EWF Guideline
EUROPEAN ADHESIVE ENGINEER

Minimum Requirements for the Education, Examination and Qualification

EWF – 517-01

MINIMUM REQUIREMENTS FOR THE EDUCATION, TRAINING, EXAMINATION, AND QUALIFICATION OF PERSONNEL

EUROPEAN ADHESIVE ENGINEER (EAE)

GUIDELINE OF THE EUROPEAN FEDERATION FOR WELDING, CUTTING AND JOINING - EWF

Issued July 1998

Published by: EWF– Secretariat
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Minimum Requirements for the Education, Examination and Qualification of European Adhesive Engineers

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Section I: Minimum Requirements for the Education of European Adhesive Engineers

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The use of this guideline is restricted to organisations approved by the Authorised National Body (ANB). The Section II of this guideline covers the examination and qualification of (EAE) of European Adhesive Engineers

Introduction

This guideline for the European education and training of Adhesive Engineers has been prepared, evaluated and formulated by Members of the Sub-Committee for Adhesive Bonding.

The adhesive engineer is responsible for the integration of adhesive bonding into the design and manufacture of products, including design, evaluation of process parameters, problem solving and failure analysis.

The guideline covers the minimum requirements for education and training, agreed upon by all national welding and joining societies within the EWF, in terms of themes, keywords and times devoted to them. It will be revised periodically by the Committee to take into account any changes which may effect the "state of the art". Students having successfully completed this course of education will be expected of being capable of applying the technology required in adhesive engineering as covered by this guideline. A subsequent document covers the examination and qualification.

The contents are given in the following structure:

Theoretical Education		Teaching Hours
1.	Adhesion and adhesives	48
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	Total	**332**

A "teaching hour" will contain at least 50 minutes of direct teaching time.

It is not obligatory to follow exactly the order of the topics given in this guideline and choice in the arrangement of the syllabus is permitted. The depth to which each topic is dealt with is indicated by the number of hours allocated to it in the guideline. This will be reflected in the scope and depth of the examination.

Theoretical Education

1. Adhesion and adhesives — 48 Hours

1.1 Introduction — 8 Hours

The purpose of this section is to act as a scene-setter for the remaining topics covered by the proposed qualifications for both a European Adhesive Engineer and a Technologist. This section should be common for both levels. It sets adhesive bonding within the context of other joining technologies. The links between the various topics contributing to the qualifications are outlined so that the overall objectives of the two qualifications, as an Engineer or a Technologist can be seen in context.

The place of the qualified Adhesive Engineer in industry - his/her role in a company,

The need to produce a rounded individual with a broad sweep of knowledge, not someone who is very focused towards one sector only.

How adhesive technology can fit into industrial manufacturing. The need to look at the use of adhesives from concept design through to final component production.

1.1.1 Historical Background

The use of adhesives (in their broadest sense) before 1900.

Industrial adoption of adhesive bonding and its increasing use in the aircraft industry.

Expanding opportunities for adhesives (and sealants) as the fabrication market becomes more diffuse.

1.1.2 Benefits and Limitation of Adhesive Bonding

The benefits and opportunities arising from the adoption of adhesive bonding by manufacturing companies, eg. reductions in cost, improved quality, greater design freedom.

The downside of adhesive bonding.

- The need to pay greater attention to health and safety.
- Cost implications in terms of new equipment, staff training etc.
- The lack of credibility in industry.

The need to look at adhesive bonding in a holistic manner, taking all factors into account: this includes design, production and cost implications.

1.1.3 Principles of Adhesion

A general overview of the theories of adhesion. Areas of agreement and areas of conflict.

The importance of surface energy and how its influences the ability to produce a good quality adhesive bond.

How pretreatment affects surface energy and hence the degree of adhesion

Environmental effects on adhesive performance.

1.1.4 Glossary of Terms

The principle terminologies used within the adhesive technology field will be introduced. This will occur on an ad-hoc basis throughout the introductory phase. However, a brief systematic examination of terms used and their meanings (eg. as defined in pr EU 923) will be included.

Common misinterpretations of specific terms will also be highlighted, so that people are aware of potential differences of opinion concerning the use of some phrases etc.

The aim is to ensure consistency of approach across Europe in the first instance and, on a worldwide basis later.

1.2 Adhesives & Sealants — 40 Hours

1.2.1 Classification

By chemical family (epoxy, silicone...)

By setting made (chemical curing, solvent evaporation, melting/cooling...)

By origin (natural, synthetic, mineral, organic...)

By end-use (wood adhesives...)

By functional types (structural, hot-melt, pressure-sensitive...)

By physical form (one or multiple components, films, tapes, pastes, liquids...).

1.2.2 Constitution of Adhesives and Sealants

Different types of polymers and their basic properties

Adhesive modifiers:

Fillers:
- Extenders and dimensional stabilizers
- Reinforcement
- Rheology control
- Thermal conductivity improvement
- Electrical property enhancement
- Flame retardance and smoke suppression
- Pigmentation

Adhesion promoters

Tackifiers

Tougheners

Solvents

1.2.3 Types of Adhesives

For each of the following chemical families:

Resin chemistry

Cure chemistry

Functional types - commercial forms

Markets and applications - major suppliers

Properties:
- Handling and storage
- Physical (prior to cure)
- Process (metering, mixing, dispensing, application)
- Mechanical, chemical, thermal, electrical (after cure)
- Health and safety

Chemical families:
- Epoxies
- Phenolics
- Urethanes
- Anaerobics
- Acrylics

- Cyanoacrylates
- Silicones
- Polysulfides
- Elastomeric adhesives
- Polyimides-polyphenylquinoxalines-polybenzimidazoles
- Inorganic adhesives

1.2.4 Types of Sealants

For each of the following chemical families:

