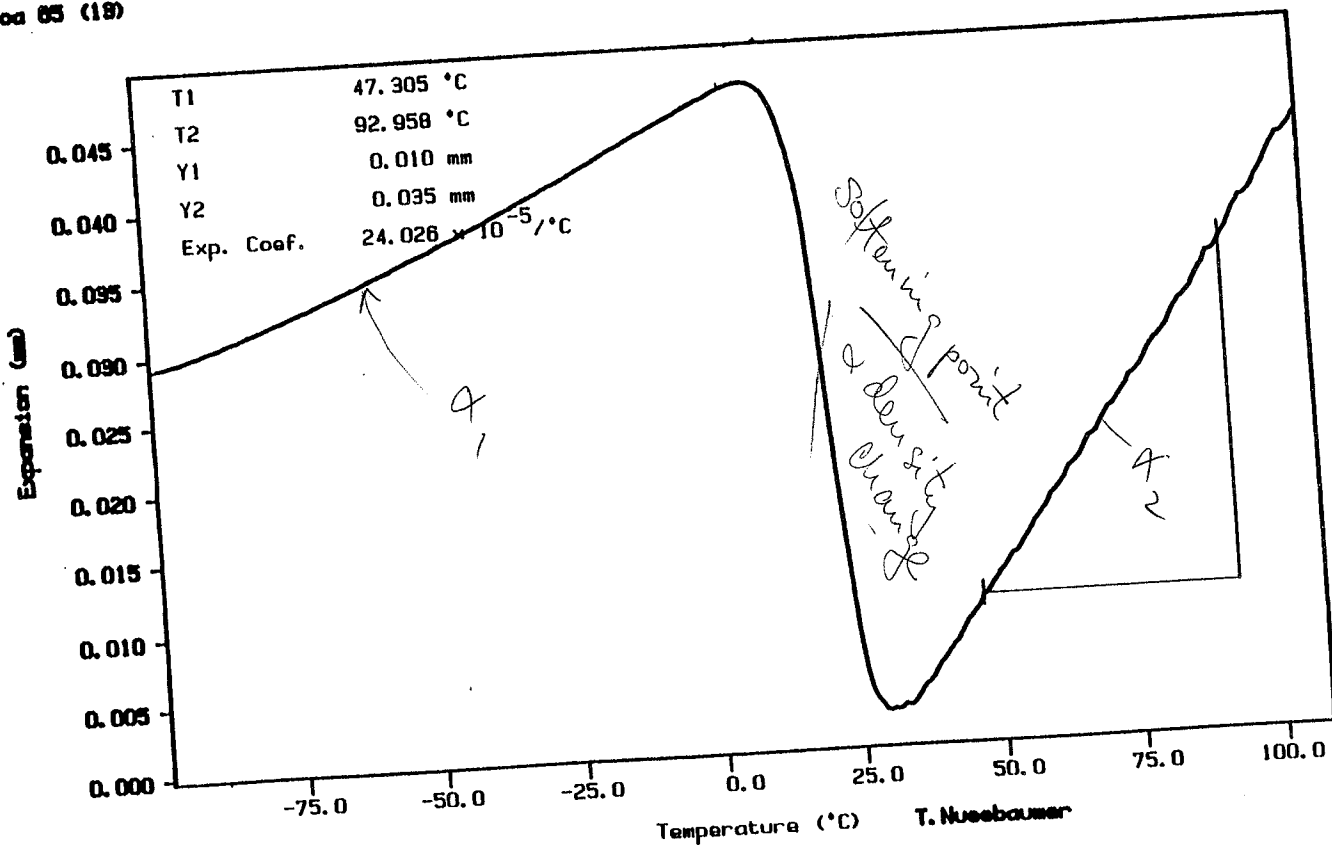
below

$\alpha \approx 100-250$

usually $< 100 \times 10^{-6}$

PERKIN-ELMER
7 Series Thermal Analysis System

TMA File Name: 018
Sample Height: 2.240 mm
Wed Jan 29 18:23:34 1991
No. 65 (18)



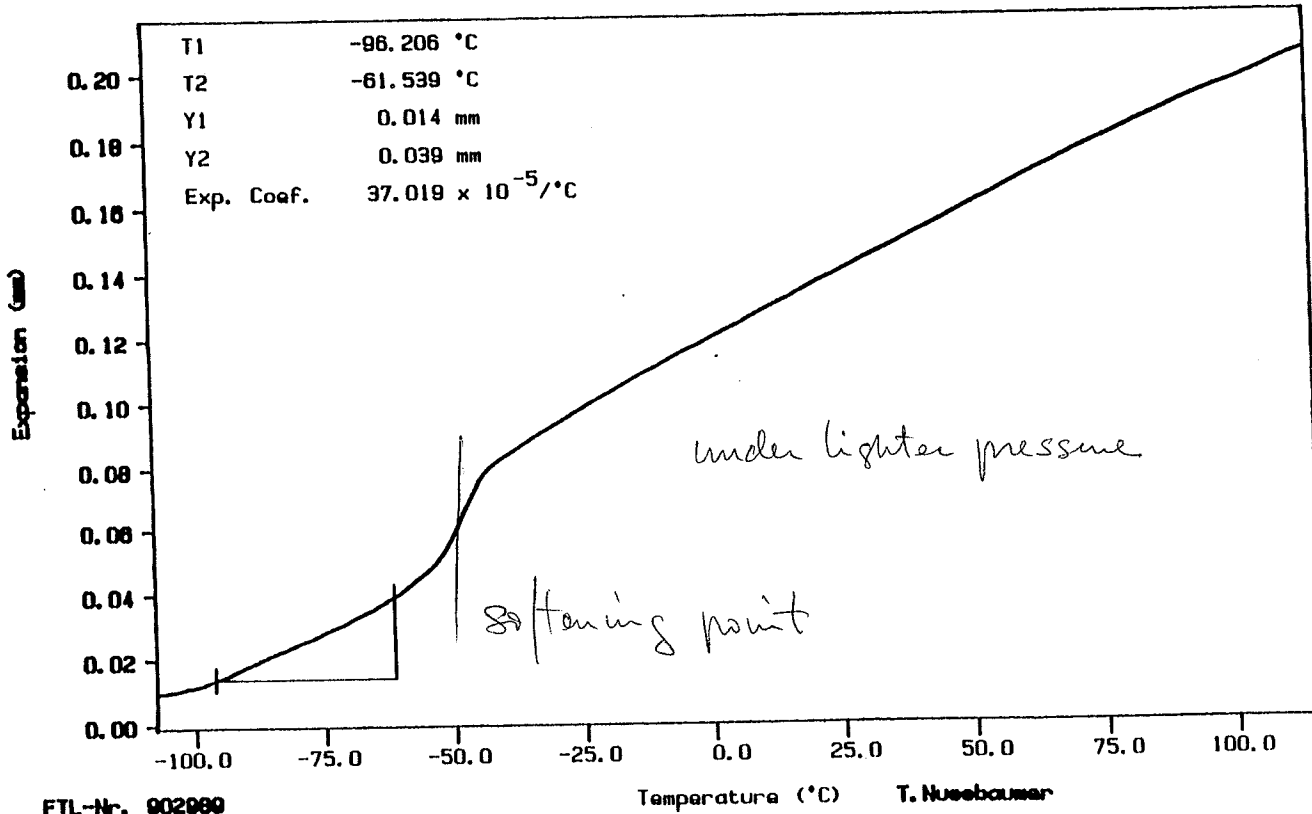
FTL-Nr. 002886
TIME: 182.88 0.0 min RATE: 10.0 C/min

