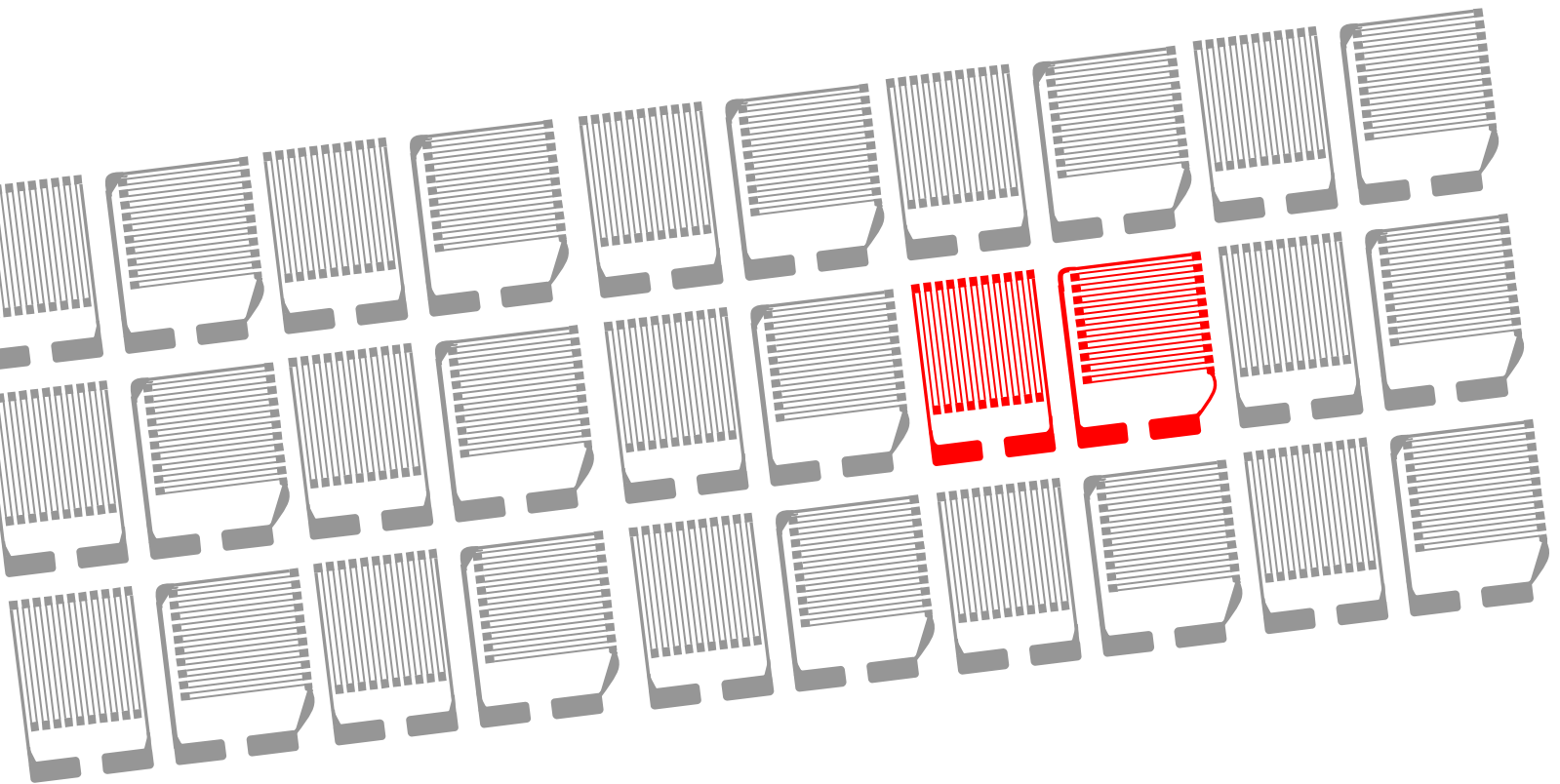


CERTIFICATION

OF

STRAIN MEASUREMENT

PERSONNEL



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INTRODUCTION

(i) **Background**

The British Society for Strain Measurement (BSSM) was founded in 1964 to promote standards in strain measurement and related areas of experimental mechanics. It has done this by holding conferences, meetings, seminars, workshops, courses and publishing a code of practice, a reference book, conference proceedings and a quarterly journal 'Strain' which is distributed to members and subscribers in over 40 countries.

