



GLOBAL WIND  
ORGANISATION

# Blade Repair Training Standard

V1.1

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# 1 LIST OF ABBREVIATIONS

GWO	Global Wind Organisation
WINDA	GWO training record database
SDS	Safety Data Sheet
PPE	Personal Protective Equipment
LOTO	Lock out Tag Out
TDS	Technical Data Sheet
TG	Glass Transition
CS	Chopped Strand
UD	Unidirectional
Biax	Biaxial
Triax	Triaxial
WI	Work Instructions



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## 2 TERMS AND DEFINITIONS

Hardback	A thin, pre-cured sheet of fibre reinforce composite material. Usually consisting of 1 layer of 600 gsm biax glass fibre.
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### 3 CHANGE LOG – VERSION 1 .1

Amendment Date	Oct. 2020	Approved by & date	
Version	1.1	Description of changes	
<ul style="list-style-type: none"> <li>- GWO Standard updated to match the Corporate Visual identity of GWO (CVI)</li> <li>- Each module now contains a cover page and the module name listed in the header as reference.</li> <li>- New ISO Code added to standard</li> <li>- All previous versions of the Change log have now been moved to Annex 5. The current change log remains at the start of the standard.</li> <li>- Duplicate information removed from Section 4. Scope</li> </ul> <p>The following sections have been removed due to this information now included in the new Requirements for Training Providers and Requirements for Certification Bodies (released May 2020)</p> <p><b>Section 5</b></p> <ul style="list-style-type: none"> <li>- 5.3 Conformity with other training – section removed</li> <li>- 5.4 Legal Requirements – Section Removed</li> </ul> <p><b>Section 6</b></p> <ul style="list-style-type: none"> <li>- 6.2 Facilities and Equipment – section removed</li> <li>- 6.3 Theory training facilities – section removed</li> </ul> <p><b>Section 8</b></p> <ul style="list-style-type: none"> <li>- 8.1 Administrative arrangements – section removed</li> <li>- 8.3 Requirement to upload training record in WINDA – section removed ( course Codes have now been moved to section 5.6)</li> <li>- 8.4 Training Providers own Records and Certificates issue – section removed</li> </ul> <p><b>Annex 1</b></p> <ul style="list-style-type: none"> <li>- Delegate Performance Assessment Form – Section removed</li> </ul> <p><b>Annex 2</b></p> <ul style="list-style-type: none"> <li>- Medical Assessment Form – Section removed</li> </ul> <p><b>All section reference numbers have now been updated</b></p>			



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Amendment Date	05/02/2019	Approved by & date	GWO SC 05/02/2019
Version	1	Description of changes	
<b>Minor corrections since launch</b>			
<b>October 2019</b>			
- Section 9.2 duration updated to clarify meaning of contact time			
<b>First Edition</b>			
New Training Module created			



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## 4 SCOPE

This Standard has been developed in response to the demand for recognizable blade repair training in the industry. It has been prepared in cooperation with the members of GWO based on specific risk assessments, data from incident and accident statistics pertaining to the installation, service and maintenance of blades on wind turbine generators and wind power plants.

This standard describes the requirements for blade repair training that are recommended by the members of the GWO.

The members of the GWO recognize trained persons as competent within blade repair in the wind industry and accept the trained person as possessing the required knowledge to stop an unsafe work situation where they as duty-holders are accountable for safety. Training is verified through the GWO database WINDA.



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## 5 GENERAL REQUIREMENT TO GWO BLADE REPAIR

Upon completion of the GWO Blade repair module (BR), delegates will be aware of the risks and hazards encountered when working with blade inspection and repair within the wind industry. Furthermore, they will be able to control and mitigate those risks and hazards.

The GWO blade repair training module will also equip participants with the knowledge, skills and confidence to appropriately respond in the event of a hazardous situation and to increase their safety through proper use of personal protective equipment, emergency equipment, procedures and safe craftsmanship.

### 5.1 Target group

Personnel who will be working in the wind industry specifically in relation to composite inspection and repair work. Personnel that perform job functions that have been risk assessed by their employer or their workplace duty holder as a function, where composite work training according to this standard may mitigate some of the identified hazards and risks.

### 5.2 Aims and strategic objectives

Training in accordance with this standard will enable delegates to support and care for themselves and others working in the wind industry by possessing the knowledge and skills of composite inspection and repair work. Upon completion of the GWO Blade repair training course, delegates will be able to work safely with composite materials while conducting inspection and basic blade repair procedures, thereby supporting an overall improvement of the safety for personnel with job functions focussing on composite repair work and inspection in the wind industry.

### 5.3 Guidance on delivering lesson elements

Section 10.4 gives approximate duration of each of the lessons. The training provider may choose to deliver elements of the training according to other timetables, provided that the total duration is not reduced, and the duration of practical elements are not reduced in length. Theoretical elements should be delivered during the practical exercises whenever feasible.

### 5.4 Validity Period

The blade repair training is an enduring qualification and therefore a validity period does not apply to this training. This assumes that the delegate is actively working with composite inspection and repair.



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## 5.5 Course Codes

Module	Course Code
Blade repair	BR

*Table 5-6 - GWO blade repair module course code*

## 5.6 Delegate prerequisites for the Blade repair module

All personnel participating in the blade repair training module shall be medically fit and capable of fully participating. Specifically, the delegates must be made aware of the risks and hazards related to completing this course while being allergic towards the materials used in the module. Furthermore, this also applies for delegates suffering from asthma and hyperhidrosis manuum (excessive hand sweating).

Training providers shall have a procedure that requires delegates to sign a statement stating that they are medically fit to participate in the training course and that they do not suffer from any medical illness that will prevent them from fully participating in the training course or subject them to hazard or risk, or are under the influence of any impeding substances like narcotics or alcohol. The Annex 2: Medical Self-Assessment Form shall be used if no other equivalent procedure is in place.

Delegates' signatures testifying to their medical fitness shall be collected prior to the start of the GWO blade repair module.

Delegates must have created a personal delegate profile in WINDA and provide their own WINDA ID prior to completing the GWO blade repair training.

## 5.7 Physical demands

The GWO blade repair training module may potentially be physically demanding.

If there is any doubt regarding the medical fitness of any delegate, the training provider shall stop training with the delegate and seek a physician's advice.

Note: Practical exercises shall be designed and delivered solely to meet this standard and shall not place any physical or mental demands on the delegates other than those required to meet this standard.



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## 6 GENERAL RESOURCES REQUIRED TO DELIVER BLADE REPAIR MODULE

The training provider shall ensure that the staff, facilities, and equipment are in place to support the training of the delegates.

### 6.1 Staff

Training staff shall possess appropriate qualifications and experience to ensure that all training and supportive activities are carried out in accordance with current legislation and the current requirements outlined on the CRITERIA FOR TRAINING PROVIDERS OFFERING GWO TRAINING document.

The Instructor must:

- 1) Hold valid certificates for GWO BST/BSTR First Aid and GWO BST/BSTR Manual Handling
- 2) Be able to demonstrate knowledge and practical skills in blade repair methods, techniques and craftsmanship comparable to those executed by the delegates during the practical exercises of the Blade repair module
- 3) Act as first responder in the case of an accident

Supporting staff:

- 1) A person with a current valid first aid qualifications shall be present during all practical training. This can be the instructor or an assigned emergency response team

### 6.2 Practical training facilities

All facilities shall be maintained and where appropriate, inspected and tested in accordance with current national legislation and manufacturers' specification. It is recommended that the facilities reach European standards.

Risk assessments shall be conducted and documented for all training facilities. The training provider shall hold the required permits to operate the facilities.

The learning process is facilitated by comparable elements, comparing the training environment and the delegates' working environment. Comparable elements enhance the application of what is learned. The practical training facilities and the training environment are therefore expected to incorporate as many comparable elements to a real wind turbine working environment as is reasonably practicable.

The practical training facility should enable each delegate to individually and/or as part of a team, see, hear and practice the taught subject matter in such a way that it resembles the working practices in a real wind turbine environment.

The following training facility items will be required for the Blade repair training:



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A workshop area, ensuring the following:

- 1) Sufficient dust extraction to ensure that the amount of dust in the air is kept below 10 milligrams per cubic metre
- 2) Sufficient filtration of extracted air to prevent environmental contamination
- 3) Sufficient exposure control measures to limit training staff and delegates to the exposure limits as stated in the safety data sheet for all materials being used
- 4) Sufficient temperature and humidity control to ensure that all materials being used are used within the usage limits specified in the technical data sheet for those materials
- 5) Sufficient segregation from classrooms and administrative areas to prevent cross contamination of chemicals
- 6) Sufficient waste segregation to prevent cross contamination

The training provider must ensure that chemical waste is disposed of in accordance with national legislation.

The training provider must provide a changing area between workshop areas and clean areas like classrooms and administration areas where delegates and staff can change their shoes to prevent contamination of clean areas with chemicals.

The above are the minimum requirements, if national legislation and regulation supersedes this, then they must be followed.

## 6.3 Training Equipment

The equipment required for training as listed in Annex 1 must be available and must fulfil national legal requirements in the country where the training is taking place.



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## 7 UNDERSTANDING GWO LEARNING OBJECTIVES

The described learning objectives (expected learning outcome) are the foundation of the course contents and what the delegate performance assessment must be based upon.

Traditionally learning objectives are prepared within three different domains of learning – knowledge, skills and attitude. A learning objective describes the expected learning outcome on completion of a module or a course, within one or more learning domains.

If a learning objective is related to more than one domain of learning, e.g. knowledge and skills, one learning objective per learning domain is often prepared – to enable a better understanding of the learning objective.

The training provider may apply teaching methods (didactics) that are appropriate to the course participants prior training, education and cultural backgrounds but should always aim to provide course participants ample possibility to perform hands-on demonstrations and learning reflection.

### 7.1 Taxonomy

To formulate a measurable learning objective, taxonomy is used to describe the level of expected learning outcome within a learning domain.

As an example, belonging to the learning domain of knowledge, to have a delegate name or recognize something, as opposed to have them explain it in their own words, or even apply or demonstrate what they have learned – describes different performance levels, i.e. different taxonomy levels.

Different taxonomies are associated with different learning domains, for instance:

Knowledge: such as Bloom's "cognitive taxonomy"

Intellectual knowledge, mental skills and procedures

Skills: such as Simpson's "psychomotor taxonomy"

Physical skills, cognitive controlled and observable

Attitude: such as Krathwohl's "affective taxonomy"

Attitude and feelings to the learning

When selecting a suitable taxonomy level, an action verb expresses the expected behaviour of the delegate, thus describing the taxonomy level of a learning objective.