T. Nussbaumer

Fig. 7.4.1.4.1.4 The diagram of the thermal expansion coefficient of the cement (No. 7 NOA 65)

PERKIN-ELMER
7 Series Thermal Analysis System

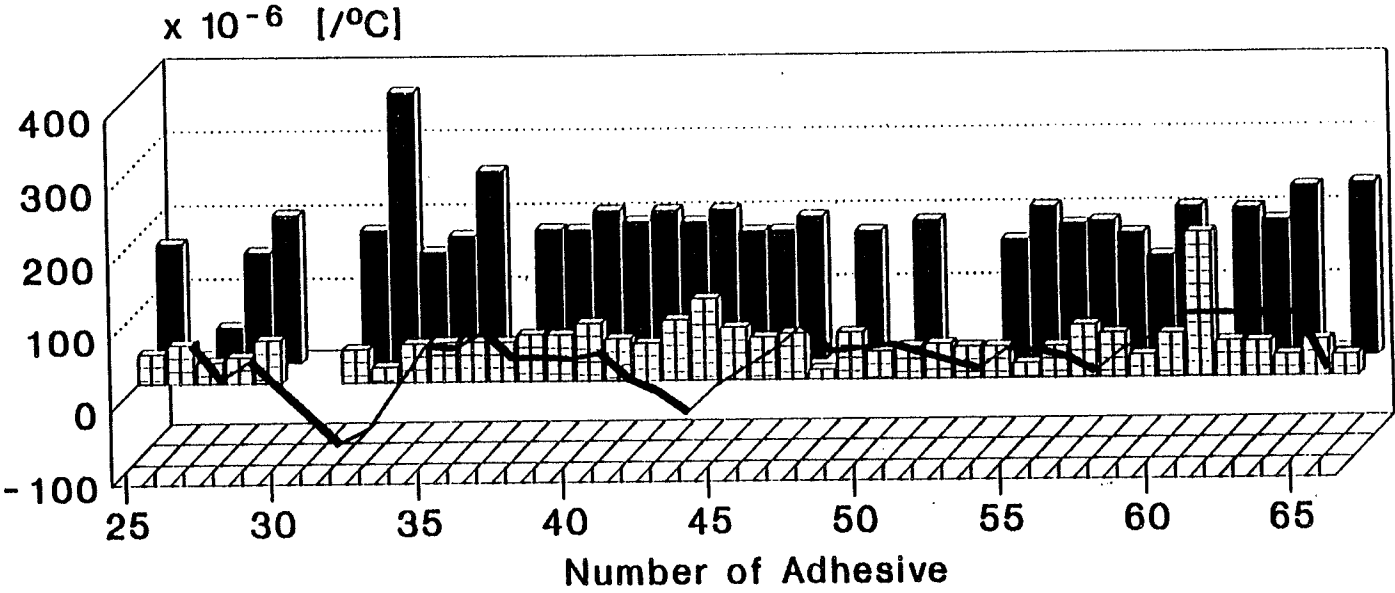
TMA File Name: c89
Sample Height: 1.059 mm
Fri Jan 25 15:16:41 1991
RTV 141 Part A+B (60)



FTL-Nr. 902980
TIME 1: 0.0 min RATE 1: 10.0 C/min

Fig. 7.4.1.4.1.7 The diagram of the thermal expansion coefficient of the cement (No. 24 Rhodorsil RTV)

Thermal Expansion Coefficient - Results for the Adhesives



Regions:

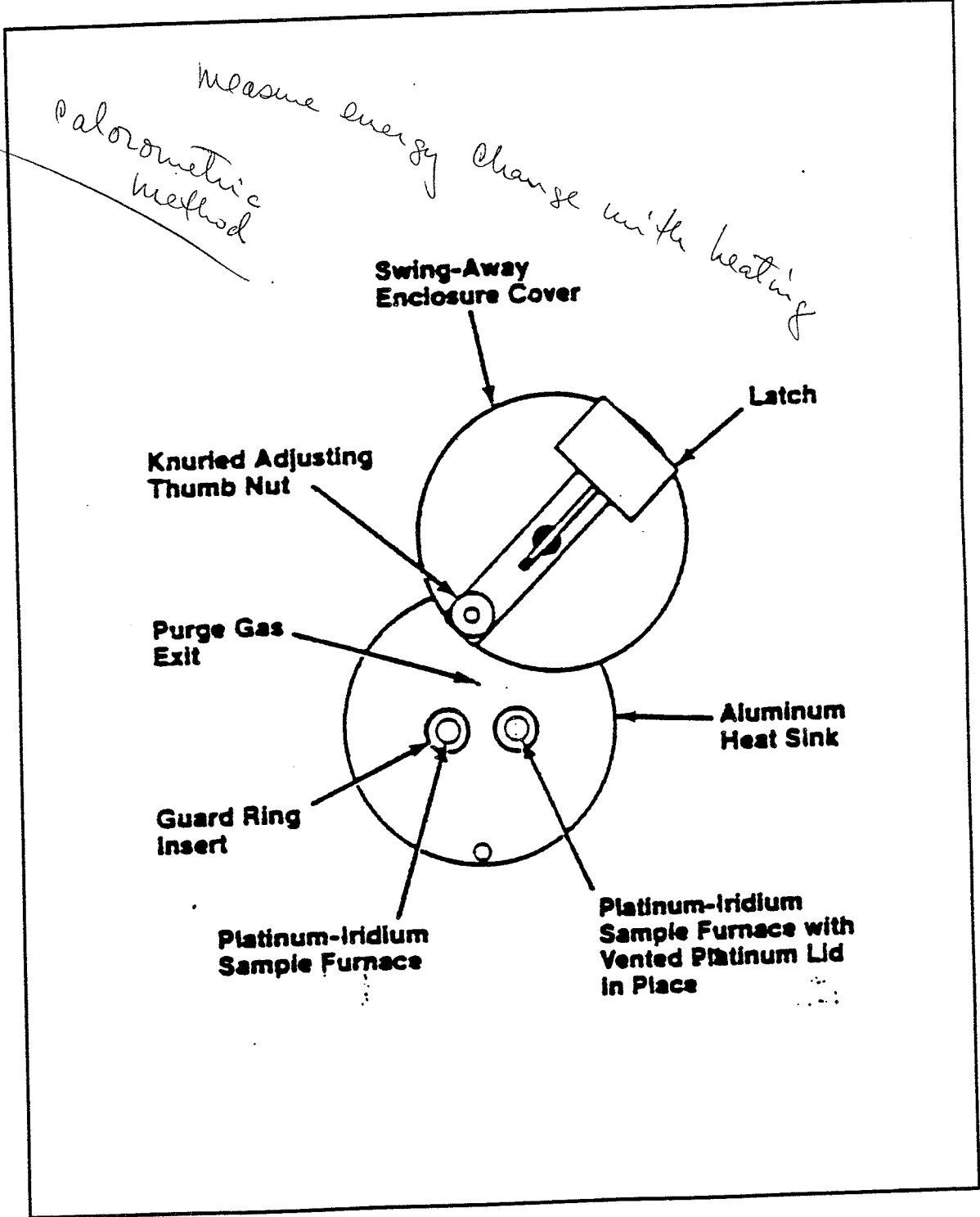
- Transition Temp.
- high Temperature
- low Temperature

Tab.7.4.1.2 Thermal Expansion Coefficient α and the phase transition point T of the adhesives (cont.)