- Polysulfides
- Butyls
- Urethanes
- Solvent acrylics
- Water-base acrylics and polyvinyl acetates
- Silicones
- Fluorocarbons

The same description as the adhesive families (see 1.2.3 above)

1.2.5 Selection Requirements of Bonded Assembly

Use

Application

Materials to be joined (surfaces)

Type of joint

Process limitations

Mechanical requirements

Service conditions

Cost requirements

1.2.6 Selection Criteria

Compatibility with the substrates

Process (number of components, physical form, pot-life, curing, viscosity/rheology, gap-filling)

Mechanical and thermal properties

Durability

1.2.7 Applications

Working examples of selection of adhesives or sealants:

- Inventory of the requirement of the bonded assembly.
- Determination of the selection criteria of adhesives or sealants
- Selection of adhesives

This work could be made with the aid of computerised-based systems or not

2. Materials as adherends **40 Hours**

2.1 Important Adherend Properties 8 Hours

The different types of substrates (plastics, metals, wood, fabrics, fibres, glass, composites, ceramics) show a wide variety of properties, conditioning the type of surface treatment and the choice of adhesive. These properties are:

Mechanical properties (modulus, strength, fracture)

Stiffness

Porosity/permeability

Roughness

Corrosion

Water absorption

2.2 Purpose of the Surface Treatment (Key Surface Features) 8 Hours

There are two types of adherends, depending on their surface energy:

Low-energy surface substrates

The surfaces of plastics, rubbers and fibre composites have low surface free energies (typically less than about 50 mJ/m2). The low level of the surface energy is mainly critical for substrates like polyolefins and cured butyl rubber.

High-energy surface substrates

The other key surface features are:

Roughness, stability, contamination, soundness, uniformity, compatibility.

The purpose of any particular surface pretreatment may be manifold but the main aims are usually one or more of the following:

1. To remove or prevent the subsequent formation of any weak surface boundary layer on the substrate.

2. To maximise the degree of intimate molecular contact that is attained between the adhesive and the substrate during the bonding operation.

3. To ensure that the level of intrinsic adhesion forces which are established across the interface are sufficient for obtaining both the initial joint strength and subsequent service life that is required.

4. To generate a specific surface topography on the substrate.

5. To assist in the hardening of the adhesive (cyanoacrylate).

6. To protect the surface of the substrate prior to the bonding operation (frequent for high energy substrate such as metals).

<u>2.3 Types of Surface Pretreatment</u> 16 Hours

The surface pretreatment depends on the type of adherend.

For high energy substrates

1. **Solvent cleaning**

Substrate surfaces are frequently contaminated with oils, greases etc, and a common pretreatment is degreasing either with steam, or by wiping the surface with solvent dipped clean cloths, or most effectively in liquid and vapour degreasing bath.

2. **Mechanical abrasion**

The methods available include wire brushes, sand and emery papers, abrasive pads and grit or shot blasting.

3. **Primers**

Primers have two different purposes:

To improve the performance of the bonded component by chemically altering the surface (eg. silane coupling agents, chromate conversion coatings).

To increase production flexibility on the bonding operation. After pretreating a high-energy substrate, the active surface will readily absorb atmospheric contamination, and after a certain "surface exposure time" this may lead to inferior joint performance especially with respect to durability.

4. Chemical treatments

With nearly all high-energy substrates the maximum durability to aqueous environments is achieved when a chemical pretreatment and/or primer is employed.

Case of steels

Steels are frequently bonded with no, or a minimum of, pretreatment being employed and good, reproducible initial joint strengths are readily obtained using a combination of degreasing/mechanical abrasion techniques, as shown above.

However, to obtain the longest service life, surface treatments are recommended, like chemical treatments or primers.

Case of titanium and its alloys

Case of aluminium and its alloys

For low-energy substrates

1. Abrasion

Simple abrasion is usually a very poor surface treatment for plastic substrates.

2. Etching treatments

Many chemical treatments have been reported for plastics but the most usual is etching acid for polyolefins, alkali metal in liquid ammonia for polytetrafluorpethylene, iodine treatment for nylon's surface etc.

3. Physico-chemical treatments

All these treatments have the same effect on the surface's substrates in order to increase bondability of the materials.

All these techniques are the only solution to increase surface tension (or wettability of the materials.

Corona discharge

Plasma

Flame treatment

Others (UV radiation, laser pretreatment)

4. **Primers**

Primers are associated with the adhesive for thermoplastic substrates.

The structure of these primers are similar to coupling agents such as silane, titanate, zirconate and aluminate.

For other materials

Wood, leather, glass......

2.4 Selection of Surface Pretreatment and Surface Pretreatment Facilities 4 Hours

The pretreatment is chosen by the user bearing in mind:

- The specifications of the assembly in terms of performance and durability
- Cost
- The productivity required (duration of the operations, storage time)
- The equipment already available
- Health and Safety considerations.

2.5 Surface Pretreatment Facilities 4 Hours

Equipment required

Chemical products and consumables

Peripheral equipment (for Health and Safety problems, for instance)

3. Construction & Design 40 hours

3.1 Fundamentals of the Strength of Materials 8 Hours

Including metallics, composites, plastics, rubbers, wood......

Stress - strain relationships

Yielding theories

Strength criteria

Different behaviours (elastic, elastic-plastic, plastic, viscoelastic, viscoplastic, elastomeric...)