Action verbs are usually highlighted in bold in this standard. The table below presents the three learning domains within taxonomy level 1-3, provided with associated action verbs applicable in the learning objective wording, defining the taxonomy level. In the GWO training standard, the learning objectives are in general described as level 2 or 3.



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	<b>Knowledge</b>	<b>Skills</b>	<b>Attitude</b>
<b>3</b>	<p><b><u>Application / Applying</u></b></p> <p>To use in a new situation. Solving problems by applying acquired knowledge, facts, techniques and rules in a different way. Applying a procedure to a familiar or unfamiliar task. Using a manual to calculate and operate.</p> <p><b>Action verbs</b> Apply, Change, Choose, Compute, Modify, Operate, Practice, Prepare, Schedule, Solve, Write.</p>	<p><b><u>Guided response</u></b></p> <p>Follows instructions to build a model. Using a tool after observing an expert demonstrate how to use it. Be able to demonstrate an activity to other learners. Can complete the steps involved in the procedure as directed.</p> <p><b>Action verbs</b> Accomplish, Achieve, Calibrate, Complete, Control, Demonstrate, Perform, Refine, Show.</p>	<p><b><u>Value</u></b></p> <p>Demonstrates belief in the company's described process. Shows the ability to solve problems. Informs management on matters that one feels strongly about. Decide worth and relevance of ideas and tasks.</p> <p><b>Action verbs</b> Argue, Challenge, Confront, Complete, Debate, Criticize, Justify, Join, Propose.</p>
<b>2</b>	<p><b><u>Comprehension / Understanding</u></b></p> <p>Construct a meaning from instructional messages, including oral, written and graphic communication. Demonstrating basic understanding of facts and ideas. Explain in your own words the steps of performing a complex task.</p> <p><b>Action verbs</b> Classify, Distinguish, Estimate, Explain, Express, Give, Illustrate, Indicate, Locate, Predict, Summarize, Translate.</p>	<p><b><u>Set</u></b></p> <p>Awareness or knowledge of the ability needed to use the skill. Carry out tasks from verbal or written instructions. Showing eagerness to assemble components to complete a task. Knows and acts upon a sequence of steps in a process.</p> <p><b>Action verbs</b> Access, Build, Complete, Conduct, Execute, Implement, Operate, Perform, Recreate.</p>	<p><b><u>Respond</u></b></p> <p>Completing work assignments with high respect to the agreement. Participating in team problem solving activities. Question new ideas and concepts in order to fully understand them. Participate actively and respectfully in discussions. Showing enthusiasm.</p> <p><b>Action verbs</b> Assist, Contribute, Discuss, Present, Question, Report, Respond, Tell, Write.</p>
<b>1</b>	<p><b><u>Knowledge / Remembering</u></b></p> <p>Memory of facts, terminology, rules, sequences, procedures, etc. Locating knowledge in long-term memory and retrieving relevant knowledge from long-term memory.</p> <p><b>Action verbs</b></p>	<p><b><u>Perception</u></b></p> <p>Watch instructor and repeat action, process or activity. Recognizing sounds or pictures that indicate certain functionalities. Estimate the event of a certain function and be prepared for it.</p> <p><b>Action verbs</b></p>	<p><b><u>Receive</u></b></p> <p>Listening to discussions of controversial issues with an open mind. Respecting the rights of others. Listen to others and remember their opinions. Be positive and creative to what is being taught.</p>



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	Arrange, Define, Describe, Find, Identify, List, Name, Outline, Recognize, Relate, Recall, Retrieve.	Attempt, Copy, Duplicate, Follow, Organize, Repeat, Sketch, Replicate, Reproduce.	<b>Action verbs</b> Ask, be open to, Concentrate, Discuss, Focus, Follow, Listen, Reply, Take part.
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*Table 7-1 - Taxonomy used by GWO*

**Note:** Higher taxonomy levels exist.



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## 8 ADMINISTRATION AND CERTIFICATION OF MODULES

### 8.1 Delegate performance assessment

Delegates will be assessed by means of direct observation and supplementary oral questions where appropriate (formative evaluation). Furthermore, the delegate will be subjected to written phase tests after the theory elements, and again after the close of the training course. (Summative evaluation)

The written tests can consist of multiple choice or descriptive answer questions and shall be set at the same taxonomy level as the objective that they are testing. There shall be at least one question for each lesson in the module.

The written tests shall be conducted in accordance with the following criteria:

- 1) There shall be an instructor present in the room where written tests are being conducted for the entire duration of the written test
- 2) The delegates shall not communicate with each other during the test
- 3) The delegates shall not communicate with any persons via email, telephone, skype (or similar) or social media during the test
- 4) The delegates shall be allowed to use training material, handouts and their own notes during the test
- 5) Where a delegate does not understand the meaning of a question or a multiple-choice option, the training staff shall be allowed to help the delegate in understanding the meaning of the question or the multiple-choice options. The training staff shall not give the delegate the correct answers to any test questions
- 6) There shall be a time limit of 1½ minutes per question
- 7) The written test questions cannot be used during the training in such a way that the delegates could recognise that they will be test questions.
- 8) Each delegate must answer at least 70% of written test questions correctly to pass the test.

If a Delegate does not reach the passing criteria in written or observational tests, then the instructor shall discuss this with the delegate to find out the reason for not reaching the passing criteria. If the reason is due to a misunderstanding of a question or due to language difficulties, then the instructor can mark a question as correct provided that the delegate is able to demonstrate understanding of the lesson element being tested. This must be documented by the instructor and stored with the tests, control measures and evaluations for the course.

Training Providers shall have a documented procedure in place for dealing with Delegates not meeting the stated learning objectives.

Throughout the entire GWO blade repair course the instructor will use the delegate assessment form (see the Requirements for Training Providers) to evaluate the delegates knowledge and skills, with a high focus on evaluating the delegate's safety awareness and craftsmanship skills.



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The instructor shall keep a delegate assessment form (or adaptation) for each delegate until the completion / evaluation of the blade repair training module.

The delegate assessment form (or adaptation) is a final evaluation tool for the instructors to assess delegates during practical elements. It allows measurement of the number of violations regarding safety, competency or attitude.

The delegate assessment form shall be used as a progressive evaluation tool to discuss the performance of a delegate in guiding them to success. It also serves as supporting documentation if a delegate passes or fails the module. If a delegate fails to meet the demands of the blade repair training module, they can attend a new blade repair training in accordance with the contractual agreement when ordering the training course. The re-entry point is dictated by the stage where the delegate stepped out of the course or where the instructor deems constructive.

Training providers may adapt the delegate assessment form to other media. Training providers must have a documented procedure in place for dealing with delegates not meeting the stated learning outcomes.



GLOBAL WIND  
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# Blade Repair Module (BR)





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## 9 MODULE - BLADE REPAIR

### 9.1 Aims and objectives of the Blade Repair Module

The aim of the GWO blade repair training module is to enable the delegate to support and care for themselves and others working in the wind industry by possessing the knowledge, skills and attitude of blade repair.

Upon successful completion of the GWO blade repair training course, the delegate will be able to perform and document a wind turbine blade inspection, execute repair work in accordance with a work instruction while maintaining the aerodynamic profile and structural integrity in glass fibre reinforced composite parts of a wind turbine within the following dimensions:

- 1) Trailing edge repairs up to 1,5 m in length
- 2) Leading edge repairs up to 1,5 m in length
- 3) Laminate repairs down to core material
- 4) Core material replacement up to 200 cm<sup>2</sup>
- 5) Surface repair to paint and gelcoat

The GWO blade repair training course is intended as an entry level course and therefore the delegate will not be expected to perform repairs in major structural elements of blades like spars, spar caps and carbon fibre.

To successfully complete the GWO blade repair training the delegate must be able to:

- 1) Demonstrate awareness of the course content and the facilities involved to ensure a clear understanding of what is expected during the course (L2 - Knowledge & Attitude)
- 2) Demonstrate the ability to work safely with applicable chemicals while utilizing the applicable personal protective equipment in a controlled manner throughout all phases of composite inspection and repair work (L3 - Skills)
- 3) Explain typical types of composite construction, materials and the importance of surface finish relating to aerodynamic performance and efficiency (L2 - Knowledge)
- 4) Distinguish between and work safely in a controlled manner with epoxy, polyester, polyurethane, vinyl ester, methacrylate, reinforcement materials and solvents related to composite inspection and repair work (L3 - Skill)
- 5) Prepare, operate and maintain the correct tools and equipment, be it electrical or mechanical (L2 - Skill)
- 6) Demonstrate the ability to safely execute and document laminate, sandwich panel and surface layer repairs in accordance with a work instruction in glass fibre reinforced composite parts



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## 9.2 Duration of the Blade repair module

The total contact time for completing this blade repair module is estimated to be 70 hours. This is based on the time estimate given in the module timetable.

The training provider must not exceed the times per day given in table 9-2 below.

The training provider must ensure that sufficient time is allowed for delegates with prior experience to share their experiences related to blade repair in a way that is constructive for the entire class.

	Maximum duration per day
Contact time	8 hours
Total training day	10 hours

Table 9-2 - Maximum durations for training day

**Note:** Contact time includes delivery of course lesson contents, practical exercises and activities directly related to these.

The total training day includes contact time, meals and breaks and travel between training sites (where applicable).

## 9.3 Blade repair module Trainer/Delegate Ratio

The ratio shown for theory sessions indicates the maximum number of delegates that can attend the course.

The ratio shown for practical sessions indicates the maximum number of delegates to be supervised by one instructor during each activity.

Module	Session	Instructor – Delegate Ratio
Blade repair	Theory	1:12
	Practical	1:6

Table 9-3 - GWO Blade Repair Instructor to delegate ratio

## 9.4 Blade Repair module Timetable

The training provider may choose the order in which to deliver the elements of this blade repair training module, provided that the order of delivery enables the delegate to safely execute all tasks and exercises given to them, and that all learning objectives are met.

The approximate duration of each lesson is given in table 9-4 below. The training provider may choose to deliver elements of the training according to other timetables, provided that the total duration is not reduced, and practical elements are not reduced in length. Theoretical elements should be delivered during the practical exercises whenever feasible.