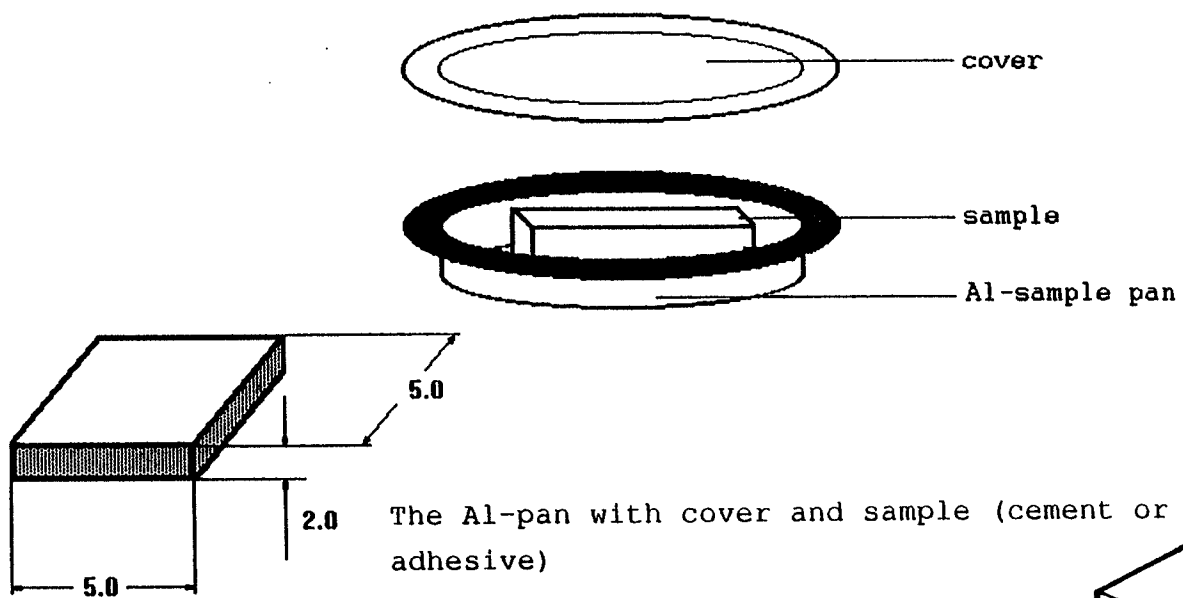
No.	Optical Cement	α_1 $10^{-6} [\frac{1}{\cdot C}]$	α_2 $10^{-6} [\frac{1}{\cdot C}]$	T [°C]
41	Araldit AY103+HY956	58	192	63
42	Araldit CY221-30TX + HY2966	52	207	27
43	Armstrong A-12/1:1	84	191	9
44	Armstrong A-12/1:2	113	208	-19
45	Armstrong A-12-T	73	178	18
46	Eccobond 45 Catalyst 14	59	179	42
47	Epicote 45 Epicure V12	64	198	67
48	EPO-TEK H74	13		101 (onset)
49	GUPALON Normal	65	177	63
50	Hysol 11C	38		

Softening point

Softening - Procedure

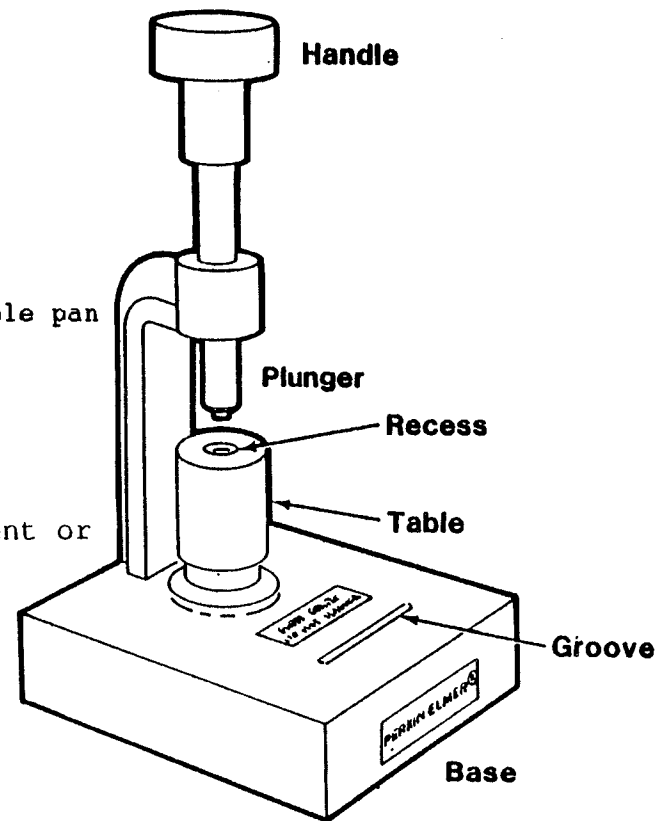


Softening - Procedure



2.0 The Al-pan with cover and sample (cement or adhesive)

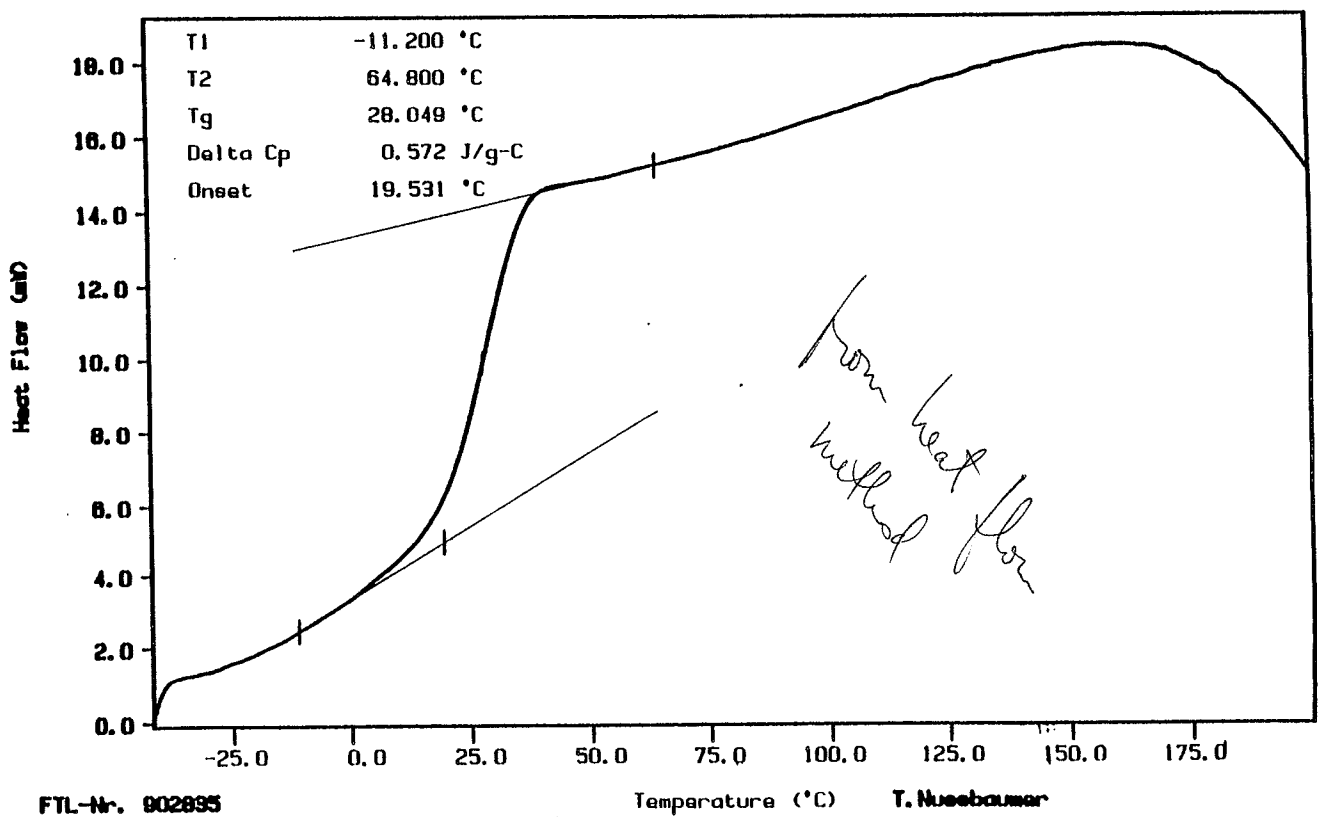
Sample shape for the cements and adhesive for the DSC examination.