Behaviours of materials under different conditions of temperature and load

Types of fracture

3.2 Design Principles of Bonded Structures — 4 Hours

Considerations unique to adhesives and sealants (compared to welded, spot welded, riveted, screwed...structures)

Design principles (rules and standards)

Design examples of bonded structures in various areas of application

Design for mechanised and automated fabrication - related to the different types of adhesives and sealants

Access and tolerances

3.3 Basics of Adhesive Bonding Design — 3 Hours

Design principles (calculation of stress)

Conditions of equilibrium

Stiffness

Moments of inertia

Types of stresses (tensile, shear, peel...multiaxial stresses and combined stresses)

Stresses induced by differential straining (heterogeneous joints)

Measurement of stresses in bonded joints

3.4 Joint Design — 3 Hours

Different types of bonded joints

Classifications (lap joints, cylindrical and tubular joints...)

Tolerance requirements

Influencing factors (experimentally constated)

- Overlap length
- Stiffness of adherends (thickness and moduli)
- Adhesive layer thickness
- Shape of the adhesive "fillet"
- Adhesive behaviour (modulus, strength)
- Coefficient of thermal expansion of adherends and adhesive

Design proof testing.

3.5 Calculation of Stresses in Bonded Joints — 12 Hours

3.5.1 Analytical Methods

Hypotheses - limitations

Mechanical loading

- Elastic analysis
- Elasto plastic analysis
- Visco elastic analysis

Thermo mechanical loading]
Single lap-joint]
Double lap-joint]
Scarf joint]-distribution of stresses in the joint
Step-lap joint]-influence of factors (geometrical
Tubular lap joint] behaviour of materials)
Pin and collar joint]-comparison with experimental results
Other types of joint]

Working examples with software -

- on the single-lap joint
- on tubular lap joints
- on cylindrical joints (pin & collar)

3.5.2 Numerical Analysis

Finite Element method

Two-dimensional analysis

Three-dimensional analysis

Mechanical and thermomechanical analysis with different mechanical behaviours for adherends and adhesives (elastic, elastoplastic, viscoelectric...)

Working examples on complex structures

- Distribution of stresses in the joint
- Influence of the characteristics of the adhesive
- Influence of the shape of the adhesive "fillet"
- Comparison with experimental results

3.6 Hybrid Joints 3 Hours

Adhesive bonding associated with:

- Riveting
- Spot welding
- Screwing
- Clinching
- Setting, crimping
- Shrinking

Advantages and limits of these assembly methods.

Rules for design of such joints

Comparison of performances of these joints compared to bonded joints and mechanically fastened joints

Influence of factors

Practical examples in industry

3.7 Design Considerations for Durability of Joints (Long-Term Performance) 3 Hours

Creep

Fatigue

Thermal effects

Environmental effects (moisture, water, chemicals)

Combined effects

Fracture mechanics

These different behaviour will be discussed in depth in sections 1, 2, 3, and 7. In this section, only design recommendations will be given for reducing or overcoming these effects in order to suit the specifications of the assembly.

Working examples and applications will be given.

3.8 Manufacturing Considerations 4 Hours

Ease of assembly

Value analysis

Automation

Costing and economics

4. Durability **24 Hours**

4.1 Introduction 1 Hour

4.2 Thermal Effects on Adhesive Joints 4 Hours

Differential thermal expansion

Thermal transition in adhesives

Thermal degradation of adhesives

Thermal conductivity of adhesives

Temperature limits of adhesives

4.3 Moisture Effects on Adhesive Joints 4 Hours

Migration of water in adhesive joints

- Water diffusion in adhesives
- Critical water concentration

Strength degradation and failure mode

Mechanism of strength loss

- Displacement of adhesive by water
- Hydration of oxide layers

Improvement of Joint Durability

- Increasing barrier to water diffusion
- Hydration inhibition or retardation
- Application of primer

4.4 Electrochemical and Corrosion Effects on Adhesive Joints 2 Hours

Exposure in electro chemically inert conditions

Effect of high cathodic potentials

Effect of impressed current

Effect of dissimilar metals in contact

Effect of mechanical strain

Effect of corrosion and adhesive joint failure

Theoretical models and failure mechanisms

Increasing resistance to cathodic bond failure in adhesive joint applications.

4.5 Chemical Effects on Adhesive Joints 2 Hours

Often encountered chemical agents.

Chemical resistance of adhesives by chemical family

Chemical resistance of common adherends

Methods of bonded joint protection

- Paints and coatings
- Water displacing materials
- Elastomeric sealants

Chemical resistance test methods.

4.6 Radiation and Vacuum Effects on Adhesives in Bonded Joints 1 Hour

Adhesives for space applications

Methods of evaluation (simulated space environment)

Results of adhesive evaluation..

4.7 Mechanical Stress Effects on Adhesive Joint Durability 4 Hours

Creep (permanent loading) - definition.

Fatigue (cyclic or dynamic loading) - definition.

Specimens for creep and fatigue testing of adhesive joints.

Allowable stresses (or strains) in adhesives for creep and fatigue.

Optimised joint geometry for creep and fatigue resistance.

Theoretical models and failure mechanisms for creep and fatigue.

Models for life predictions.

4.8 Combined Temperature - Moisture - Mechanical Stress Effects on Adhesive Joints 3 Hours

Evaluation parameters

Accelerated service life testing

4.9 Weathering and Ageing Effects on Adhesive Joints 1 ½ Hours

Definition of an environment

Short term testing

Long term testing

Comparison of short and long term testing

4.10 Durability Assessment and Life Prediction for Adhesive Joints 1½ Hours

Durability test techniques

Diffusion dominated durability: spring loaded share specimens

Adhesion dominated durability: wedge, test, wet peel test

Corrosion dominated durability: salt spray test.