The Society has always been fully aware that measurement accuracy depends critically on the skill, knowledge and understanding of measurement personnel as well as the inherent capability of equipment. In recognition of this the Society established standards of competence and a code of practice for the installation of strain gauges. A personnel certification scheme based on these standards and the code has been run for over 30 years.

The current version of the scheme, outlined in this document, is designed for strain gauge users. It has three levels, consistent with the European Standard EN473:2005, General Principles for Qualification and Certification of NDT Personnel.

The three levels make it possible to have an entry level appropriate for technicians who spend most of their time installing gauges to carefully prepared instructions and are normally concerned with only a limited range of applications, whilst the top level is aligned to the activities of strain measurement engineers. The gap between these two levels is bridged by an intermediate certificate, so that there is a smooth progression between levels.

(ii) **Administration**

BSSM is an independent certification body, as defined by the European Standard EN ISO/IEC 17024:2003 covering general requirements for bodies operating personnel certification schemes.

All examination arrangements, and the development and maintenance of the certification scheme, are handled by the Certification Committee (CERCO). This committee is responsible to the National Council of the Society (NATCO).

Examinations are held on a regular basis several times each year. The venues used have been chosen to suit candidates from a wide range of geographical locations. Dates and venues for these scheduled examinations are published in 'Strain'; they can also be obtained from the BSSM office and www.bssm.org. When there are several candidates from the same company an examination may be held on the company's premises.

All examinations are carried out by BSSM examiners.

(iii) **Aims**

The scheme is run to promote good practice in strain measurement and to confirm the competence of a strain gauge user by awarding a recognized qualification.

(iv) **Benefits**

Experience with the certification scheme over a period of more than 30 years has shown that certification has benefits for firms and their personnel. It:

- increases the confidence of staff
- makes staff more interested in extending their skill and understanding
- enhances the standing of staff within the company
- makes it easier for firms to demonstrate the competence of staff to external bodies

(v) **Levels**

Awards are made at three levels to provide appropriate qualifications for:

- (1) staff who install strain gauges
- (2) staff who install gauges, supervise gauge installation and use gauges either to measure strain or to provide an output from a sensor
- (3) staff having considerable responsibility for strain gauging and strain measurement, and who have direct contact with stress analysts or sensor designers

The levels are identified by the numbers used above. This numbering sequence is consistent with the European Standard EN473.

CERTIFICATION OF STRAIN MEASUREMENT PERSONNEL

SECTION ONE – LEVEL 1

1.1 LEVEL OF COMPETENCE

Certified personnel are able to:

- 1.1.1 perform at least one of the standard installations of 1.2.4 as specified in drawings and written instructions, using a standard procedure consistent with the BSSM Code of Practice CP1
- 1.1.2 perform installation checks covering visual inspection and electrical tests, and classify the results in terms of specific criteria.
- 1.1.3 provide a report recording all aspects of the installation, using standard forms.

They will not be responsible for choosing gauges and materials.

1.2 KNOWLEDGE BASE

1.2.1 Linear Strain

Basic concept of strain and its transmission to a bonded gauge

1.2.2 Linear Strain Gauges

Foil and wire gauges: component parts of a gauge and a bonded installation and their function; length, resistance, STC number

Wheatstone bridge: basic bridge arrangement for strain gauge measurements; colour coding; connections for one of the installations listed in 1.2.4

1.2.3 Installation of Foil and Wire Gauges

Basic rules for gauge installation

Surface preparation and marking out: methods and materials for common substrate materials

Gauge handling and bonding methods for one installation from 1.2.4

Leadwire attachment methods for the selected conditions

Installation protection: methods for applying a base coating and protection to one installation from 1.2.4

Installation checks: visual inspection for physical damage, position and orientation, appearance of bond, colour coding of lead wires, appearance of soldered joints and lead wires; electrical test for continuity, resistance, bridge balance of sensors, insulation resistance; protection; output stability

Documentation

Health and safety

1.2.4 **Standard Installations:**

- (a) single foil gauge for quarter bridge operation at a temperature between 0°C and 50°C
- (b) full bridge of foil gauges for long life at a temperature between 0°C and 50°C

1.2.5 **Other Installations**

- (c) foil gauge(s) for quarter bridge or half bridge operation at a temperature between -200°C and 250°C
- (d) gauges for operation at a temperature above 250°C

1.3 **EXAMINATION**

- 1.3.1 The Level 1 examination will consist of a written test and a practical examination. Candidates must choose to be examined in one of the installations of Section 1.2.4, but candidates may also choose to be examined in additional installations from 1.2.4 and 1.2.5. A separate certificate will be issued for each installation.