The Standard Crimper Press

PERKIN-ELMER
7 Series Thermal Analysis System

DSC Data File: c3b
Sample Weight: 44.650 mg
Mon Jan 21 14:50:12 1991
Epo-Tek 305 (3)



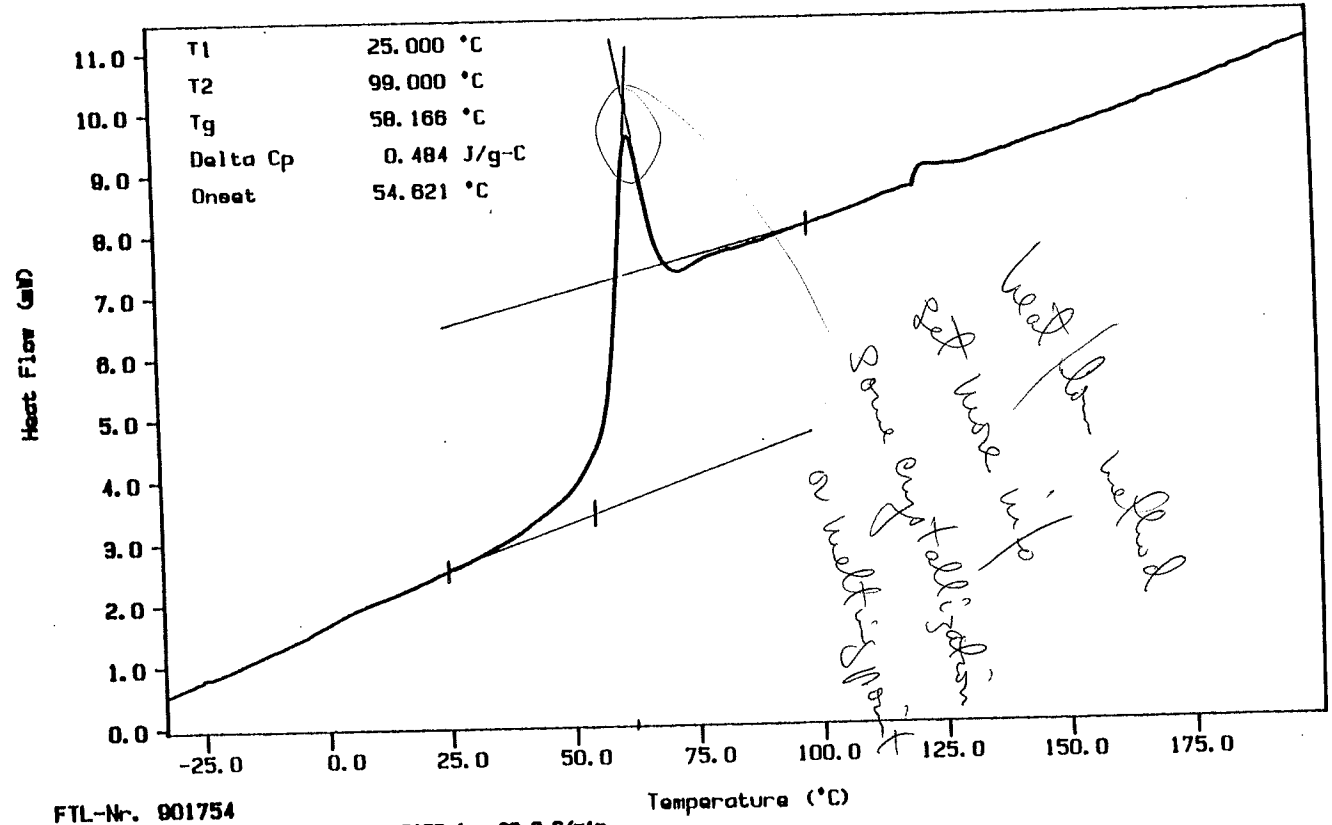
FTL-Nr. 902895
TIME: 22.88 RATE: 20.0 C/min
T. Nussbaumer

Fig. 7.4.2.4.1.2

The cp-diagram of the cement No.17
EPO-TEK 305

PERKIN-ELMER
7 Series Thermal Analysis System

DSC Data File: c382
Sample Weight: 22.840 mg
Fri Jan 11 12:17:57 1991
Epo-Tek 301 Part A+B (38)