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Topic		Lesson		Approx. Duration
1	General safety	1	Introduction	15 min.
		2	Safety Data Sheet	15 min.
		3	Work instruction	10 min.
		4	Risk assessment	20 min.
		5	Secure an area	10 min.
		6	Contamination	15 min.
		7	Waste Segregation	10 min.
		8	Ergonomic	15 min.
		9	Lock out tag out	10 min.
<b>TOTAL</b>				<b>120 min.</b>
2	Personal Protective Equipment	10	Personal Protective Equipment	100 min.
		11	Masks and Filters	45 min.
<b>TOTAL</b>				<b>145 min.</b>
3	General Knowledge	12	Chemical Safety	90 min.
		13	Composites and blade construction	60 min.
		14	Materials	75 min.
		15	Tools and equipment	40 min.
		16	Phase test	30 min.
<b>TOTAL</b>				<b>295 min.</b>
4	Craftmanship	17	Lamination skills	150 min.
		18	Basic lamination	290 min.
		19	Sandwich panel	420 min.
		20	Painting	120 min.
		21	Blade inspection	230 min.
		22	Lightning protection system inspection	50 min.
		23	Grinding skills	45 min.
		24	Sanding	45 min.
		25	Laminate repairs	600 min.
		26	Filling	180 min.
		27	Surface repairs	180 min.
		28	Trailing edge repairs	440 min.
		29	Leading edge repairs	440 min.
		30	Sandwich panel repairs	180 min.
		31	Bond line repairs	180 min.
		32	End of course test	60 min.
33	Feedback	30 min.		
<b>TOTAL</b>				<b>3640 min.</b>



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GRAND TOTAL

4200 min.

*Table 9-4 - GWO Blade repair module timetable*



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## 9.5 Detailed description of the blade repair module

### Lesson 1 - INTRODUCTION

15 min.

The aim of this lesson is to give the delegate the needed awareness of the course content and the facilities involved in order to ensure that all delegates are aware of what to expect and what is expected of them during the course.

After this lesson the delegate will be aware of the following:

- 1) Safety instructions and emergency procedures
- 2) Facilities
- 3) Introduction
- 4) Scope and main learning objectives
- 5) Ongoing assessment (Delegate Assessment Form)
- 6) Motivation

#### ELEMENT 1.1 - SAFETY INSTRUCTIONS AND EMERGENCY PROCEDURES

The Instructor shall **explain**:

- 1.1.1 Safety instructions according to internal procedures
- 1.1.2 Emergency procedures and emergency exits in the areas where the delegates can be expected to be located during the course
- 1.1.3 Site specific chemical safety rules and instructions

#### ELEMENT 1.2 - FACILITIES

The Instructor shall **explain**:

- 1.2.1 General description of the facilities at the training location (Administration, dining area, restrooms, toilets, etc.)

#### ELEMENT 1.3 - INTRODUCTION

The Instructor shall **give**:

- 1.3.1 A short introduction of themselves, including their backgrounds as instructors

Delegates shall give:



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- 1.3.2 A short introduction of themselves, including job function and expected primary geographic work location

The Instructor shall **explain**:

- 1.3.3 The programme of the blade repair training module, including breaks and meal times

#### ELEMENT 1.4 - SCOPE AND MAIN LEARNING OBJECTIVES

The Instructor shall **explain**:

- 1.4.1 The scope and main objectives of the blade repair training module

#### ELEMENT 1.5 - ONGOING ASSESSMENTS (DELEGATE ASSESSMENT FORM)

The Instructor shall **explain**:

- 1.5.1 The reasons for the ongoing assessment  
1.5.2 The layout of the GWO delegate assessment form and how it will be used

#### ELEMENT 1.6 - MOTIVATION

The Instructor shall **explain**:

- 1.6.1 The importance of personal involvement in the course  
1.6.2 The definition of and the need for blade inspection and repair

## Lesson 2 - SAFETY DATA SHEETS

15 min.

The aim of the lesson is to give the delegate the knowledge, skills and attitude to be able to read, explain and apply the information obtained from a safety data sheet (SDS).

To successfully complete this lesson the delegate shall be able to:

- 1) Explain the origin, purpose and content of safety data sheets (L2 - Knowledge)
- 2) Explain where to locate the most up to date safety data sheet in the applicable language (L2 - Knowledge)
- 3) Describe safety instructions according to internal and national procedures (L2 - Knowledge)
- 4) Explain the different types of hazard labels and their implications, covering at least toxic, flammable and hazardous environment symbols (L2 - Knowledge)



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- 5) Demonstrate how to identify what type of personal protective equipment is to be used with the applicable chemical (L2 - Knowledge)

## ELEMENT 2.1 - SAFETY DATA SHEETS

Training Staff shall:

- 2.1.1 Describe the requirement for chemical manufacturers to produce safety data sheets for the chemicals they produce
- 2.1.2 Explain the purpose of safety data sheets
- 2.1.3 Show examples and explain the contents of safety data sheets with emphasis on sections 1.4, 2, 4 and 5

## ELEMENT 2.2 - SAFETY DATA SHEET LOCATION

Training Staff shall:

- 2.2.1 Explain how to locate safety data sheets
- 2.2.2 Explain how to find safety data sheets written in local languages

Delegates shall:

- 2.2.3 Demonstrate the ability to locate the safety data sheet
- 2.2.4 Demonstrate how to find the safety data sheet in the applicable language

## ELEMENT 2.3 - SAFETY INSTRUCTIONS

Training Staff shall:

- 2.3.1 Explain how to locate company specific safety instructions
- 2.3.2 Explain the requirement to follow national safety procedures
- 2.3.3 Explain how to react in case of an accident

Delegates shall:

- 2.3.4 Explain safety instructions according to internal and national procedures
- 2.3.5 Explain how to react in case of an accident
- 2.3.6 Locate at least one example of a chemical from the safety data sheet which will be used during the course, including the mitigation steps

## ELEMENT 2.4 - HAZARD LABELS AND SYMBOLS

Training Staff shall:



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- 2.4.1 Show examples from a safety data sheet and explain the meaning of hazard identification labels and their implications
- 2.4.2 Show examples of and explain the meaning of toxic, flammable and hazardous symbols

Delegates shall:

- 2.4.3 Be able to recognise toxic, flammable and hazardous symbols
- 2.4.4 Be able to recognise different types of safety label and explain their implications

## ELEMENT 2.5 - PERSONAL PROTECTIVE EQUIPMENT

Training Staff shall:

- 2.5.1 Demonstrate how to identify the personal protective equipment to be used with a chemical from the safety data sheet

Delegates shall:

- 2.5.2 Demonstrate how to identify the personal protective equipment to be used with the applicable chemical from the safety data sheet

## Lesson 3 - WORK INSTRUCTION

10 min.

The aim of the lesson is to give the delegate the knowledge and attitude to be able to explain the need to locate the correct company specific work instruction and the implications of not seeking the latest information from the Work instruction before initiating work.

To successfully complete this lesson the delegate shall be able to:

- 1) Explain the content and purpose of a work instruction (L2 - Knowledge)
- 2) Explain how to locate the most updated company specific work instruction (L2 - Knowledge & Attitude)
- 3) Explain the risks and hazards associated with NOT working with an updated company specific work instruction (L2 - Knowledge & Attitude)

## ELEMENT 3.1 - THE WORK INSTRUCTION

Training Staff shall:

- 3.1.1 Explain the reasons for using a work instruction during blade repair
- 3.1.2 Explain the risks and hazards posed by not following a work instruction



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3.1.3 Show an example and explain the content of a work instruction

### ELEMENT 3.2 - LOCATE WORK INSTRUCTION

Training Staff shall:

3.2.1 Explain how to locate the most updated company specific WI. To be obtained from site lead or a company representative

## Lesson 4 - RISK ASSESSMENT

20 min.

The aim of the lesson is to give the delegate the knowledge, skills and attitude to be able to explain and use risk assessments.

To successfully complete this lesson the delegates shall be able to:

- 1) Explain the content and purpose of a risk assessment (L2 - Knowledge & Attitude)
- 2) Explain how to locate the most updated company specific risk assessment (L2 - Knowledge & Attitude)
- 3) Explain the risks and hazards associated with NOT working with an updated company specific risk assessment (L2 - Knowledge)
- 4) Explain the characteristic of lightning strike, implications and mitigation (L2 - Knowledge & Attitude)
- 5) Explain the effect of wind/temperature on an assigned task (L2 - Knowledge & Attitude)

### ELEMENT 4.1 - THE RISK ASSESSMENT

Training Staff shall:

- 4.1.1 Explain the purpose of risk assessments
- 4.1.2 Show examples of and explain the contents of risk assessments
- 4.1.3 Delegates shall:
- 4.1.4 Explain the purpose and content of a risk assessment

### ELEMENT 4.2 - LOCATE UPDATED RISK ASSESSMENT

Training Staff shall:

4.2.1 Explain how to locate the most updated company specific risk assessment. To be obtained from site lead or a company representative



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Delegates shall:

- 4.2.2 Explain how to obtain the most updated company specific risk assessments

#### ELEMENT 4.3 - OUTDATED RISK ASSESSMENT

Training Staff shall:

- 4.3.1 Explain why it is important to have updated company specific risk assessments
- 4.3.2 Explain the risks and hazards associated with using outdated risk assessments

#### ELEMENT 4.4 - LIGHTNING STRIKES

Training staff shall:

- 4.4.1 Explain the characteristics of a lightning strike
- 4.4.2 Explain the risks, hazards and implications of a lightning strike
- 4.4.3 Explain how to mitigate the risks of lightning strikes, by leaving site or moving to a safe area on site

Delegates shall:

- 4.4.4 Describe how to avoid lightning strike

#### ELEMENT 4.5 - WIND/TEMPERATURE

Training staff shall:

- 4.5.1 Explain the effects of wind when completing a task on site, by considering the health and safety risks posed by high winds and wind chill
- 4.5.2 Explain the effects of high and low temperature when completing a task on site, by considering the health and safety risks posed by high and low temperatures
- 4.5.3 Explain how to mitigate the risks posed by wind and temperature when completing a task on site

The delegate shall:

- 4.5.4 Explain how to mitigate the health and safety risks posed by wind and temperature when completing a task on site

### Lesson 5 - SECURE AN AREA

10 min.



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The aim of the lesson is to give the delegate the knowledge, skills and attitude to be able to explain and demonstrate how to secure an area

To successfully complete this lesson the delegates shall be able to:

- 1) Explain how to find the procedures for securing a blade repair work area (L2 - Knowledge)
- 2) Demonstrate how to secure a blade repair work area (L2 - Skills & Attitude)

## ELEMENT 5.1 - LOCATE PROCEDURES

Training staff shall:

- 5.1.1 Explain how to locate the specific information for securing a blade repair work area

## ELEMENT 5.2 - SECURING AREA

Training staff shall:

- 5.2.1 Explain the reasons for securing a blade repair work area
- 5.2.2 Explain and demonstrate how to secure a blade repair work area

Delegates shall:

- 5.2.3 Explain how to locate specific information for securing a blade repair work area
- 5.2.4 Demonstrate the ability to secure a blade repair work area

## Lesson 6 - CONTAMINATION

15 min.