5. Bonding Process **35 Hours**

5.1 Introduction to the Bonding Process 1 Hour

5.2 Sourcing and Storing Adhesives 1 Hour

5.3 Preparation of the Adhesive 2 Hours
(Focusing each type of adhesives)

5.4 Adhesive Application 4 Hours

5.4.1 Methods of Adhesive Application

Brushing

Flowing

Spraying

Roll coating

Knife coating

Silk screening

Melting

Other

5.4.2 Metering

Procedure and equipment

5.4.3 Mixing

Procedure and equipment

5.4.4 Dispensing

Procedure and equipment

5.4.5 Control

Procedure and equipment

5.5 Assembly 4 Hours

5.5.1 Order of Assembly

5.5.2 Methods of Adhesive Bonding

Wet bonding

Reactivation bonding

Pressure sensitive bonding

Curing

Other methods of bonding

5.5.3 Environmental Aspects

Thermal effects

Moisture effects

5.5.4 Tooling

5.5.5 Inadequate Bonding

5.6 Bonding Pressure — 2 Hours

5.6.1 Bonding Pressure Equipment

Hydraulic presses

Hydraulic pads

Weight loading

Clamps

Vacuum bag application

Autoclave vessels

5.7 Adhesive Curing — 4 Hours

Room temperature

Direct heat curing

Radiation curing

- UV curing
- Visible light curing
- Infrared curing

Microwave curing

Moisture curing

Electric heaters

High frequency dielectric heating

Induction heating

Low-voltage electric heating

Ultrasonic activation

5.8 Inspection 3 Hours

Destructive and non-destructive testing

Process control and quality assurance

Evaluation of fabricated parts

Standards

5.9 Repair 5 Hours

Repair concepts

Surface preparation for adhesive bonded repair

Surface contamination considerations

Examples for several applications

- Repair on automotive applications
- Repair on aerospace applications (aluminium structures, advanced composite structure etc)
- Repair on industrial applications

5.10 Health and Safety 2 Hours

5.11 Automation and Robotics 3 Hours

Dispensing equipment for robotic applications

Advancements in dispensing technology

Other levels of automation

Applications

Developing a robotic system

5.12 Factory Layout (Including Economic Aspects) 2 Hours

5.13 Bonding Co-ordination (Equivalent to PrEN 719) 2 Hours

6. TESTING AND ANALYSIS **22 Hours**

6.1 Standard Test Methods and Others 4 Hours

American (ASTM)

British (BS)

French (AFNOR)

International (ISO)

German (DIN)

European (EN)

Others

Specifications from industry:

- Military Industry
- Aerospace
- Automotive
- Electronic
- Other

6.2 Property Determination for Adhesive, Adherend or Joint 8 Hours

To deduce the nature and magnitude of the stresses in an adhesive joint requires the basic mechanical properties of the adhesive and substrate to be known and a mathematical analysis of the joint geometry to be available.

6.2.1 Adhesive

To analyse the stresses in adhesive joints requires a knowledge of the basic engineering properties of the adhesive. Typically, the main properties required are the tensile, or Young's modulus, the shear modulus and the yield stresses and the fracture stresses and strains in uniaxial tension and in pure shear. Most of the common standard joint tests do not enable theses properties to be deduced due to the complex state of stress induced in the adhesive layer by the specimen geometry.

Two different approaches have been adopted in an effort to overcome these problems:

- One is to measure these properties by preparing bulk specimens of the adhesive (static testing, dynamic testing, rheological characterisation)

- The second is to measure these properties by using especially designed joint geometries to measure the failure strength and to analyse the fracture and failure behaviours.

6.2.2 Adherend or substrate

Surface energy

Roughness

Mechanical properties

Chemical properties (resistance to corrosion, compatibility with chemicals)

Thermal properties

Other properties (electrical, optical...)

6.2.3 Joint

Study of the geometry of the joint.

There are several important general aspects to bear in mind when designing adhesive joints.

The designer should not only attempt to keep stress concentrations to a minimum but also attempt to distribute the imposed loads within the adhesive layer as a combination of compressive and shear stresses; avoiding tensile, cleavage and peel stresses as much as possible.

6.3 Characterisation of Raw Material 4 Hours

Viscosity

Reaction time for adequate adhesive (epoxy, acrylic, polyurethane etc)

DSC (Dynamic Scanning Calorimetry)

Infra-red spectrometry

Chemical determination of the composition of the adhesive (solvent, filler, epoxy equivalent etc)

6.4 Characterisation of Cured Adhesive — 4 Hours

Mechanical characterisation as other materials

DMA (Dynamic Mechanical Analysis)

Chemical properties

Thermal properties

Electrical and optical properties

6.5 Mechanical Properties of the Assembly — 4 Hours

Destructive testing of the assembly:

- Failure strength measurements
- Fracture testing and failure analysis
- Fatigue testing
- Thermal properties and temperature effects
- Electrical properties

6.6 Performance in Service — 4 Hours

Tests for the durability of the assembly:

- Thermal constraints
- Moisture
- Chemical environment
- Mechanical constraints (dynamic behaviour)
- UV
- Combined effects

6.7 Non-Destructive Testing — 4 Hours

The basic aim of any non-destructive test of an adhesive joint must be in direct correlation of some parameter measurable by the test with the failure property to be measured or predicted, without impairing the effectiveness of the bonded part for its intended application.

Some industrial test techniques:

- Visual control: thickness of the joint, flowing etc
- Sonic vibration techniques
- X-ray radiography
- Thermal inspection methods
- Holography
- Liquid penetrant
- Transmission and pulse-echo ultrasonics

6.8 Examination of Joint Fracture Surfaces and Adhesive Layer 4 Hours

In adhesive bonding, failure analysis is critically important aspect of both manufacturing and scientific investigation. Identification of the locus of failure of a manufactured product or a test structure is necessary to establish the cause of the failure and either to recommend a remedy to the problem or to understand the mechanisms of crack initiation and propagation and identify the weakest link in the structure.

A variety of techniques have been developed over the years to study surfaces and interfaces.