The total time allowed for one installation and the associated written test is normally 3.5 hours.

1.3.2 **Written**

Each candidate will take only one written test, which will be taken at the time of the first practical test.

The test will contain 20 multiple choice questions based on general knowledge related to the Level 1 competences and points which can arise during either the

type (a) or the type (b) installation. The test will normally be completed in about 30 minutes.

Questions will be selected in an unpredictable way from the collection of approved questions.

1.3.3 **Practical**

The practical examination will verify the candidate's ability to install gauges.

The minimum requirement is one of the standard installations in 1.2.4. A separate practical examination will be held for each type of installation, but candidates may be tested in more than one type of installation on the same occasion.

The test bodies used for the practical examinations will be selected from the collection of approved examples.

1.3.4 **Regulations**

Regulations for the examination are given in Section 4

1.3.5 **Booklet**

Further details regarding the operation of the examination are given in booklet CSMP11

SECTION TWO – LEVEL 2

2.1 LEVEL OF COMPETENCE

Certified personnel are able to:

- 2.1.1 perform at least the two Level 1 standard installations of 1.2.4
- 2.1.2 choose gauges, materials, installation methods, circuits and instruments for specified installations on structural components and sensors
- 2.1.3 state the limitations of an installation
- 2.1.4 understand the BSSM Code of Practice CP1 and manufacturer's literature and use them to prepare detailed installation instructions for the actual working conditions
- 2.1.5 calibrate measurement systems
- 2.1.6 perform strain measurement tests and correct the raw data
- 2.1.7 report the final results of strain measurement tests and tests on sensors using a standard presentation
- 2.1.8 carry out and supervise all Level 1 duties
- 2.1.9 train and guide personnel below Level 2

2.2 KNOWLEDGE BASE

All Level 1 topics are included and must be supplemented by the following:

2.2.1 Linear Strain

Deformation and strain in tension, compression and bending; variation of linear strain with orientation of gauge axis; Poisson's ratio. Strain in simple pressure vessels and pipes; variation of linear strain with orientation of gauge axis. Thermal strain.

Empirical relationships between load and strain in tension and compression; monotonic and cyclic loading; ductile and brittle materials; plastic strain and shakedown; creep; impact.

Stress in tension and compression; Young's modulus; prediction of stress from strain in tension/compression bars and beams in the elastic range. Strain profiles.

2.2.2 **Shear Strain**

Deformation and strain in torsion; variation of linear strain with orientation of gauge axis

2.2.3 **Strain Gauge Installation**

Gauges: structure, materials, patterns, length

Adhesives: types, characteristics

Leadwires: attachment methods, materials, resistance, length

Protection: systems, materials

Noise reduction

Selection of gauges, adhesives, leadwire and other materials for systems to make specified measurements under specified conditions

Procedures for making at least the two standard installations of 1.2.4

Limitations of installations: strain capacity in monotonic and fatigue loading; effects of temperature, humidity and pressure

Writing of detailed instructions for Level 1 personnel based on the BSSM Code of Practice CP1 or employer's validated methods

2.2.4 **Measurements using Linear Strain Gauges**

Measurement of foil and wire gauge output: strain/resistance relationship; Wheatstone bridge; configurations; bridge output; compensation for the effect of temperature change and long leads; calibration; bridge input voltage

Methods for correcting measured data: linearisation of elastic data; correction for transverse sensitivity, temperature response, and lead wire resistance. Errors due to distance of gauge above the surface

Instruments: commercial bridges, scanning units, recording devices

2.2.5 **Certification Scheme**

Certification of personnel at Level 1

2.3 EXAMINATION

2.3.1 The Level 2 examination will consist of a written test, with general and specific sections, and a practical examination.

The total time allowed for the examination is normally 6.5 hours. The time spent on each element is decided by the candidate.

2.3.2 Written - General

This is a test of general knowledge of strain measurement, solid mechanics and materials.

The paper will contain 10 multiple choice questions, all of which should be attempted.

2.3.3 Written - Specific

This is a test covering points which can arise during normal employment as a Level 2 strain gauge user, and will relate to the installations (a), (b), (c), (d) given in 1.2.4 and 1.2.5

The paper will have separate parts covering each type of installation.