The aim of the lesson is to give the delegate the knowledge, skills and attitude to be able to explain contamination characteristic, implications and mitigations.

To successfully complete this lesson the delegate shall be able to:

- 1) Explain contamination characteristics, implications and mitigations (L2 - Knowledge)
- 2) Explain how to mitigate the above with the information from a work instruction (L2 - Knowledge & Attitude)
- 3) Explain how to locate the specific information in a work instruction and /or a safety data sheet to avoid contamination (L2 - Knowledge & Attitude)
- 4) Demonstrate the ability to understand the information from a risk assessment / work instruction (when working in workshop) (L2 - Knowledge & Attitude)



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## ELEMENT 6.1 - CHARACTERISTICS

Training staff shall:

- 6.1.1 Explain the characteristics of chemical cross contamination during all phases of blade repair (preparation, transport, inspection, repair and leaving site)
- 6.1.2 Explain the characteristics of chemical contamination of adjacent work areas during all phases of blade repair (preparation, transport, inspection, repair and leaving site)
- 6.1.3 Explain the risks and implications of chemical contamination
- 6.1.4 Explain how to prevent chemical contamination

## ELEMENT 6.2 - WORK INSTRUCTION AS MITIGATION

Training staff shall:

- 6.2.1 Explain how to mitigate the risk of chemical contamination with information from work instructions, risk assessments and/or other documents

## ELEMENT 6.3 - AVOIDING CONTAMINATION

Training staff shall:

- 6.3.1 Explain how to locate specific information in a work instruction and a safety data sheet to avoid contamination

Delegates shall:

- 6.3.2 Explain how to locate specific contamination control information in the work instruction and safety data sheet
- 6.3.3 Explain the characteristics of cross contamination and adjacent work area contamination
- 6.3.4 Explain the risks and implications of contamination
- 6.3.5 Explain how to mitigate the risk of contamination

## Lesson 7 - WASTE SEGREGATION

10 min.

The aim of the lesson is to give the delegate the knowledge, skills and attitude to be able to explain and demonstrate the ability to perform waste segregation correctly.

To successfully complete this lesson the delegate shall be able to:

- 1) Explain the reasons for performing waste segregation correctly (L3 - Knowledge & Attitude)



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- 2) Demonstrate the ability to correctly segregate waste (L3 - Skills & Attitude)
- 3) Demonstrate the ability to locate waste segregation information in a work instruction and a safety data sheet (L3 - Skills & Attitude)

#### ELEMENT 7.1 - WHY WASTE SEGREGATION

Training staff shall:

- 7.1.1 Explain the risks to the public posed by chemical waste
- 7.1.2 Explain the reasons for performing waste segregation correctly

#### ELEMENT 7.2 - CORRECT WASTE SEGREGATION

Training staff shall:

- 7.2.1 Explain the difference between ordinary waste and chemical waste
- 7.2.2 Explain and demonstrate how to segregate waste correctly

#### ELEMENT 7.3 - WASTE SEGREGATION INFORMATION

Training staff shall:

- 7.3.1 Demonstrate how to locate information about waste segregation in a work instruction and a safety data sheet

Delegates shall:

- 7.3.2 Demonstrate the ability to correctly segregate chemical and ordinary waste during practical exercises

## Lesson 8 - ERGONOMIC

15 min.

The aim of the lesson is to give the delegate the knowledge, skills and attitude to be able to explain and demonstrate the ergonomic ramifications of work during the blade repair module and later on a blade.

To successfully complete this lesson, the delegate shall be able to:

- 1) Demonstrate correct ergonomics when receiving training in the classroom (L1 - Knowledge & Attitude)
- 2) Demonstrate correct ergonomics when working in the workshop (L1 - Knowledge & Attitude)
- 3) Explain correct ergonomics when working on a blade (L1 - Knowledge & Attitude)



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ELEMENT 8.1 - CLASSROOM

Training staff shall:

- 8.1.1 Explain correct ergonomics during training in the classroom

ELEMENT 8.2 - WORKSHOP

Training staff shall:

- 8.2.1 Explain correct ergonomics during training in the workshop

ELEMENT 8.3 - BLADEWORK

Training staff shall:

- 8.3.1 Explain correct ergonomics when working on a blade

Delegates shall:

- 8.3.2 Demonstrate the ability to maintain correct ergonomics when receiving training in the classroom
- 8.3.3 Demonstrate the ability to maintain correct ergonomics when receiving training in the workshop
- 8.3.4 Demonstrate the ability to maintain correct ergonomics when working on a blade, or equivalent structure
- 8.3.5 Demonstrate the ability to position themselves ergonomically correctly on a chair
- 8.3.6 Demonstrate the ability to stand and position themselves ergonomically correctly in the workshop

## Lesson 9 - LOCK OUT TAG OUT

10 min.

The aim of the lesson is to give the delegate the knowledge and attitude to be able to describe how to secure the turbine before start of work using Lock out tag out.

To successfully complete this lesson the delegates shall be able to:

- 1) Explain the purpose of lock out tag out
- 2) Describe the contents of a lock out tag out procedure
- 3) Explain the requirement to use lock out tag out procedures prior to starting work



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## ELEMENT 9.1 - PURPOSE

Training staff shall:

- 9.1.1 Explain the purpose of Lock out tag out

## ELEMENT 9.2 - ELEMENTS

Training staff shall:

- 9.2.1 Show an example and describe the contents of a Lock out tag out procedure

## ELEMENT 9.3 - REQUIREMENTS

Training staff shall:

- 9.3.1 Explain the requirement to use lock out tag out procedures prior to starting work
- 9.3.2 Explain that additional, company specific, lock out tag out training may be required

Delegates shall:

- 9.3.3 Explain the purpose of lock out tag out
- 9.3.4 Describe the contents of a lock out tag out procedure
- 9.3.5 Explain the requirement to use lock out tag out procedures prior to starting work

## Lesson 10 - PERSONAL PROTECTIVE EQUIPMENT

100 min.

The aim of the lesson is to give the delegate the knowledge, skills and attitude to be able to explain the limitations of and demonstrate how to select and use personal protective equipment (PPE) correctly.

To successfully complete this lesson the delegate shall be able to:

- 1) Explain the reasons for using PPE (L3 - Knowledge)
- 2) Demonstrate the ability to use PPE correctly including (but not limited to) mask, gloves, filter, suit, cut resistant gloves etc. (L3 - Knowledge, Skills & Attitude)
- 3) Explain the limitations of the applied PPE (L3 - Knowledge & Attitude)
- 4) Demonstrate the ability to select the correct types of PPE to be used during training with the applicable chemicals (L3 - Knowledge, Attitude & Skills)
- 5) Explain the purpose of disposing of contaminated PPE correctly and safely (L3 - Knowledge & Attitude)



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- 6) Demonstrate the ability to dispose of contaminated PPE correctly and safely (L3 - Knowledge, Attitude & Skills)

#### ELEMENT 10.1 - PURPOSE

Training staff shall:

- 10.1.1 Describe the hierarchy of control and where PPE fits into this
- 10.1.2 Explain the reasons for using PPE

#### ELEMENT 10.2 - APPLICATION

Training staff shall:

- 10.2.1 Explain and where appropriate demonstrate how to apply PPE correctly including, but not limited to, mask, gloves, filter, suit, cut resistant gloves and anti-vibration gloves

#### ELEMENT 10.3 - LIMITATIONS

Training staff shall:

- 10.3.1 Explain the limitations of PPE by considering breakthrough times of gloves

#### ELEMENT 10.4 - TASK SPECIFIC

Training staff shall:

- 10.4.1 Demonstrate how to select the correct types of PPE to be used during training with the applicable chemicals

Delegates shall:

- 10.4.2 Explain the purpose for using PPE
- 10.4.3 Demonstrate how to apply PPE correct including (but not limited to) mask, gloves, filter, suit, cut resistant gloves etc.
- 10.4.4 Explain the limitations of the applied PPE
- 10.4.5 Demonstrate the ability to select the correct types of PPE to be used during training with the applicable chemicals

**NOTE:** These skills must be assessed during practical training exercises in the workshop

#### ELEMENT 10.5 - DISPOSAL

Training staff shall:



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- 10.5.1 Explain the purpose of disposing of contaminated PPE correctly and safely
- 10.5.2 Explain how to dispose of contaminated PPE correctly and safely

Delegates shall:

- 10.5.3 Explain the purpose of disposing of contaminated PPE correctly and safely
- 10.5.4 Demonstrate the ability to dispose of contaminated PPE correctly and safely

NOTE: These skills must be assessed during practical training exercises in the workshop

## Lesson 11 - MASKS AND FILTERS

45 min.

The aim of the lesson is to give the delegates the knowledge, skills and attitude to be able to explain and demonstrate how to select, categorise, use masks and filters safely and correctly

To successfully complete this lesson the delegate shall be able to:

- 1) Explain the purpose of categorising filters and masks (L3 - Knowledge & Attitude)
- 2) Explain how to select the correct filter for a given application (L3 - Knowledge & Attitude)
- 3) Demonstrate how to identify the lifetime of the filter for a given application (L3 - Knowledge & Attitude)
- 4) Explain how masks are categorised and for how long a mask can be used for in each work situation (L3 - Knowledge & Attitude)
- 5) Demonstrate how to install a mask filter (L3 - Skills)
- 6) Demonstrate how to replace a mask filter (L3 - Skills)

### ELEMENT 11.1 - PURPOSE

Training staff shall:

- 11.1.1 Explain the purpose of categorising masks and filters

Delegates shall:

- 11.1.2 Explain the purpose of categorising masks and filters

### ELEMENT 11.2 - FILTER CATEGORIES

Training staff shall:



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- 11.2.1 Explain the filter categories, the applications and chemicals for which each category is intended

Delegates shall:

- 11.2.2 Explain the filter categories, the applications and chemicals for which each category is intended

### ELEMENT 11.3 - CATEGORIES AND LIFETIME

Training staff shall:

- 11.3.1 Demonstrate how to identify the lifetime of the filter for a given application or chemical
- 11.3.2 Explain how to recognise when a filter needs to be replaced

Delegates shall:

- 11.3.3 Demonstrate how to identify the lifetime of the filter for a given application or chemical

### ELEMENT 11.4 - MASKS

Training staff shall:

- 11.4.1 Explain how masks are categorised and their life expectancy for different applications and chemicals
- 11.4.2 Explain the maximum working times for different types of masks
- 11.4.3 Explain the limitations for using masks by considering the effect of facial hair on mask to face

Delegates shall:

- 11.4.4 Explain how masks are categorised and their life expectancy for different applications and chemicals
- 11.4.5 Explain the maximum working times for different types of masks

### ELEMENT 11.5 - APPLY FILTERS

Training staff shall:

- 11.5.1 Explain and demonstrate how to correctly install and replace mask filters

Delegates shall:

- 11.5.2 Explain and demonstrate how to correctly install and replace mask filters



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## 10 TOPIC 2 - GENERAL KNOWLEDGE

### Lesson 12 - CHEMICAL SAFETY

90 min.