Each of these techniques provides different information concerning the composition, structure or electronic properties of the material.

Specifically, they can provide qualitative and quantitative analyses and indicate chemical bonding, or they can measure the distribution of materials, elements, or, in a few cases, even individual atoms with depth or along the surface.

The surface and the fracture can be analysed by:

SEM: Scanning electron microscopy
AES: Auger electron microscopy
IETS: Inelastic scattering spectroscopy
ISS: Ion scattering spectroscopy
SIMS: Secondary ion mass spectroscopy
SRIRS: Surface reflectance infra-red spectroscopy
STEM: Scanning transmission electron microscopy
XPS: X-ray photoelectron spectroscopy

7. Health & Safety 8 Hours

Adhesives and the work environment

Introduction

Structural adhesive bonding of load-bearing parts has become increasingly widely used in recent years. Bonding has replaced other methods of joining parts, and is even used successfully in applications with very high requirements in respect of structural integrity, such as aircraft parts. An advantage of structural adhesives is their excellent technical performance, but a drawback can be their effects on the work environment and on the wider environment.

The objective of training in this module is to present the working procedure as follows:

Selection of adhesive
Checklist
} → New form of adhesive (same type of adhesive) → New type of adhesive → Automated application → Protective equipment

When considering the use of structural adhesives, such as epoxy and polyurethane adhesives, it is important also to consider the method by which the adhesives will be applied. It may be possible, for example, to apply an adhesive which is a health hazard in such a way as to reduce the overall risk. The converse applies for a relatively non-hazardous adhesive: applying it manually can make it more hazardous. What we want to show here is that the choice of adhesive cannot be made on its own: it is necessary also to consider how it is to be applied.

The contents of the training material

This material comprises the following elements:

7.1 - Selection of adhesive/Selection tables and performance specifications for selection of the appropriate adhesive.

7.2 - Checklist with comments, indicating the risks associated with a particular choice of adhesive.

7.3 - Countermeasures that can be applied to suit a workplace to a particular type of adhesive, so that bonding can be performed as safely as possible.

7.4 - Data section, including information such as the design of bonded joints, pretreatment, preparation and application of adhesives, summaries of health risks associated with constituents of adhesives.

7.5 - National rules and regulations.

7.1 Selection Tables and Performance Specifications ½ Hour

Technical performance specifications.

Adhesive/adherend cross scheme (adjusted regarding to the adhesive type health risk).

Regardless of how good an adhesive may be from a work environment or external environment viewpoint, there is no point in using it if it cannot provide the necessary technical performance for the particular bond concerned.

The performance specification may reveal that unnecessarily high demands are being made on the adhesive by designing the joint so that it is exposed to extremely high loads. In such cases, the first line of attack could be to redesign the joint: a well-designed joint can reduce the performance requirements of the adhesive itself.

When the design of the joint has been settled, and the necessary performance of the adhesive been decided on, it will probably be found that there are several adhesives that meet the requirements. An adhesive can then be selected that represents as little risk as possible. Risks associated with the use of an adhesive are due to such factors as the constituents of the adhesive and how hazardous they are. A very simple guide for selection of an appropriate adhesive should be given in a table of adhesives.

7.2 Checklist with Comments 2 Hours

The checklist is including all the different steps in the adhesive process with regards to the health effects. Each question in the checklist is accompanied by comments.

Generally

Design

Surface treatment

Adhesive dispensing/application

Curing/solidification

Control/inspection

Repair

It might be thought that selection of a non-hazardous adhesive has solved all problems. Unfortunately, this is not always the case. Some 'non-hazardous' adhesives may require pretreatment of the joint to ensure a sound bond: post-treatment may also be necessary. These aspects of the entire process from start to finish must also be considered if work environment problems are to be foreseen and prevented. This can be done with the help of a checklist, which can help in identifying the various work environments and determining the technical aspects of the adhesive selection. Each question in the checklist is accompanied by comments which describe the various problems in more detail and indicate alternative methods.

7.3 Countermeasures 1 Hour

Examples with countermeasures from different common "workstations" for example::

Adhesive bonding with epoxy

- fluid state
- solid state

Adhesive bonding with polyurethane

- Polyurethane - one and two component
- Polyurethane/hot melt

Adhesive bonding with acrylate

- Cyanoacrylate
- Anaerobic
- SGA
- UV curing

Primer, accelerator

Finishing treatment

The countermeasures list describes the risks associated with the use of various types and forms of adhesives, and how they can be reduced. The advantages and drawbacks of various measures are also discussed. This section is a help when planning new work positions for bonding work, and can also be used to check the standard of existing workplaces.

7.4 Data Section — 3 ½ Hours

Health hazards for different types of adhesives

Synonymous chemical name list

Health hazards for different forms of adhesives

Design aspects

Surface treatment aspects

- Surface treatment methods for different adherends and applications
- Alternative surface treatment/cleaning methods

Aids for preparation, measuring and mixing adhesives

Equipment for dispensing/application of different adhesive forms

Equipment for various automation levels of dispensing application of:

- Adhesives in fluid state
- Adhesives in solid state

Health hazards for different ways of curing/solidification

Health hazards for equipment used for curing/solidification

This section contains information on various stages of the bonding process. Much of this information is concerned with the inherent risks associated with particular adhesives and how the adhesives can be applied.

No adhesives represent health hazards before users or others come into contact with them in some way. Factors that have a bearing on such contact, such as the form in which the adhesive is encountered or applied, or the method of handling, therefore also affect the health hazard.

Adhesives can be supplied in various forms, such as thick liquids, viscous pastes, powders, films, tape, granulates or blocks that must be melted prior to application. Some adhesives are single-component types, while others are of two-component form.