FTL-Nr. 901754
TIME 1: 0.0 min RATE 1: 20.0 C/min

Fig. 7.4.2.4.1.6 The cp-diagram of the cement No.15

EPO-TEK 301

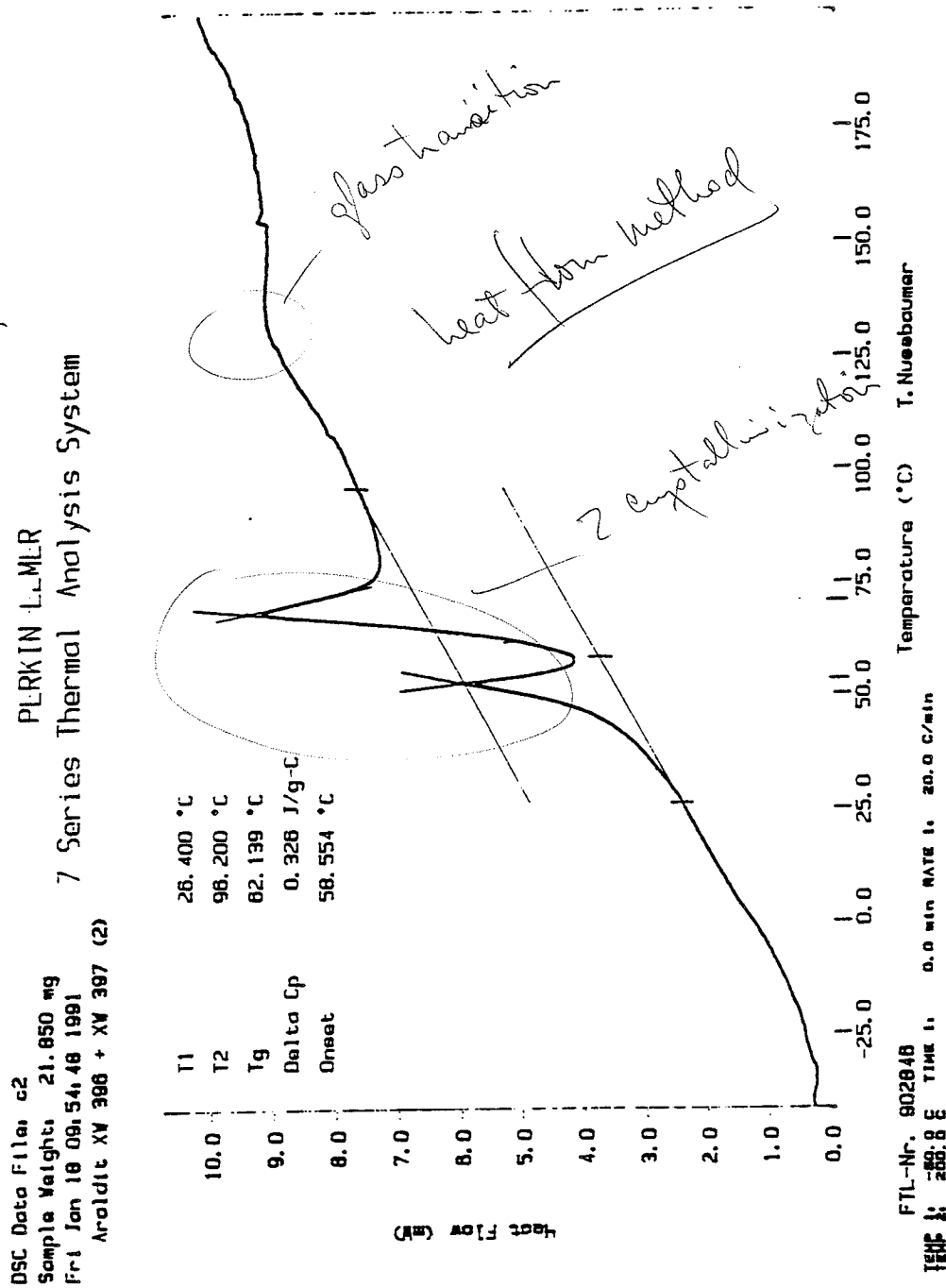


Fig.7.4.2.4.1.9

The c_p -diagram of the cement No.13
Araldit XW 396 + XW 397

DSC Data File: e22
 Sample Weight: 27.820 mg
 Fri Jan 11 14:57:18 1991
 Eccobond 45 + Catalyst 15 (22)

PERKIN ELLMER

7 Series Thermal Analysis System

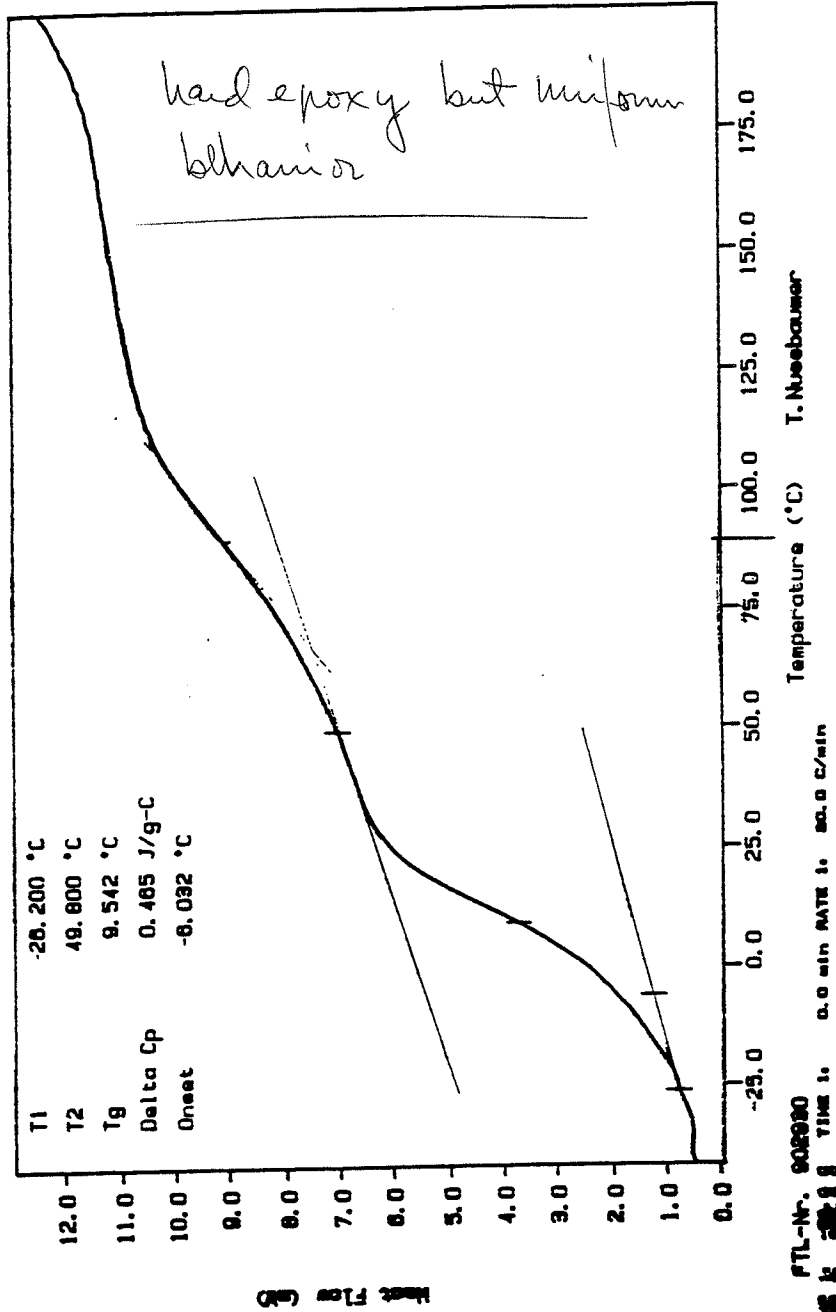
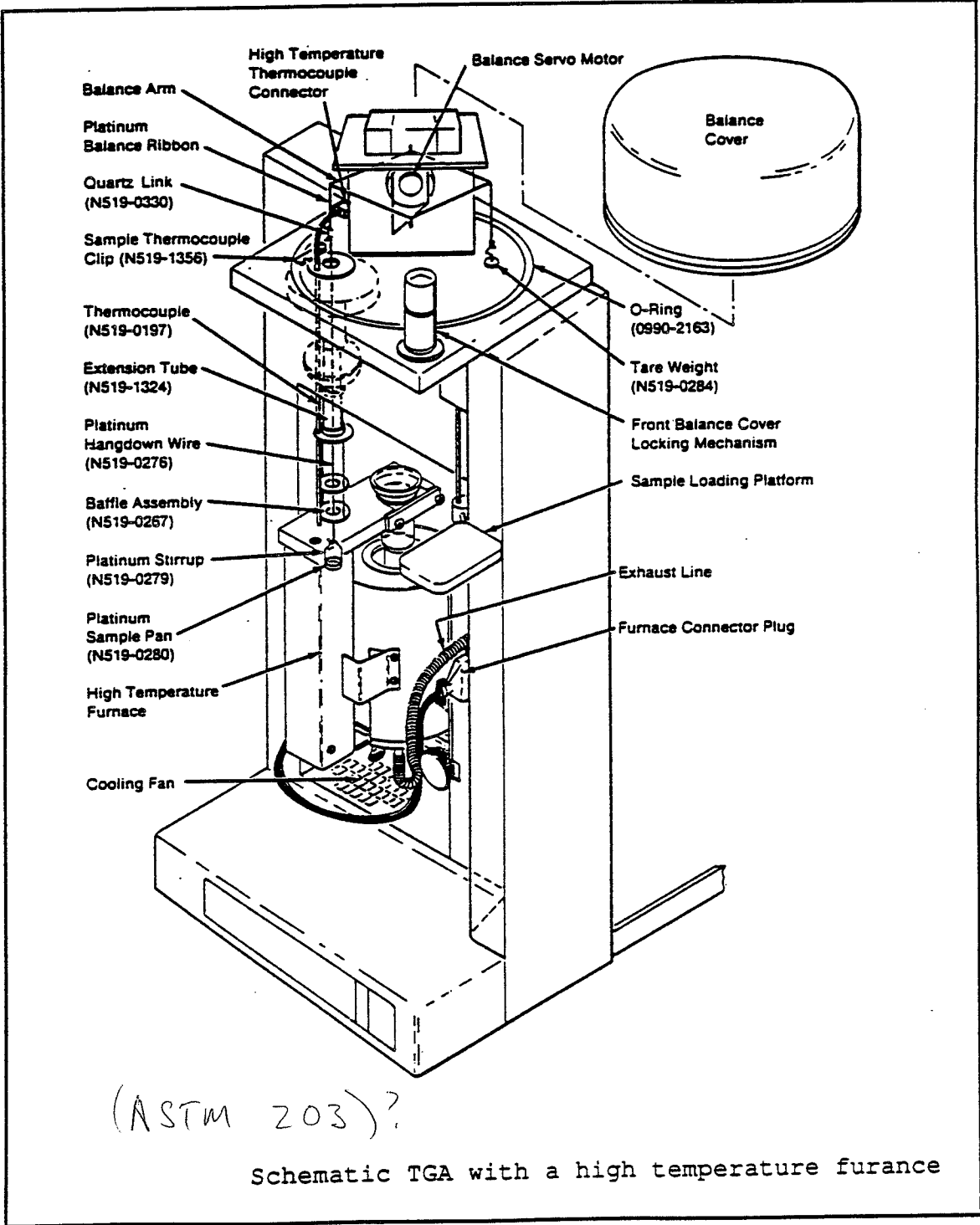