All questions will be multiple choice. Candidates will attempt 15 questions from any part of the paper. There will be:

- 10 questions relevant to installation type (a)
- 10 questions relevant to installation type (b)
- 5 questions relevant to installation type (c)
- 5 questions relevant to installation type (d)

The written test, covering both the General and Specific elements, will normally be completed in less than 1 hour.

Questions for the written test will be selected in an unpredictable way from the collection of approved questions.

2.3.4 Practical

The practical examination will verify the candidate's ability to perform technical tasks appropriate to Level 2 and prepare written instructions

The examination will normally be completed in around 5.5 hours and will include:

- a gauge bonding and full-bridge wiring installation
- preparation of written installation instructions based on the gauge bonding exercise
- a measurement exercise using pre-installed gauges

The practical examination question paper will be selected from the collection of approved papers.

2.3.5 **Regulations**

Regulations for the examination are given in Section 4.

2.3.6 **Booklet**

Further details regarding the operation of the examination are given in booklet CSMP12

SECTION THREE – LEVEL 3

3.1 LEVEL OF COMPETENCE

Certified personnel are able to:

- 3.1.1 take full responsibility for strain gauge installation and strain measurement
- 3.1.2 carry out and supervise all Level 2 duties
- 3.1.3 establish and validate techniques and procedures
- 3.1.4 interpret standards, codes, specifications and procedures
- 3.1.5 plan gauging and testing to satisfy the strain measurement objectives
- 3.1.6 evaluate stresses and stress distributions from strain measurements or interpret the output of sensors
- 3.1.7 appreciate the scope and standard operating procedures of other strain/stress analysis methods

3.2 KNOWLEDGE BASE

All Level 2 topics are included, and must be supplemented by the following:

3.2.1 Strain

Shear strain

Plane combinations of linear and shear strain; variation of strain components with orientation of axes; principal values. Errors due to gauge misalignment.

Strain gauge rosettes; configurations; calculation of principal strains and directions from the output of rectangular rosettes

Strain profiles in structural components and sensor bodies

3.2.2 Stress from Measured Strains

Calculation of stress from measured strains. Principal stresses and von Mises stresses. Stress profiles in structural components and sensor bodies

3.2.3 **Measurements using Strain Gauges**

Choice of gauge locations, orientation of gauges, and the instrumentation to satisfy stress analysis objectives or the functional design of sensors

Validation of gauge installation techniques and instrumentation

Writing of measurement procedures based on BSSM Code of Practice CP1 and customer specifications

3.2.4 **Other Strain/Stress Analysis Methods**

A basic knowledge of at least three of the following methods

- Mechanical, inductive and strain-gauged beam extensometers
- Capacitance strain gauges
- Vibrating wire strain gauges
- Semiconductor strain gauges
- Transmission photoelasticity
- Photoelastic coatings
- Residual stress determination
- Finite element analysis

3.2.5 **Common Structural Materials**

General characteristics and properties

Mechanical behaviour:

- load-deformation response in tension, compression, bending and torsion for bars and simple components
- stiffness, yield point, ultimate strength
- hardness
- impact energy
- fracture toughness
- fatigue stress-life relationships
- creep
- effect of manufacturing methods

Residual Stresses:

- origins
- typical stress profiles and values

3.2.6 **Component Failure Modes**

Change in shape due to elastic deformation, creep, yielding, buckling, crack propagation, wear and corrosion

Fracture due to ductile rupture, brittle rupture, creep rupture, impact, fatigue

3.3 **EXAMINATION**

3.3.1 The Level 3 examination will consist of the practical test outlined in 3.3.2, the written test outlined in 3.3.3, and an interview.

3.3.2 **Practical**

The practical examination will verify the candidate's ability to make measurements and calculations appropriate to Level 3 and validate gauge installations.

The examination will normally last 6 hours and will include:

- one stress analysis task using pre-installed strain gauges
- one load measurement task using pre-installed gauges
- one written report based on an examination of an installation and the original specification

The practical examination questions will be selected from the collection of approved questions.

3.3.3 **Written**

The written test will last 2 hours and has two main sections:

Basic

Resistance strain gauge applications

The basic questions test the candidate's knowledge of:

- (i) material and solid mechanics related to component behaviour
- (ii) three methods of strain/stress analysis, chosen by the candidate from the list given in 3.2.4

The basic section will contain the following multiple choice questions, all of which should be attempted:

- 10 questions based on (i)
- 15 questions based on (ii)

The resistance strain gauge applications section is a test of general knowledge and understanding covering points which can arise during normal employment as a Level 3 strain gauge user. The questions will relate to competences 3.1.1 to 3.1.6 only.