The most commonly encountered form of adhesive today is the liquid form. Two-component adhesives usually have to be prepared before application. This involves measuring and mixing, with resulting risks of skin contact and inhalation of fumes. The use of single-component adhesives involves less preparation and is therefore to be preferred, unless the single-component adhesives suitable for the particular application are very health-hazardous.

Adhesives in solid form are usually of the single-component type, which means that there is no measuring or mixing. Adhesives in film form, which have a defined thickness, are easy to apply in the correct quantity, and there is no need to add a little more adhesive in order to err on the side of safety, which must subsequently be removed. Adhesives in solid form are heated at some point in the bonding process in order to melt them: fumes can be released at this stage.

The form in which the adhesive is encountered also affects the choice of equipment for use with it. Appropriate choice of measuring, mixing and application equipment, together with proper ventilation, can reduce the work environment risks associated with the use of adhesives.

The way of and the equipment for curing / solidification is also important. Is the heat curing equipment, UV lamp safe etc?

Simplified, the application of adhesive can be divided into different independent elements: the adhesive itself, measuring/mixing equipment, application equipment and the curing / solidification stage.

7.5 National Rules and Regulations 1 Hour

This section should include general rules for people and aspects such as:

Importers/manufacturers

Employers

Marking for use on packaging

Hazard symbols as used on packaging

Data sheets

Details of hazard substances

Applications

Exceptions

Lists of types

Written hazard and protection information

Marking

Product inspection at the place of use

Measuring equipment for different substances

Protection equipment (clothes, gloves etc).

In order to be able safely to handle a hazardous substance, it is necessary first to know the risks associated with the substance and the characteristics of the substance in general that can influence the risk picture. For example who will be exposed and for how long time? It is also necessary to know what protective measures are needed in order to ensure that the material is handled correctly, and the rules for this can vary from country to country.

8. Quality Management — 29 Hours

8.1 Introduction - The Adhesive Bonding Process — 1 Hour

Adhesive bonding fits into ISO 9000 as a special process, the results of which cannot be fully verified by subsequent inspections and testing. The problem of assuring the quality and reliability of an adhesive joint is in the absence of suitable non-destructive examination methods, in all but a few special cases. Therefore, inspection of adhesive bonds is not a feasible way of assuring quality and in modern manufacturing philosophy, is after the event an unnecessary activity in a well-controlled process. The only way to provide assurance is to systematically manage and control the whole operation from design of the joint through to final assembly. In this way, the possibility of poor quality joints being produced is reduced to the minimum because proven procedures are being followed at all times.

8.2 Raw Materials Control — 4 Hours

Supplier certification - Status of all suppliers of any materials in the bonding process (adherends, consumables, adhesive, fixed equipment).

Manufacturing system qualifications.

Incoming specifications - Defined by the final customer or the manufacturer.

Testing - The testing that is required on any incoming materials, to prove conformance to incoming specification. Tests appropriate to the process, eg. viscosity, lap shear strength. Or reliance on a specification and the supplier's quality system.

Correct storage of all materials in the bonding process, eg. control of temperature, humidity, airborne dust, shelf life.

8.3 Process — 8 Hours

Procedure specifications - documentation of all the process steps (adhesive storage and application, surface treatment, assembly, cure). Bonding coordination, the equivalent of EN 719 (Welding Coordination), should be considered here and also in Section 5 (the Bonding Process).

Staff training - Documentation of skill, experience of staff, and training where required to achieve product reliability and to conform with the company's quality system.

Statistical monitoring methods - Measurements made during the process (flow rate, optical detection of adhesive bead, laminate thickness), then data analysis and presentation of results (eg. SPC charts), for the purpose of continuous process improvement. Methods of feedback and problem solving.

8.4 End-product Control — 8 Hours

Visual - simple ways to check process is correct, eg. joint appearance, alignment, visible excess adhesive.

Physical - measurement of a useful feature, to detect correctly made product, eg. Tg of cured adhesive fillet, flexural test of a laminate, proof loading of finished product.

NDT - non-destructive tests that are available to detect flaws or failed product, eg. ultrasonic C-scan, electrical measurement, gas leak test.

Destructive - parallel test pieces (witness samples) tested to destruction. Tear-down of complete product, with an agreed frequency or in the event of a dispute.

Sampling and statistics - Procedures for sampling. Frequency and cost of sampling to ensure process capability. Statistical techniques.

Limitations of end-product control - after the joint has been made.

8.5 Available Quality Tools and Techniques — 4 Hours

Overview of main quality tools and techniques, what they can do and when they should be used. The seven basic tools, then advanced tools eg. QFD, Taguchi, FMEA, Ishikawa diagrams, Poka-yoke.

8.6 Employee Training and Certification 2 Hours

The need to train staff as evidence of continuous improvement to test and certify staff when appropriate, so that the process in reliable, and with an acceptable cost of the product.

8.7 Company Quality Management System and Certification 2 Hours

In-company or externally audited quality systems, eg. ISO 9000.
Certification of:
- the company,
- the manufacturing site,
- the production line.

The need to be a certified manufacturer
Legal requirement for some products (EU directives).
The need and the procedures for some manufacturing processes to be externally assessed and certified.

9. Manufacturing Case Studies 24 Hours

The purpose of this topic is to give students an opportunity to look at a number of adhesively bonded applications in their entirety. This provides a chance to see how all the different topics interrelate.

9.1 Industrial Case Studies 12 Hours

Applications from a range of industrial sectors, eg. automotive, construction, marine, packaging, etc., will be examined to demonstrate the methods used in take a product from concept to final production.

Emphasis will be given to the importance of factors such as design, surface preparation, choice of application method, quality management, costing, health and safety considerations etc.

Where possible, these applications will be presented by industrial experts who have actual experience of the case studies they describe.