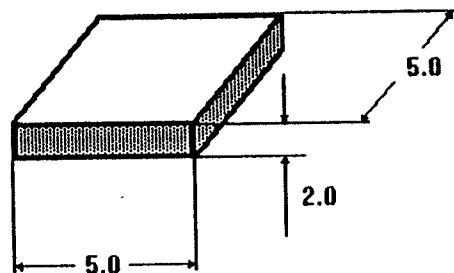
Fig.7.4.2.4.2.5

The cp-diagram of the adhesive No.46
 Eccobond 45 + Catalyst 15

Outgassing (TML Leica) - Procedure



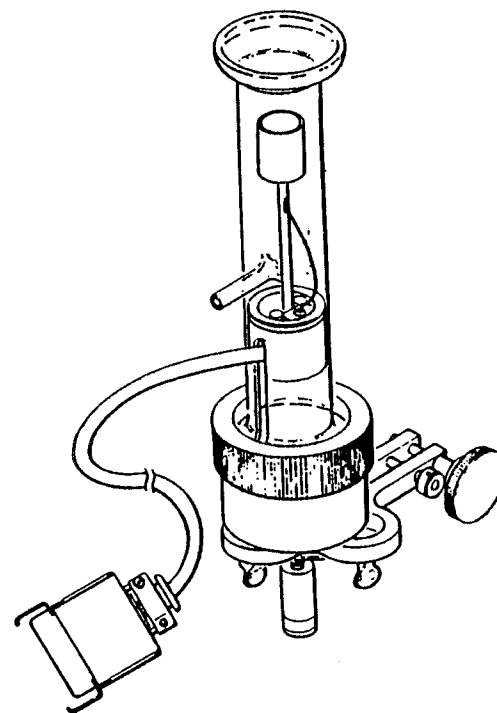
Outgassing (TML Leica) - Procedure



sample shape of cements and adhesive

Schematic TGA standard furnace and thermocouple
(this equipment is used for the decomposition
and outgassing measurements)

Equipment and the specification of the PERKIN
ELMER Thermo-Gravimetric Analyzer **TGA**

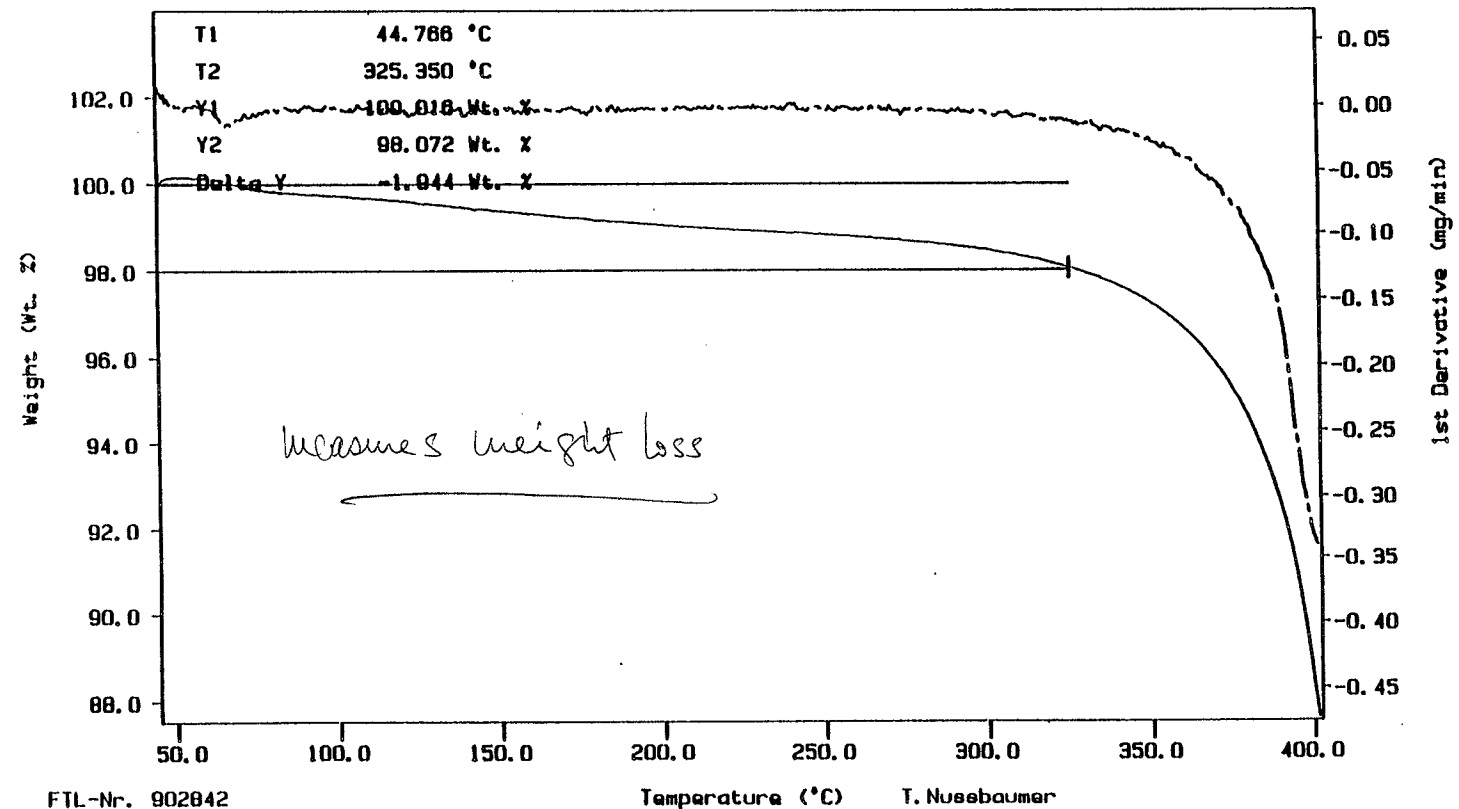




TGA 1st Derivative: a19
Sample Weight: 1.510 mg
Mon Jan 14 17:24:13 1991
Armstrong A12 1:1 (19)