The aim of the lesson is to give the delegate the knowledge and attitude to be able to explain and demonstrate how to handle chemicals at all stages of blade repair work.

To successfully complete this lesson the delegate shall be able to:

- 1) Explain the reasons for handling chemicals in a correct and safe way (L3 - Knowledge & Attitude)
- 2) Explain the safe procedures before, during and after transfer of chemicals (L3 - Knowledge & Attitude)
- 3) Demonstrate how to locate information of the chemicals before, during and after handling and transportation (L3 - Knowledge & Attitude)
- 4) Demonstrate how to conduct an equipment check before transferring chemicals (L3 - Skills & Attitude)
- 5) Explain how to mitigate related risks including curing (L3 - Skills & Attitude)

#### ELEMENT 12.1 - PURPOSE

Training staff shall:

- 12.1.1 Explain the reasons for handling chemicals in a correct and safe way
- 12.1.2 Explain the consequences of incorrect handling by considering exothermic reactions, faulty mixing and storage of chemicals, spillage etc.

Delegates shall:

- 12.1.3 Explain the reasons for handling chemicals in a correct and safe way
- 12.1.4 Explain the implications of incorrect handling, including exothermic reactions, faulty mixing and storage of chemicals, spillage etc.

#### ELEMENT 12.2 - TRANSFER PROCEDURES

Training staff shall:

- 12.2.1 Explain the safe procedures before, during and after transfer of chemicals

Delegates shall:



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12.2.2 Explain the safe procedures before, during and after transfer of chemicals

### ELEMENT 12.3 - INFORMATION ABOUT CHEMICALS

Training staff shall:

12.3.1 Demonstrate how to locate information about the chemicals before, during and after handling and transportation

Delegates shall:

12.3.2 Explain and demonstrate how to locate information of the chemicals before, during and after handling and transportation

### ELEMENT 12.4 - EQUIPMENT CHECK

Training staff shall:

12.4.1 Demonstrate how to conduct an equipment check before transferring chemicals

Delegates shall:

12.4.2 Demonstrate how to conduct an equipment check before transferring chemicals

### ELEMENT 12.5 - PREVENTION AND MITIGATION

Training staff shall:

12.5.1 Explain how to correctly handle chemicals, including exothermic reactions, faulty mixing and storage of chemicals, spillage etc.

12.5.2 Explain the health risks posed by epoxy, polyester and polyurethane materials

12.5.3 Explain how to mitigate the health risks posed by epoxy, polyester and polyurethane materials

Delegates shall:

12.5.4 Explain how to prevent and mitigate incorrect handling, including exothermic reactions, faulty mixing and storage of chemicals, spillage etc.

12.5.5 Explain the health risks posed by epoxy, polyester and polyurethane materials

12.5.6 Explain how to mitigate the health risks posed by epoxy, polyester and polyurethane materials

## Lesson 13 - COMPOSITES AND BLADE CONSTRUCTION

60 min.



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The aim of the lesson is to give the delegate the knowledge and attitude to be able to understand, apply and explain basic information about blade construction, components and aerodynamics.

To successfully complete this lesson the delegate shall be able to:

- 1) Describe basic aerodynamic principles and how these causes a wind turbine rotor to turn (L2 - Knowledge)
- 2) Define terms used to describe blade construction parts and enhancements (L2 - Knowledge)
- 3) Explain common faults, implication and mitigations (L2 - Knowledge)

### ELEMENT 13.1 - AERODYNAMICS

Training staff shall:

- 13.1.1 Describe the aerodynamic principles of a wind turbine blade
- 13.1.2 Explain how blade aerodynamics causes the rotor of a wind turbine to turn
- 13.1.3 Describe typical aerodynamic and safety add-ons used on wind turbine blades
- 13.1.4 Explain how aerodynamic performance and safety add-ons change blade performance
- 13.1.5 Explain how blade surface defects affect blade noise and productivity

### ELEMENT 13.2 - BLADE CONSTRUCTION

Training staff shall:

- 13.2.1 Define the following blade elements:
  - a. Leading edge
  - b. Trailing edge
  - c. Shell
  - d. Root
  - e. Tip
  - f. Webs (Chambers)
  - g. Bolts
  - h. Bulkhead
  - i. Suction side/leeward side
  - j. Pressure side/windward side
  - k. Spar
  - l. Chord
  - m. Bond line



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- 13.2.2 Describe how a blade is constructed by considering:
  - a. Manufacturing techniques
  - b. Materials used
- 13.2.3 Explain how to define positions on a blade using radius measurements and use them as vantage points for measuring damage
- 13.2.4 Explain the importance of weight and balance in terms of both blade and turbine performance

Delegate shall:

- 13.2.5 Be able to correctly define all the parts of a blade
- 13.2.6 Explain how to use radius measurements to determine the position and size of blade damage
- 13.2.7 Explain the importance of weight and balance in terms of both blade and turbine performance

### ELEMENT 13.3 - BLADE ENHANCEMENTS

Training staff shall:

- 13.3.1 Describe typical aerodynamic upgrades that can be applied to a blade surface like vortex generators, trailing edge serrations etc.
- 13.3.2 Describe the function of the lightning protection system
- 13.3.3 Describe the function of de-icing equipment
- 13.3.4 Describe the hazards posed by electrical de-icing systems
- 13.3.5 Describe typical blade protection systems like leading edge tape

Delegate shall:

- 13.3.6 Describe typical aerodynamic performance and protection systems used in blades

### ELEMENT 13.4 - FAULTS, IMPLICATIONS AND MITIGATIONS

Training staff shall:

- 13.4.1 Show examples of and explain typical blade faults, damages and the subsequent performance implications:
  - a. Erosion
  - b. Lightning
  - c. Delamination
  - d. Foreign object collisions
  - e. Handling



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f. Cracks

13.4.2 Explain the role of the following in reducing blade damage:

- a. Proper handling
- b. Lightning protection systems
- c. Inspection and maintenance
- d. Leading edge protection
- e. Temporary repairs which can protect the blade against additional damage before final repairs
- f. Final repair with using proper materials in an approved weather condition according to work instruction (grinding, lamination, leading edge protection...)

## Lesson 14 - MATERIALS

75 min.

The aim of the lesson is to give the delegate the knowledge and attitude to be able to recognise the various materials and understand the differences in characteristics and application of the material types when working with inspection and repair in a safe and efficient manner.

To successfully complete this lesson the delegates shall be able to:

- 1) Demonstrate the ability to distinguish between different material types when working with composite inspection and repair (L2 - Knowledge)
- 2) Explain the procedures for handling and applying chemicals (L2 - Knowledge & attitude)
- 3) Explain the characteristics of curing material types and their application (L2 - Knowledge)

### ELEMENT 14.1 - REINFORCEMENT MATERIALS

Training staff shall:

- 14.1.1 Explain that reinforcement materials resist tensile loads in a laminate structure
- 14.1.2 Describe the different types of reinforcement materials used in blade production (glass fibre and carbon fibre)
- 14.1.3 Define the terms 'UD', 'Biax' and 'Triax' in relation to reinforcement materials
- 14.1.4 Show examples of and explain the characteristics of UD, biax and triax glass fibre mats
- 14.1.5 Explain how a laminate is constructed from multiple layers of fibres
- 14.1.6 Show an example of and explain the characteristics of 'hardback' materials
- 14.1.7 Define the term 'prepreg'



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- 14.1.8 Explain how prepreg materials are used during production

Delegate shall:

- 14.1.9 Describe the reinforcement materials used in composite laminates and how those materials resist tensile loads in the blade

## ELEMENT 14.2 - MATRIX MATERIALS

Training staff shall:

- 14.2.1 Explain that matrix materials resist compression loads in blades
- 14.2.2 Define the terms 'Base resin', 'hardener' and 'accelerator'
- 14.2.3 Describe the component parts of and at a basic level the chemical reactions that take place during curing in the following materials: Epoxy, polyester vinyl ester and polyurethane

**NOTE:** The description of chemical reactions should be kept to a low level along the lines of base material and hardener are mixed, they react together causing cross links to form creating a thermo-set plastic material, during the reaction process heat is produced.

- 14.2.4 Describe the differences between the curing process of epoxy materials and polyester materials.
- 14.2.5 Show examples of typical matrix materials used during blade repair

Delegate shall:

- 14.2.6 Describe matrix materials used in composite laminates and how the matrix resists compression loads in a blade

## ELEMENT 14.3 - ADHESIVES

Training staff shall:

- 14.3.1 Explain the difference between 'structural' and 'non-structural' adhesives
- 14.3.2 Explain where adhesives are used during blade construction
- 14.3.3 Describe typical materials used for adhesives: polyurethane, epoxy, methacrylate
- 14.3.4 Show examples of typical adhesives used during blade repair

Delegate shall:

- 14.3.5 Describe typical materials used for adhesives and explain where they are used in blade construction
- 14.3.6 Explain the difference between 'structural' and 'non-structural' adhesives



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#### ELEMENT 14.4 - SURFACE COATINGS

Training staff shall:

- 14.4.1 Explain why gelcoat and paint is used on a blade surface
- 14.4.2 Describe typical materials used for paint and gelcoat
- 14.4.3 Show examples of typical paints and gelcoats used during blade repair

#### ELEMENT 14.5 - SANDWICH PANELS

Training staff shall:

- 14.5.1 Show an example of and describe the parts that make up a sandwich panel
- 14.5.2 Describe how a sandwich construction creates a lightweight, stiff panel by considering the tensile and compression loads in the laminate and the shear loads in the core material
- 14.5.3 Describe typical materials used for core material: PVC foam, PET foam and balsa wood

Delegate shall:

- 14.5.4 Describe the loading on a sandwich panel
- 14.5.5 Describe typical materials used for core material

#### ELEMENT 14.6 - CHEMICAL HANDLING AND APPLICATION

Training staff shall:

- 14.6.1 Explain how to properly store chemicals by considering the following:
  - a. Separation list (which materials can't be stored together)
  - b. Temperature condition
  - c. Proper labels
  - d. Transportation rules
  - e. How to prevent spills
  - f. How to neutralize spills
- 14.6.2 Explain how to properly apply chemicals by considering the following:
  - a. Which chemicals can/must be mixed before use
  - b. Correct mixing ratio (percentage or weighing)
  - c. How to properly apply chemicals
  - d. What to do with excess materials
  - e. How to dispose of chemical waste by conducting correct waste segregation



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Delegate shall:

- 14.6.3 Explain how to properly store chemicals and demonstrate (during practical exercises) how to properly apply chemicals to a repair

## ELEMENT 14.7 - CURING

Training staff shall:

- 14.7.1 Explain different methods for curing blade repair materials by considering the following:
- Ambient curing
  - Curing using heat
  - Curing using UV source
- 14.7.2 Explain how to find and use the technical datasheet to determine the curing method and duration for a given chemical

Delegate shall:

- 14.7.3 Explain the differences between the curing methods listed in 14.7.1
- 14.7.4 Demonstrate the ability to use a technical data sheet to find the correct curing method and duration for a given material

## Lesson 15 - TOOLS AND EQUIPMENT

40 min.