9.2 Group Exercises 12 Hours

Groups of students will work together as a team to provide a manufacturing solution for an adhesively bonded product. Their assessment of the problem will be discussed with industrial experts and others who will provide feedback on the actual solution employed in practice and the reasons why certain approaches were adopted.

Some exercises will incorporate analysis of failed components from which examples of insufficient detail at the design stage, poor workmanship, inadequate quality assurance etc. will be highlighted. Consideration of these factors will lead to the development of revised manufacturing schemes, including additional quality checks etc.

The aim of these exercises is to demonstrate that joining must be considered at every stage of the design and manufacturing cycle.

10. Practical Skills Training 40 Hours

The objectives of this section are to give experience and appreciation to the Engineer, of processes he or she will specify, and to the Technologist, of tasks he or she will be asking others to perform.

10.1 Surface Preparation of Adherends

Practical experience of each main surface pretreatment type, [as defined in section 2.3, Materials as Adherends, Types of Surface treatment], i.e. cleaning and degreasing, surface roughening, chemical treatments including anodising, physical treatments including at least one from plasma, corona, flame or UV/ozone, primers including coupling agents, conversion coatings and protective coatings. Measurement and assessment of treated surface, related to key surface features, eg. wettability by contact angle or surface tension inks.

10.2 Use of Different Adhesives

Manual dispensing of liquid, paste and film adhesives, in order to appreciate viscosity, cure speed, plus safe and efficient handling

10.3 Use of Adhesive Application Equipment

Simple and complex dispensing equipment. Automatic dispensing, using demonstration equipment.

10.4 Joint Types

Lap joints, coaxial joints, lamination of multilayers and skin - core (foam, honeycomb)

10.5 Manufacture of Bonded Joints with Different Materials

Metals - mild steel, aluminium; Plastics - thermoplastic (eg. polypropylene), thermoset composite (eg. GRP); Others - rubber, concrete, fabric.

10.6 Examination and Testing of Bonded Joints

Mechanical testing of bonded joints in shear, peel and tensile mode. Microscopic examination of fracture surfaces.

10.7 Practical Inspection Techniques

Visual assessment and physical measurement of joint features, eg. Tg of cured adhesive fillet, to detect correct assembly. NDT methods including ultrasonics, acoustic (eg. coin-tap) or electrical tests.

11. Examination **8 Hours**

i) Adhesion and adhesives
ii) Materials as adherends
iii) Construction and design
iv) Durability
v) The Bonding process
vi) Testing and analysis
vii) Health and safety
viii) Qualification Management

Written examination

At the discretion of the Board of Examiners the examination shall consist of:

a) A series of essay questions covering the whole field of the subject
or b) A series of multiple choice questions covering the whole field of the subject.
or c) A combination of a) and b) with equal marks allocated to each type.

The time devoted to the written examination shall be a minimum of 1 hour per subject ie. 8 hours in all.

Oral examination

The total time devoted to the oral examination covering all eight subjects shall be a minimum of one hour per candidate.

APPENDIX 1

Access to the Education

It is agreed that entry to such a programme should be on the basis of an engineer having received prior education training to a postgraduate level. Participates should have a primary degree in an engineering or related discipline recognised by the national government and assessed by the ANB. Therefore, it would be expected that participants should have at least a BSc degree. Definitions for each country are given below. Applicants not fulfilling the access conditions may follow the course as guests, but entry to the EWF examination is not permitted.

National definitions for the minimum requirements for access to the Adhesive Engineer's education and training.

Austria

Certificate of a university degree in engineering or materials (Dipl-Ing), or
Certificate of an engineering or materials plus three years of documented industrial experience in a leading position.

Belgium

Either a civil or an industrial engineer with five years experience in the design, manufacturing or assembly of manufactured products.

Denmark

Civilingeniorer (MSc)
educated at the technical University in Copenhagen, all lines are accepted.

Akademiingeniorer (BSc)
Educated at the Danish Engineering academy in Copenhagen or at the Aalborg university center, all lines are accepted.

Technikumingeniorer (BSc),
educated at the various engineering colleges in Denmark, eg. Helsingor, Horsens, Esjerb, Odense, Haslev, all lines are accepted.

Participants educated in other countries might enter the course and the examination, provided their background education corresponds to the Danish requirements. Approval to participate in the examination shall be given from the Danish ANB. The ANB has the responsibility to assure, that the rules given in this guideline are followed both with respect to the education and the examination.

Finland

Minimum requirements for the access to the Adhesives Engineer's education and examination: Certificate of a university degree in engineering (M.Sc.Eng) in the following Universities in Technology: Helsinki, Tampere, Lappeenranta and in the University of Oulu. Also certificates of an engineering college level (BSc Tech) will be approved.

France

Engineer's diploma recognised by the Ministry of Education from University or Engineering School. Engineering diploma from University DEA or DESS.

Germany

Diploma of an engineer's degree got at universities (minimum four years study), techical universities or medium universities (minimum three years study).

Italy

Certificate of an engineering degree or diploma obtained at University.

Ireland

The following primary degrees from Irish universities are deemed to meet the entrance requirements:

B.E. (Mech.Eng)
B.E. (Prod.Eng)
B.E. (Manf.Tech)
B.E. (Mat.Eng)
B.A.I. (Mech.Eng)
B.A.I. (Manf. Tech)

It should also be noted that the local approval board for entrance to curses has the discretion to consider candidates with qualifications other than those listed above and to approve such candidates for entry to the course as the approval board considers appropriate.

Luxembourg

Diploma of an engineer's degree got at universities (miniumum four years study), technical universitiies or medium universities (minimum three years study).