PERKIN-ELMER
7 Series Thermal Analysis System

TGA File Name: a19
Sample Weight: 1.510 mg
Mon Jan 14 17:24:13 1991
Armstrong A12 1:1 (19)



FIL-Nr. 902842
TEMP 1: 40.0 °C TIME 1: 0.0 min RATE 1: 40.0 C/min
TEMP 2: 40.0 °C TIME 2: 0.0 min RATE 2: 40.0 C/min
T. Nusebaumer

Fig. 7.4.3.3.2.1.3 TML for the Adhesive No.43
Armstrong A-12/1:1

TGA File Name: all
 Sample Weight: 1.098 mg
 Mon Jan 14 14:23:50 1991
 CS 3204 A/B Class A2 (9)

PERKIN-ELMER
 7 Series Thermal Analysis System

TGA 1st Derivatives: all
 Sample Weight: 1.098 mg
 Mon Jan 14 14:23:50 1991
 CS 3204 A/B Class A2 (9)

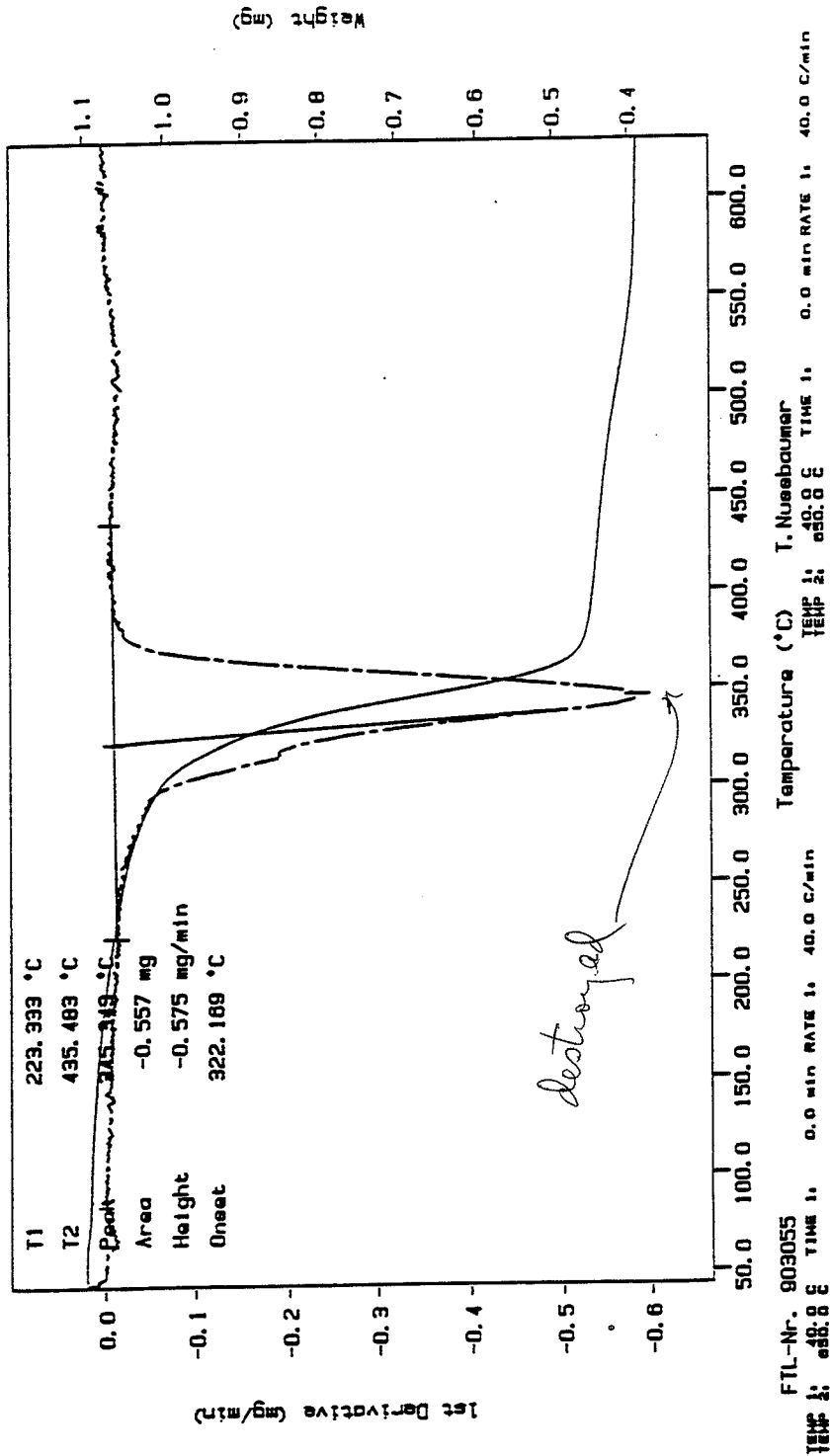
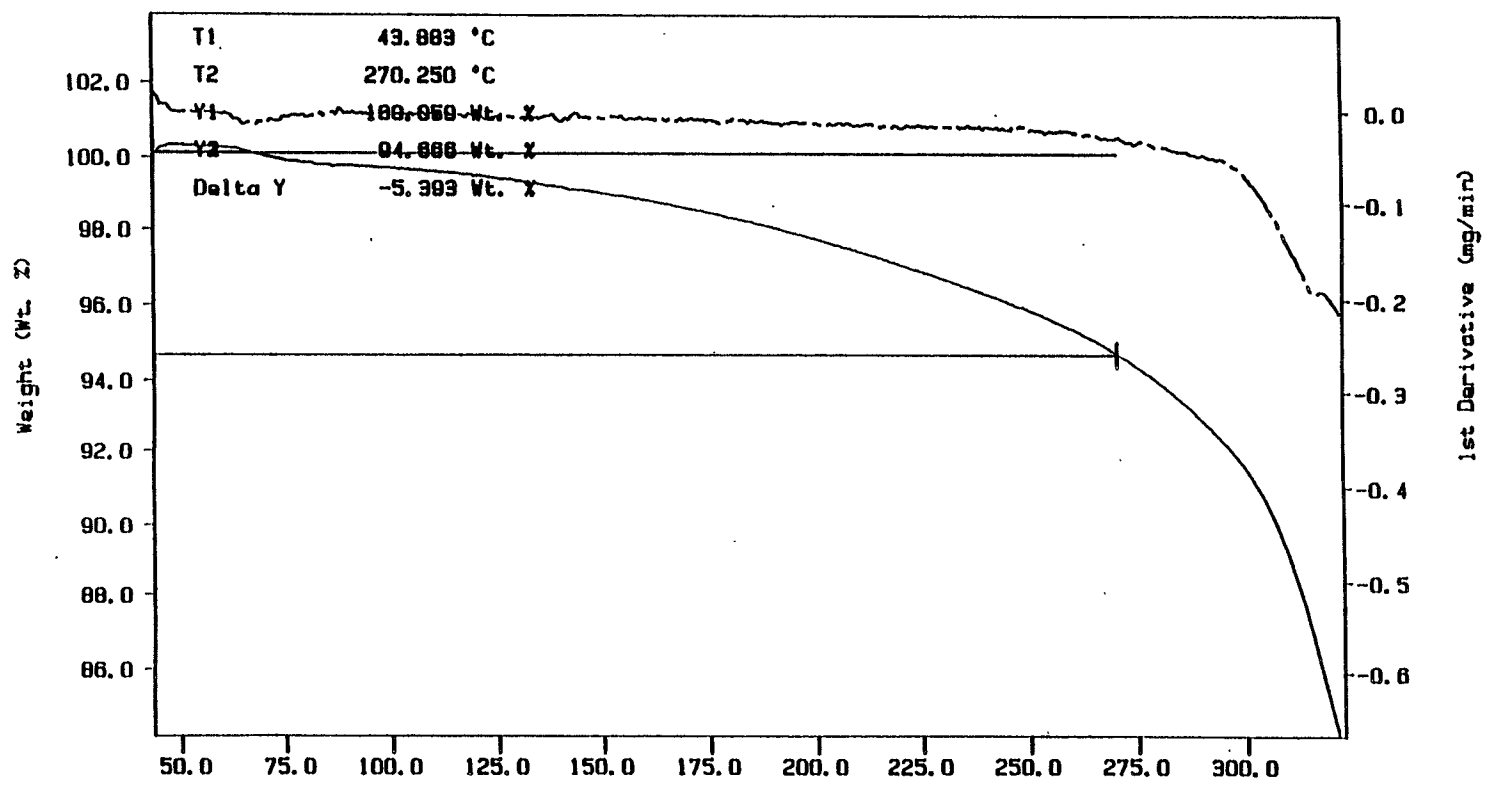