The aim of the lesson is to give the delegate the knowledge, skills and attitude to handle tools and equipment correctly in accordance with the task at hand in a safe and efficient manner.

To successfully complete this lesson the delegates shall be able to:

- 1) Explain basic mechanical, electrical, hydraulic principles and associated risks (L2 - Knowledge)
- 2) Explain how to utilize the correct tools/materials (L2 - Knowledge)
- 3) Describe the importance of calibration (L2 - Knowledge & Skills)
- 4) Explain applicable equipment type/category usage and handling (L2 - Knowledge)
- 5) Explain lamination tools and their application (L2 - Knowledge)
- 6) Explain thermal blankets, application and handling (L2 - Knowledge & Skills)
- 7) Explain procedures for checking electrical tools/equipment (L2 - Knowledge)
- 8) Describe the hazards of working with vibration tools (L2 - Knowledge)
- 9) Describe the requirements to use a residual current device/grounding (L2 - Knowledge)



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- 10) Demonstrate basic knowledge of documentation types, content and their application (L2 - Knowledge)

#### ELEMENT 15.1 - MECHANICAL, ELECTRICAL AND PNEUMATIC PRINCIPLES

Training staff shall:

- 15.1.1 Describe which tools are required for blade inspection and repair processes
- 15.1.2 Describe the principle of the operation of electrical and pneumatic grinders, sanders and drills
- 15.1.3 Explain the risks associated with electrical and pneumatic grinders, sanders and drills
- 15.1.4 Explain how to safely and correctly use electrical, pneumatic grinders, sanders and drills by considering guarding, personal protective equipment and ergonomic practices
- 15.1.5 Explain how to safely and correctly use a pneumatic glue gun
- 15.1.6 Explain how to safely and correctly use a manual glue gun
- 15.1.7 Describe the principle of the operation of a vacuum pump
- 15.1.8 Explain how to use a vacuum pump and how to protect the pump from excess resin using a resin trap
- 15.1.9 Explain the risks and hazards associated with working with a megohmmeter (Megger) or equivalent
- 15.1.10 Explain how to safely and correctly use a megohmmeter or equivalent

Delegate shall:

- 15.1.11 Explain how to correctly and safely use the tools required for blade inspection and repair

#### ELEMENT 15.2 - UTILIZATION OF TOOLS AND MATERIALS

Training staff shall:

- 15.2.1 Show examples of and explain the correct use of the tools required for the following activities and applications:
  - Core steps:
    - a. Blade inspection
    - b. Removal of paint, gelcoat and fibre layers
    - c. Sanding
    - d. Grinding
    - e. Finishing
    - f. Taking samples



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- g. Aerodynamic upgrades, such as vortex generator, trailing edge serration etc
- h. Lightning protection equipment
- i. De-icing equipment
- j. Blade protection systems i.e. leading-edge tape

Delegate shall:

- 15.2.2 Explain how to select and correctly use tools appropriate to the repair activity or application

### ELEMENT 15.3 - CALIBRATION

Training staff shall:

- 15.3.1 Explain how to verify the validity of the tool calibration status on: Shore D and barcol hardness testers, thermocouple thermometers and temperature / humidity data loggers

Delegate shall:

- 15.3.2 Explain how to verify the validity of the calibration on tools used during practical exercises

### ELEMENT 15.4 - LAMINATION TOOLS

Training staff shall:

- 15.4.1 Explain the different types of hand tools, their characteristics and functions used during lamination

### ELEMENT 15.5 - THERMAL BLANKETS

Training staff shall:

- 15.5.1 Explain the risks and hazards associated with working with heating blankets
- 15.5.2 Explain how to find the correct temperature and time used for the applicable repair
- 15.5.3 Explain when a heating blanket needs to be used
- 15.5.4 Explain and demonstrate how to use a heating blanket
- 15.5.5 Explain why temperature is important
- 15.5.6 Demonstrate how to control the temperature under the blanket
- 15.5.7 Explain how to store a hot heating blanket

Delegate shall:

- 15.5.8 Demonstrate how to safely and correctly use a heating blanket



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## ELEMENT 15.6 - CHECKING ELECTRICAL TOOLS AND EQUIPMENT

Training staff shall:

15.6.1 Explain the reasons for performing a pre-use check on electrical tools and equipment

15.6.2 Explain how to perform pre-use check for:

### **Electrical tools**

- a. Tool integrity
- b. Check the plug and socket (must be the same standard)
- c. Check electrical cable
- d. Check allowed Voltage (110 or 230) if cabled tool
- e. Check battery package integrity (if applicable)
- f. Check emergency switch/residual current device

### **Pneumatic equipment**

- a. Tool integrity
- b. Check hose and connector (air spill)
- c. Check maximum pressure allowed

Delegate shall:

15.6.3 Demonstrate the ability to perform pre-use checks on electrical and pneumatic tools and equipment

## ELEMENT 15.7 - VIBRATING TOOLS

Training staff shall:

15.7.1 Explain the risks, hazards and implications of working with vibrating tools

15.7.2 Explain how to reduce the risks associated with working with vibrating tools using personal protective equipment and work breaks

Delegate shall:

15.7.3 Explain the implications of working with vibrating tools

15.7.4 Explain how to reduce the risks associated with working with vibrating tools

## ELEMENT 15.8 - ELECTRICAL SAFETY DEVICES

Training staff shall:

15.8.1 Describe typical electrical safety devices like residual current devices



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- 15.8.2 Explain the importance of grounding a generator
- 15.8.3 Explain the importance of using a residual current device when using electrical tools
- 15.8.4 Explain where to place a residual current device with regards to extension leads
- 15.8.5 Explain and demonstrate how to perform a pre-use check of a residual current device

Delegate shall:

- 15.8.6 Explain the importance of using a residual current device
- 15.8.7 Demonstrate how to perform a pre-use check of a residual current device

**NOTE:** Where residual current device is used in this element it has the same meaning as 'ground fault circuit interrupter'

## ELEMENT 15.9 - DOCUMENTATION TYPES

Training staff shall:

- 15.9.1 Recap the importance of risk assessments for blade repair work
- 15.9.2 Recap the importance of work instructions for blade repair work
- 15.9.3 Explain the principles of a technical drawing of a blade to determine the number of layers, the fibre orientation and materials used at a given radius
- 15.9.4 Explain the importance of using a photo card when taking photographs of damage and repair steps
- 15.9.5 Explain the information that is required in inspection and repair reports
- 15.9.6 Describe the information contained in material lists / Bill of materials
- 15.9.7 Recap the importance of safety data sheets
- 15.9.8 Explain the information contained in a technical data sheet

Delegate shall:

- 15.9.9 Explain the different types of documentation that are required during blade inspection and repair activities

## Lesson 16 - PHASE TEST

30 min.

The aim of this lesson is to test the delegates understanding of the theoretical parts of the GWO Basic blade repair module trained so far and to assist the instructor in planning focus areas for the remainder of the course.



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To successfully complete this lesson the delegate must:

- 1) Successfully complete the phase test

## ELEMENT 16.1 - PHASE TEST

Training staff shall:

- 16.1.1 Introduce the phase test and explain the criteria for the test with reference to the delegate performance assessment
- 16.1.2 Conduct the test in accordance with the delegate performance assessment criteria
- 16.1.3 Upon completion of the test, check the delegates answers and give feedback to the delegates about the test results
- 16.1.4 In the case that a delegate does not pass the test, conduct an interview with the delegate in accordance with the delegate performance assessment Craftsmanship

## Lesson 17 - LAMINATION SKILLS

150 min.

The aim of the lesson is to give the delegate the knowledge, skills and attitude to be able to explain and demonstrate how to laminate repairs down to the core material.