Netherlands

The access to the course is restricted to graduates of Polytechnics and Technical Universities in the fields of mechanical, metallurgical, civil, ship and aircraft engineering and, to the discretion of the course management, to persons with equivalent knowledge. For access to the NIL examination following conditions should be fulfilled:

1. The student has to be a graduate of the above mentioned institutes in one of the mentioned fields or, to the discretion of the NIL, in an other field of study but with sufficient practice in adhesive bonding.

2. The student must have followed the theoretical part of the course, with sufficient results, at the applicable polytechnic.

3. The student must have followed the practical part of the course, with sufficient results, at the applicable institute.

Norway

Engineers with the following basic education shall have access to the adhesive engineer education:

1. Sivilingenior (MSc)k
   degree obtained from a technical university or equivalent institution.

2. Ingeniorer (BSc)
   degree obtained from a college of engineering or equivalent institution

Applicants graduates in accordance with the previous education system may, at the discretion of the Norwegian Society (NSF) enter the course and participate in the examination provided their background meets the Norwegian requirements, point 2. above.

Portugal

The access to the education should be given to

* Graduates of Technical Universities

* Graduates of Polytechnical Institutes with a minimum degree of BSc and one year of industrial experience.

* Graduates of Polytechnical Institutes with a minimum degree of BSc and the Adhesive Specialist degree issued by EWF.

Graduate Engineers are graduated in Technical Universities with a minimum scholar full time of five years in a recognised university.

BSc Engineers are graduated in Polytechnical Institutes with a minimum scholar full time of three years.

Spain

1. Diploma of Engineering achieved after 6 years in a Politechnical University.

2. Diploma of Technical Engineer achieved after 3 years in a Politechnical University, with 2 years experience in engineering.

3. Diploma of Physics or Chemistry Science in the speciality of Metallurgy or Industry achieved after 4 years in a University, with 2 years experience in adhesives.

Sweden

Civilingenj_r or Ingenj_r with at least the following basic education has access to the EAE course and examination.

1. Civilingenj_r, MSc with diploma from Teknisk H_gskola (University of Technology), with at least four years of academic education.

2. Ingenjör, BSc with diploma from Teknisk H_gskola (University of Technology) with at least two years of academic education.

Switzerland

Certificate of an engineer's degree got at Eidgenossiche Technische Hochschule Zurich or Lausanne (ETH or EPFL) or a certificate of an Engineer's School (HTL - Hoehere Technische Lehranstalt). The degree has to come from the field of engineering, chemistry, physics or materials science.

United Kingdom

Accredited degree in engineering or equivalent professional qualification prescribed by the UK Engineering Council.

In addition the educational requirements, an adhesive engineer in the UK cannot be registered by TWI until he has completed a period of training and responsible experience, including three years of experience in adhesive engineering. This complies with the Engineering Council's requirements for the award of Chartered Engineer (CEng) status and provides for registration through FEANI as a Eur Ing.

Section II: Examination and Qualification

1. Introduction

This guideline seeks to achieve harmonisation and a common standard in the examination and qualification of professional adhesive engineers in Europe. The national welding and joining organisations, being member of the EWF, mutually acknowledge the Certificate awarded in any Member State to European Adhesive Engineers, following examination conducted in accordance with this Guideline.

Education must have followed this EWF guideline "European Adhesive Engineer" and the examination must have been conducted by the national body authorised by EWF for this purpose.

This "Authorised National Body" will normally be the National Welding and Joining organisation, but may be another organisation with the agreement of the EWF-member.

2. Approval of the post-graduate course

Any training course leading to the EWF examination must be approved by the Authorised National Body. The number of teachers required to give the course shall be sufficient to ensure that the essential expert knowledge and industrial experience to cover the syllabus is adequately represented in the team of teachers and visiting lecturers.

3. Board of Examiners

The Chairman and the members of the Board of Examiners shall be nominated by the Authorised National Body. The examining board shall consist of

a) the Chairman shall be a representative of the Authorised National Body, and he shall be independent from the training school.
b) Main teachers of the subjects
c) Experts from industry and other organisations.

The responsibilities of the Board of Examiners are give in the Doc EOTC 001/416.

4. Admission to the examination

Admission to the examination leading to the award of European Adhesive Engineer certificate will be restricted to those:

a) who comply with the minimum requirements specified in Section 1

and

b) who have attended the course, according to this guideline and approved by the Authorised National Body, for at least 90%. Exceptions are at the discretion of the ANB.

5. Examination procedures

The examination procedures described below are designed to simulate the different situation of an adhesive engineer activity in industry. There will be written examinations in each of the following subjects:

i) Adhesion and adhesives
ii) Materials as adherends
iii) Construction and design
iv) Durability
v) The Bonding process
vi) Testing and analysis
vii) Health and Safety
viii) Qualification Management

5.1 Written examination

At the discretion of the Board of Examiners the examination shall consist of:

a) A series of essay questions covering the whole field of the subject
or b) A series of multiple choice questions covering the whole field of the subject.
or c) A combination of a) and b) with equal marks allocated to each type.

The time devoted to the written examination shall be a minimum of 1 hour per subject ie. 8 hours in all.

5.2 Oral examination

The total time devoted to the oral examination covering all eight subjects shall be a minimum of one hour per candidate.

6. Evaluation of performance

In order to pass the examination candidates must achieve at least

60% of the maximum possible mark in each subject.

Successfully completed individual parts of the examination remain valid for a period of three years. The examination in all eight subjects shall be completed within a period of three years from the start of the course.

7. Re-examination and appeals procedure are covered by Doc EOTC 001/416.

8. European Adhesive Engineer's Certificate

After successful examination a Certificate is awarded to the candidate by the Authorised National Body. Those qualified as "European Adhesive Engineer" may be called European Adhesive Engineer in the national language and use the professional designation "EAE" (invariable in all member companies).