This section will contain 20 multiple choice questions, all of which should be attempted.

Questions for the written test will be selected in an unpredictable way from the collection of approved questions.

3.3.4 **Interview**

The interview will normally last half an hour, and will be concerned with the candidate's:

- education and training
- experience in the analysis of strain and stress
- understanding and breadth of knowledge of strain measurement and stress analysis methods
- experience at Level 3

3.3.5 **Regulations**

Regulations for the examination are give in Section 4

3.3.6 **Booklet**

Further details regarding the operation of the examination are given in booklet CSMP13

SECTION FOUR – EXAMINATION REGULATIONS

4.1 ELIGIBILITY FOR EXAMINATION

All candidates for examinations must have received appropriate training, had relevant experience, and must normally have satisfied the requirements set out in Table 1. It is strongly recommended that they attend the pre-examination seminar, which is normally held around two weeks before each examination.

At Level 1 the training element will normally be a two-day course, but for some candidates a one-day workshop followed by the seminar may be sufficient.

It is expected that most candidates will start at Level 1, but suitably qualified candidates may take the Level 2 examination without a Level 1 certificate.

Candidates for the Level 3 examination must have held Level 2 certification. If this certification has expired, it must be renewed (5.5.1 & 5.5.3).

TABLE 1 TRAINING AND EXPERIENCE

| | Tertiary Education | Level 1 | Level 2 | | Level 3 |
|------------------------|---------------------------|---------|---------|-----|---------|
| | | | (2) | (3) | |
| Training (Days) | Degree/HNC ⁽¹⁾ | 2 | 4 | 5 | 3 |
| | None | 2 | 5 | NA | 4 |
| Experience (Months) | Degree/HNC ⁽¹⁾ | 2 | 6 | 12 | 9 |
| | None | 2 | 12 | NA | 18 |

(1) Engineering or Science

(2) After passing Level 1

(3) Direct entry to Level 2

(4) After passing Level 2

NA Not appropriate

4.2 CONDUCT OF EXAMINATIONS

The Certification Committee of BSSM is responsible for conducting all examinations.

An examiner will be appointed with responsibility for the examination; an assistant examiner or an invigilator may be appointed to assist the examiner. Level 3 interviews will be conducted by three members of the Certification Committee. The pre-examination seminar will be conducted by another experienced examiner.

Examinations will be held in approved examination centres. The pre-examination seminar will normally be held at the same location as the examination. Any unsatisfactory features of the venue will, if possible, be rectified before the examination, and will be reported to the Certification Committee. BSSM will provide gauges, adhesives, test bodies, loading rigs and instruments. All other materials and tools will normally be provided by the candidate.

Question papers for the practical tests and written tests will be selected from the sets of approved papers.

The examiner will award marks based on an approved marking scheme or procedure. A practical test Marking Record Sheet and an examination Marking Summary Sheet will be completed for each candidate. If the candidate has failed, the Summary Sheet will include a list of the main unsatisfactory aspects.

A moderator will review the test pieces and scripts and the examiner's marking sheets for each group of candidates, and will send the scripts and marking sheets to the BSSM office.

The examiner and the moderator will determine the final marks and the list of unsatisfactory aspects. The examiner will produce an Examination Result Sheet for the group of candidates, and will attach a list of unsatisfactory aspects for any candidate who has failed. This document will be sent to the BSSM office within 4 weeks.

The Certification Committee will confirm the result of the examination.

4.3 MARKING OF EXAMINATIONS

4.3.1 Level 1

An aggregate mark for the examination will be calculated using 20% of the mark for the written test and 80% of the mark for the practical examination.

To qualify for a Level 1 certificate a candidate must obtain an aggregate mark of at least 70%. A pass with Distinction will be awarded to a candidate who achieves a mark of 85% or higher.

For an additional Level 1 certificate the aggregate mark will be calculated using the mark for the practical examination and the mark for the original written test.

4.3.2 **Level 2**

An aggregate mark for the examination will be calculated using:

- 35% of the mark for the gauge bonding and wiring installation
- 20% of the mark for the installation instructions
- 20% of the mark for the measurement task
- 25% of the mark for the written test

To qualify for a Level 2 certificate a candidate must obtain an aggregate mark of at least 70%, with at least 60% in the written test and 60% in the practical examination.