Fig. 7.4.3.3.2.2.6 The decomposition diagram of the adhesive No.63 CS 3204 Class A2

TGA 1st Derivative: all
 Sample Weight: 1.096 mg
 Mon Jan 14 14:23:50 1991
 CS 3204 A/B Class A2 (9)

PERKIN-ELMER
 7 Series Thermal Analysis System

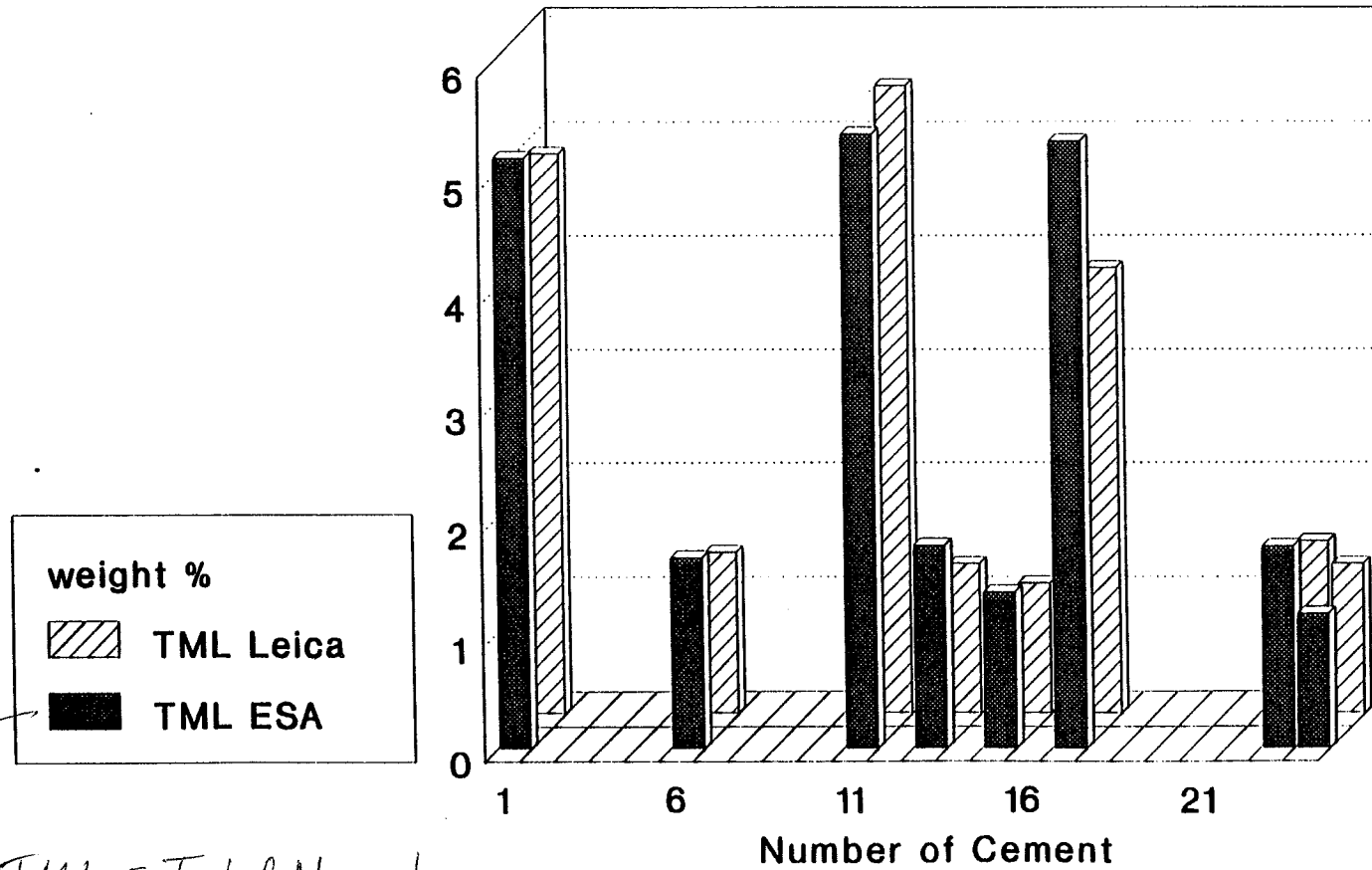
TGA File Name: all
 Sample Weight: 1.096 mg
 Mon Jan 14 14:23:50 1991
 CS 3204 A/B Class A2 (9)



FTL-Nr. 903055
 TEMP 1: 40.0 C TIME 1: 0.0 min RATE 1: 40.0 C/min
 TEMP 2: 350.0 C
 T. Nussbaumer
 TEMP 1: 40.0 C TIME 1: 0.0 min RATE 1: 40.0 C/min
 TEMP 2: 350.0 C

Fig. 7.4.3.3.2.1.6 TML for the Adhesive No.63
 CS 3204 Class A2

Outgassing TML ESA/Leica of the Cements



TML = Total Mass Loss

Outgassing TML ESA/LEICA of the Adhesives