To successfully complete this lesson the delegate shall be able to:

- 1) Explain the importance of fibre orientation in a laminate structure (L2 - Knowledge)
- 2) Explain the consequences of kinked or bent fibres in a laminate structure (L2 - Knowledge)
- 3) Explain the importance of overlaps between the repair material and existing material (L2 - Knowledge)
- 4) Explain the effect of dry fibres and air voids on the strength of a laminate structure (L2 - Knowledge)
- 5) Explain the importance of calculating the correct mixing ratio between resin and hardener (L2 - Knowledge)
- 6) Demonstrate the ability to calculate the amount of matrix material and the ratio of resin to hardener required for a given weight of reinforcement material (L2 - Knowledge)
- 7) Explain how curing at elevated temperature affects the glass transition (TG) temperature and strength of a composite material (L2 - Knowledge)
- 8) Demonstrate the ability to ascertain that the matrix material has correctly cured using a barcol/ shore D hardness tester (L2 - Skills)



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- 9) Explain how ambient temperature and humidity affect the lamination process (L2 - Knowledge)
- 10) Demonstrate the ability to record ambient temperature and humidity during the process using a data logger (L2 - Skills)

#### ELEMENT 17.1 - FIBRE ORIENTATION

Training staff shall:

- 17.1.1 Explain how a composite laminate structure is built up of multiple layers of reinforcement material
- 17.1.2 Explain how each layer of reinforcement material resists tensile loads in a specific direction
- 17.1.3 Explain the importance of aligning repair fibres with the existing fibres in each layer that is being repaired

Delegate shall:

- 17.1.4 Explain the importance of aligning the repair fibres in the direction of the fibres in each layer of the existing fibres in the context of tensile load transfer through the repair

#### ELEMENT 17.2 - KINKED OR BENT FIBRES

Training staff shall:

- 17.2.1 Show an example and explain how easily glass fibres will break if they are kinked
- 17.2.2 Explain how bent fibres in a laminate will lead to uneven load transfer in the laminate and how this can lead to premature failure of the laminate
- 17.2.3 Explain how to carefully handle and lay-up dry fibreglass mats to keep the fibres as straight as possible

Delegate Shall:

- 17.2.4 Explain the Consequences of and how to reduce the possibility of kinked and bent fibres in a laminate repair

#### ELEMENT 17.3 - OVERLAPS

Training staff shall:

- 17.3.1 Define the term 'overlap' in the context of blade repair fibre materials
- 17.3.2 Explain how the strength of the repair depends on each layer of repair fibres overlapping the corresponding layer of existing fibres to ensure the correct load transfer through the repair
- 17.3.3 Explain that each layer of damaged fibres must be repaired



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Delegate shall:

- 17.3.4 Explain the importance of maintaining the correct overlaps between each repair layer and the corresponding existing layer in the damaged composite laminate

#### ELEMENT 17.4 - DRY FIBRES AND AIR VOIDS

Training staff shall:

- 17.4.1 Define the word 'Matrix' in the context of blade repair materials
- 17.4.2 Define the term 'fibre content' and explain how this affects the properties of the cured laminate
- 17.4.3 Explain how the matrix material resists compression loads in the laminate structure and how air voids will create localised weak spots, and how dry fibres will be able to bend and kink leading to failure of the laminate structure

Delegate shall:

- 17.4.4 Explain the function of the matrix material and how air voids and dry fibres can lead to failure of the laminate structure
- 17.4.5 Explain how the fibre content can affect the properties of the laminate

#### ELEMENT 17.5 - MIXING RATIO

Training staff shall:

- 17.5.1 Recap the terms 'mixing ratio', 'two component' and 'three component' materials, 'base resin', 'hardener' and 'accelerator'
- 17.5.2 Describe the chemical reaction between the base resin and hardener in epoxy, polyester, vinyl ester and polyurethane materials
- 17.5.3 Explain where to find the mixing ratio for blade repair chemicals from the manufacturer technical data sheet (TDS)
- 17.5.4 Explain how the TDS must be cross referenced with a blade manufacturer specific work instruction relating to mixing and curing materials
- 17.5.5 Explain how care must be taken to ensure that the correct mixing ratio is used as these are given in the TDS by weight and volume
- 17.5.6 Explain how incorrect mixing ratios will affect the cured product, focus on the implications to health and safety of sanding in unreacted materials
- 17.5.7 Explain why it is important to calculate the mixing ratio for each batch of chemical that is being mixed

Delegate shall:



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- 17.5.8 Explain the term 'mixing ratio'
- 17.5.9 Explain how the incorrect mixing ratio of a multi component material will affect the properties of the cured material
- 17.5.10 Explain where to find the mixing ratio for a given material
- 17.5.11 Describe the chemical reaction between the base resin and hardener in epoxy, polyester and polyurethane materials

## ELEMENT 17.6 - CALCULATION OF MATRIX MATERIAL

Training staff shall:

- 17.6.1 Define the variables required for calculating the amount of matrix material required for a given weight of reinforcement material
- 17.6.2 Explain and demonstrate how to calculate the amount of matrix material required for a repair
- 17.6.3 Define the variables required for calculating the correct amounts of each component of a multi component material given the mixing ratio
- 17.6.4 Explain and demonstrate how to calculate the amount of each component material given a mixing ratio

Delegate shall:

- 17.6.5 Demonstrate the ability to correctly calculate the total amount of matrix required for a given weight of reinforcement material
- 17.6.6 Demonstrate the ability to correctly calculate the amount of each component in a multicomponent material given the mixing ratio for that material

## ELEMENT 17.7 - CURING AT ELEVATED TEMPERATURES

Training staff shall:

- 17.7.1 Define the term 'glass transition temperature'
- 17.7.2 Explain how curing at an elevated temperature will affect the glass transition temperature of the cured material
- 17.7.3 Explain how to find the correct curing temperature for a material from the manufacturer technical data sheet (TDS)
- 17.7.4 Explain that the TDS curing temperature must be cross-checked with the blade manufacturer mixing and curing work instructions

Delegate shall:

- 17.7.5 Explain how curing at elevated temperature will affect the glass transition temperature (TG)



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- 17.7.6 Explain how the TG will affect the strength of the cured material and explain where to find the correct curing temperatures for a given material

#### ELEMENT 17.8 - ASCERTAINING CORRECT CURING

Training staff shall:

- 17.8.1 Demonstrate how to find the correct cured hardness values for a laminate from the material technical data sheet and from the blade manufacturer work instruction
- 17.8.2 Demonstrate how to use a barcol and / or a shore D hardness tester to test the hardness of a cured laminate
- 17.8.3 Explain how to collect a sample of laminate for testing in a laboratory

Delegate shall:

- 17.8.4 Demonstrate the ability to use a barcol and / or a shore D hardness tester to ascertain whether a laminate has cured correctly in accordance with the material technical data sheet or the blade manufacturer work instruction

#### ELEMENT 17.9 - AMBIENT TEMPERATURE AND HUMIDITY

Training staff shall:

- 17.9.1 Define the terms 'pot life' and 'gel time' and explain how the pot life and gel time are affected by the ambient temperature
- 17.9.2 Explain how the ambient humidity can affect lamination resins

Delegate shall:

- 17.9.3 Explain how the ambient temperature and humidity will affect the lamination process and the materials used for lamination

#### ELEMENT 17.10 - RECORDING AMBIENT TEMPERATURE AND HUMIDITY

Training staff shall:

- 17.10.1 Explain the importance of recording the ambient temperature and humidity by considering the need to demonstrate to the customer that the levels of humidity and temperature were not exceeded during the repair
- 17.10.2 Demonstrate how to use a data logger to record and document the ambient temperature and humidity throughout all the repair processes
- 17.10.3 How the ambient humidity can affect lamination resins

Delegate shall:



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- 17.10.4 Demonstrate the ability to use a data logger to record and document the ambient temperature and humidity throughout all the repair processes

**NOTE:** Where the delegate must demonstrate the ability to perform a skill, these skills will be continually assessed during the subsequent practical exercises.

## Lesson 18 - BASIC LAMINATION

290 min.

The aim of the lesson is to give the delegate the knowledge, skills and attitude to be able to produce two 2-3 layer flat laminate panels safely and in accordance with a work instruction.

To successfully complete this lesson the delegate shall be able to:

- 1) Apply the knowledge gained during the general safety topic to the working environment to minimise the risks associated with composite repair work (L3 - Skills)
- 2) Explain the different types of fibre glass mats used in blades (L2 - Knowledge)
- 3) Explain the importance of fibre orientation in a laminate structure (L2 - Knowledge)
- 4) Demonstrate the ability to produce two 2-3 layer flat laminate panels covered on one side with gel-coat in accordance with a work instruction and drawing. Creating one with epoxy and one with polyester resin systems (L3 - Skills)

### ELEMENT 18.1 - MINIMISE RISKS ASSOCIATED WITH FIBRE WORK

Training staff shall:

- 18.1.1 Explain the safety precautions and personal protective equipment requirements for working in the workshop area (Recap from general safety)
- 18.1.2 Continually assess the delegate on their ability to apply the knowledge gained during the general safety module to the working environment to mitigate the risks associated with composite repair work

Delegate shall:

- 18.1.3 Demonstrate the ability to apply the knowledge gained during the general safety and chemical safety lessons to their working environment by correctly selecting and using PPE appropriate to the task in hand and to work in a safe manner with the materials and tools required for each process

### ELEMENT 18.2 - FIBRE GLASS MATS

Training staff shall:



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- 18.2.1 Define the terms 'chopped strand' (CS), 'unidirectional' (UD), 'biaxial' (Biax), 'triaxial' (triax), 'areal weight' and 'zero direction' in relation to fibre glass mats used in composite laminate structures
- 18.2.2 Describe the terms 'woven mat' and 'stitched mat'
- 18.2.3 Explain why stitched mats are used in wind turbine blades

Delegate shall:

- 18.2.4 Describe the different terms used for describing fibre glass mats used for blade repair

### ELEMENT 18.3 - FIBRE ORIENTATION

Training staff shall:

- 18.3.1 Explain the exercise and show the delegate where the required materials and tools are stored
- 18.3.2 Using a flat aluminium mould, demonstrate how to prepare the mould surface with release agent and explain the purpose of the release agent and the drying time required before adding materials
- 18.3.3 Demonstrate how to mark out the 400mm by 300mm rectangle on the surface using flash tape
- 18.3.4 Demonstrate how to calculate the required amount of gel coat for the marked-out mould area at a layer thickness of 0.8 mm
- 18.3.5 Demonstrate how to correctly calculate, measure out and mix the separate components of the gel coat
- 18.3.6 Demonstrate how to apply the gel coat to the mould surface and how to distribute the gel coat evenly on the mould
- 18.3.7 Demonstrate how to use a wet film gauge to determine the layer thickness
- 18.3.8 Explain the requirement to allow the gel coat to tack off and demonstrate how to determine that the gel coat is ready for the next layer of materials
- 18.3.9 Demonstrate how to measure and cut two pieces of biax fibre glass reinforcement material and how to mark the zero direction of the roll on the cut pieces
- 18.3.10 Demonstrate how to correctly calculate the required amount of matrix material required for the given amounts of reinforcement material
- 18.3.11 Demonstrate how to correctly calculate, measure out and mix the separate components of the matrix material
- 18.3.12 Demonstrate how to apply the first layer of fibre glass and matrix material focusing on the fibre straightness, wetting out the fibres and removing air from the matrix using a bolt roller. Repeat with the second layer of fibre glass



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- 18.3.13 Demonstrate how to apply peel ply to the laminate, place the thermocouple and how to cover the laminate with vacuum film to protect the heating blanket from resin
- 18.3.14 Demonstrate how to place the heating blanket without folds and how to adjust the temperature of the heating blanket in accordance with the temperature reading from the thermocouple to the required curing temperature in accordance with an approved work instruction or the matrix technical data sheet
- 18.3.15 Demonstrate how to determine the required curing time
- 18.3.16 Explain that the curing time starts when the matrix material has reached the required curing temperature
- 18.3.17 After the curing time, demonstrate how to safely remove the heating blanket and place it to cool down
- 18.3.18 Demonstrate how to safely remove the vacuum film and peel ply and measure the hardness of the cured laminate with a barcol/ shore D tester