A pass with Distinction will be awarded to a candidate who achieves an aggregate mark of 85% or higher.

4.3.3 **Level 3**

An aggregate mark will be calculated using 30% of the mark for the written test, and 70% of the mark for the practical examination. A mark will be awarded for the interview, but it will not be included in the aggregate.

The mark for the practical examination will be determined by allocating:

- 40% for the stress analysis task
- 30% for the load measurement task
- 30% for the report on an installed gauge

To qualify for a Level 3 diploma a candidate must obtain a mark of at least 70% for the interview and an aggregate mark of at least 70%, with at least 60% in the written tests, and 60% in the practical examination.

A pass with Distinction will be awarded to a candidate who achieves an aggregate mark of 85% or higher.

4.4 RE-EXAMINATION

4.4.1 Level 1

A candidate who fails to obtain the minimum aggregate mark for the examination may re-take the examination

4.4.2 Level 2

A candidate who fails to obtain the minimum aggregate mark for the examination, but has achieved the required mark for the written part and the practical part, may be re-tested once in one of these elements. If a pass is not achieved in this way the candidate may repeat the whole examination.

4.4.3 Level 3

A candidate who fails to obtain the minimum aggregate mark, but has achieved the required mark for the written test and the practical examination, may be re-tested once in one of these elements. If a pass is not achieved in this way the candidate may repeat the whole examination.

A candidate who fails the interview, but satisfies the other requirements, may retake this element once.

4.4.4 Level 2 and Level 3

A candidate who obtains the required aggregate mark but fails to achieve the pass mark in one part of the examination may be re-tested once in that part, but the mark awarded will not exceed 60%. If a pass is not achieved in this way the candidate may repeat the whole examination.

SECTION FIVE – CERTIFICATION

5.1 Application for Examination

Application to take an examination must be made on standard forms which can be obtained from BSSM. Details of training, experience and previous certification are required; they must be supported by appropriate evidence. Applications must be submitted to BSSM at least 5 weeks before the examination date. Registrations are confirmed after a review by the Chairman of the Certification Committee.

5.2 Notification of Results

Candidates will be informed of the examination result by letter, usually within 5 weeks of the examination. For candidates who fail an examination the letter will include the main reasons for the failure and the opportunities for re-examination.

A letter will also be sent to the candidate's employer.

5.3 Issue of Certificates

A certificate will normally be issued within two months of the examination.

The issue of a certificate confirms that the holder has demonstrated appropriate levels of competence measured by an approved examination. No other capability may be implied.

5.4 Validity of Certification

Certification is valid for 5 years from the date on the certificate.

5.5 Renewal of Certification

- 5.5.1 Holders of Level 1 and Level 2 certification will be required to complete appropriate practical tasks and submit a review of their recent strain gauging experience.

At Level 1 the practical test will be either a Type (a) or a Type (b) installation. At Level 2 the practical test will involve design of gauge installations, installation of the gauges and wiring, and measurements using the gauges. It will not include the writing of instructions.

- 5.5.2 Holders of Level 3 certification have a choice. They may either undertake a practical test and submit a review of their recent strain measurement experience, or show that they are operating at Level 3 by accumulating at least 30 points over the 5 year period, based on the credit scheme given in Table 2.

5.5.3 At all levels the practical tasks will be done at the candidate’s workplace, under the supervision of a senior colleague, who will be required to confirm the candidate’s experience and that the renewal tasks were done by the candidate. There will not be a limit on the time taken to do the tasks. Test samples and documentation will be assessed by an examiner. The pass mark for the practical test will be 70%.

5.6 Appeals

Appeals against the result of an assessment may be made to the Society Manager, who will inform the Certification Committee.

5.7 Records

BSSM will retain records of examination results for at least 10 years. Examination scripts and marking sheets will be kept for one year.

5.8 Register

BSSM will keep an up-to-date register of certificated personnel.

TABLE 2 CREDIT SCHEME FOR LEVEL 3 RE-CERTIFICATION.

| Activity (1) | Points awarded for each activity | Maximum points per year |
|---|----------------------------------|-------------------------|
| Attendance at a conference, seminar or course (per day) | 1 | 3 |
| Attendance at a meeting of a committee or working group | 1 | 3 |
| Authorship of a technical report or publication | 1-3 | 6 |
| Experience as a training instructor (per 3 hours) | 1 | 6 |
| Experience as an examiner | 1 | 6 |
| Total activity | - | 10 |

(1) Concerned with strain measurement/stress analysis