Delegate shall:

- 18.3.19 Demonstrate the ability to prepare a flat aluminium mould surface with release agent, allow sufficient time for the release agent to dry and mark out the required area with flash tape
- 18.3.20 Demonstrate the ability to accurately measure out and mix the required quantities of each component of gel coat. Apply the gel coat evenly and at the correct layer thickness in accordance with a work instruction
- 18.3.21 Demonstrate the ability to accurately measure and cut the required pieces of glass fibre. Mark the zero direction of the roll on the cut pieces
- 18.3.22 Demonstrate the ability to safely and accurately measure out and correctly mix the required quantities of each component of the matrix material in accordance with an approved work instruction
- 18.3.23 Demonstrate the ability to wet out all the fibres using a bolt roller and to keep the fibres as straight as possible
- 18.3.24 Demonstrate the ability to apply the peel ply, thermocouple and vacuum foil in the correct order
- 18.3.25 Demonstrate the ability to safely handle and apply a heating blanket to the laminate
- 18.3.26 Demonstrate the ability to adjust the temperature of the heating blanket with reference to the thermocouple temperature in accordance with an approved work instruction
- 18.3.27 After the curing time, demonstrate the ability to safely remove the heating blanket, vacuum foil, thermocouple and peel ply
- 18.3.28 Demonstrate the ability to measure the hardness of the cured laminate with a barcol/ shore D tester



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- 18.3.29 Explain the importance of aligning the repair fibres in the direction of the fibres in each layer of the existing fibres in the context of tensile load transfer through the repair

## Lesson 19 - SANDWICH PANEL

420 min.

The aim of this lesson is to give the delegate the knowledge, skills and attitude to be able to produce a trailing edge section from two sandwich panels, which they will then use to carry out the following repairs as described in later lessons:

- 1) sandwich repairs with damage extending through both the inner and outer laminates
- 2) laminate repairs, which do not affect the core material
- 3) surface repairs to gelcoat and paint layers
- 4) open trailing edge repairs to both laminates
- 5) bond line repairs by adhesive injection.

The dimensions of the trailing edge section must be sufficient to allow the delegate to carry out the repairs mentioned above while challenging them to carry out the repairs with minimal areal limits in order to achieve a sufficient skill level. It is recommended that the trailing edge section measures 500 mm along the trailing edge and 600 mm parallel to the trailing edge.

The final thickness of the trailing edge, including laminates and bond line, must be no more than 2 mm.

The sandwich panels should include an outer laminate consisting of one layer each of triax and biax and an inner laminate consisting of one layer of biax with 10 mm core material (i.e. pvc foam or balsa) tapered towards the trailing edge to produce a bond line no wider than 50 mm.

To successfully complete this lesson the delegate shall be able to:

- 1) Apply the knowledge gained during the general safety lessons to the working environment to minimise the risks associated with composite repair work (L3 - Skills)
- 2) Explain the reasons for using a sandwich construction (L2 - Knowledge)
- 3) Demonstrate the ability to cure a fibre reinforced composite laminate using heat and vacuum and record the vacuum level and temperature. (L2 - Skills)
- 4) Demonstrate the ability to produce a composite sandwich panel covered on one side with gelcoat in accordance with a work instruction and drawing (L2 - Skills)
- 5) Demonstrate the ability to bond two surfaces together to create a trailing edge section (L2 - Skills)

### ELEMENT 19.1 - MINIMISE RISKS ASSOCIATED WITH COMPOSITE FIBRE WORK



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Training staff shall:

- 19.1.1 Continually assess the delegate on their ability to apply the knowledge gained during the general safety lessons to the working environment to mitigate the risks associated with composite repair work

Delegate shall:

- 19.1.2 Demonstrate the ability to apply the knowledge gained during the general safety and chemical safety modules to their working environment by correctly selecting and using PPE appropriate to the task in hand and to work in a safe manner with the materials and tools required for each process

## ELEMENT 19.2 - SANDWICH CONSTRUCTION

Training staff shall:

- 19.2.1 Explain the function of the inner and outer laminates and the core material in a sandwich construction
- 19.2.2 Describe common materials used for core material in wind turbine blades
- 19.2.3 Explain how a sandwich construction produces a lightweight and stiff structure
- 19.2.4 Explain why this is important in terms of wind turbine blades by considering the loads on a blade, the structural requirements of the blade and the implications for transport and lifting operations

Delegate shall:

- 19.2.5 Describe common materials used for core material
- 19.2.6 Explain the function of the inner and outer laminates and the core material in a sandwich construction
- 19.2.7 Explain the reasons for using a sandwich construction in wind turbine blades

## ELEMENT 19.3 - CURING OF FIBRE REINFORCED COMPOSITE LAMINATE

Training staff shall:

- 19.3.1 Explain the function of the tools required to cure a laminate with heat and vacuum, and the instruments required to record the vacuum level and curing temperature
- 19.3.2 Explain the health and safety risks associated with using heating blankets and vacuum pumps by considering the risk of burns, the risk of fire and electrical hazards
- 19.3.3 Demonstrate how to mitigate the above described risks using PPE, pre-use inspections, correct handling of the blankets and the use of electrical safety devices such as residual current devices



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- 19.3.4 Explain how vacuum is used to remove air and to consolidate the laminate during the curing process
- 19.3.5 Explain how an absolute pressure gauge (vacuum gauge) is used to record the vacuum level during the entire curing process
- 19.3.6 Explain how to find the blade manufacturer specific vacuum levels for curing a laminate
- 19.3.7 Explain the function of the vacuum consumable materials:
  - a. peel ply
  - b. release film
  - c. breather fabric
  - d. tacky tape
  - e. vacuum foil
  - f. vacuum tube
  - g. resin trap
- 19.3.8 Demonstrate how to create a vacuum bag over a laminate repair, where to place the thermocouple to get the most accurate temperature reading and how to use a resin trap to protect the vacuum pump from excess resin
- 19.3.9 Explain the limitations with the temperature settings on the heating blankets
- 19.3.10 Demonstrate how to use the reading from the temperature gauge to adjust the heating blanket to the correct curing temperature
- 19.3.11 Explain how to record and document the vacuum level and curing temperature at regular intervals during the curing process
- 19.3.12 Explain the health and safety implications of removing the vacuum bagging materials after curing the repair by considering sharp edges and the possibility of uncured material. Demonstrate how to mitigate those risks using PPE
- 19.3.13 Explain how the peel ply should not be removed until immediately before the application of the next repair layer
- 19.3.14 Explain how the peel ply protects the surface of the laminate and can give the laminate the correct surface finish for the application of the next layer
- 19.3.15 Explain that the blade manufacturer work instructions will detail the exact surface finish for the application of repair layers

Delegate shall:

- 19.3.16 Explain the functions of the tools, instruments and vacuum consumables used during the curing process
- 19.3.17 Demonstrate the ability to mitigate the risks posed during the curing process and subsequent removal of vacuum bagging materials



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- 19.3.18 Demonstrate the ability to apply vacuum consumables in the correct order with the correct placement of a thermocouple, and to achieve, record and document the correct vacuum levels in accordance with a work instruction
- 19.3.19 Demonstrate the ability to adjust a heating blanket to the correct temperature according to the temperature displayed on a temperature gauge. Record and document that temperature in accordance with a work instruction

#### ELEMENT 19.4 - PRODUCING A COMPOSITE SANDWICH PANEL

Training staff shall:

- 19.4.1 Introduce the exercise. Hand out a work instruction and drawing with details on how to build the sandwich panel
- 19.4.2 The work instruction and drawing must contain sufficient detail about dimensions and areal weight of each layer of fibre glass and the core material to enable the delegate to build the panel, the dimensions stated in the following delegate actions are the recommended sizes
- 19.4.3 The work instruction must contain details of the curing temperature, mix ratios of the gel coat and matrix but shall not contain details of the amount of gel coat and matrix required as these must be calculated by the delegate
- 19.4.4 Demonstrate how to correctly cut and shape core material to the dimensions required in a blade drawing or work instruction

Delegate shall:

- 19.4.5 Demonstrate the ability to prepare a flat mould (aluminium is preferred) with release agent and to apply flash tape to the correct dimensions in accordance with a work instruction
- 19.4.6 Demonstrate the ability to calculate the correct amount of gel coat required for a given area and layer thickness and to calculate, accurately measure and mix the required quantity of each component given the mixing ratio of the gelcoat
- 19.4.7 Demonstrate the ability to evenly apply the gel coat to the mould surface at the required layer thickness and to measure the layer thickness with a wet film gauge
- 19.4.8 Demonstrate the ability to measure and cut fibre glass mats to the correct dimensions required and to mark the roll zero direction on the cut mats
- 19.4.9 Demonstrate the ability to lay up the fibre glass mats on the gelcoat in the correct order and orientation referenced to zero direction with straight fibres and where applicable the correct overlaps between the layers
- 19.4.10 Demonstrate the ability to accurately cut and shape the required core material for the sandwich panel in accordance with a blade drawing
- 19.4.11 Demonstrate the ability to correctly calculate the total amount of matrix material required for the sandwich panel from the weight of the reinforcement material



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- 19.4.12 Demonstrate the ability to correctly calculate, measure and mix the required quantities of each component of the matrix material
- 19.4.13 Demonstrate the ability to apply the matrix material to the glass fibre mats within the pot life and gel time of the matrix
- 19.4.14 Demonstrate the ability to select and use the correct tools to wet out all the fibres in each layer of fibre glass while keeping the fibres in each layer straight
- 19.4.15 Demonstrate the ability to apply vacuum consumables to the mould in the correct order with the correct placement of a thermocouple, and the ability to apply, measure and record the vacuum levels required and achieved
- 19.4.16 Demonstrate the ability to adjust the temperature of a heating blanket according to the readings from the thermocouple, to the correct curing temperature for the matrix material used, and to control and record the curing temperature throughout the entire curing process
- 19.4.17 Demonstrate the ability to record the ambient temperature and humidity throughout the entire process of building and curing a sandwich panel
- 19.4.18 After the curing time demonstrate the ability to safely remove and dispose of the vacuum consumables except for the peel ply

#### ELEMENT 19.5 - TRAILING EDGE SECTION

Training staff shall:

- 19.5.1 Explain the differences between a structural and non-structural adhesive and give some examples of products in each category
- 19.5.2 Explain how surface finish and cleanliness will affect the ability of an adhesive to bond to a surface. Explain that the peel ply on a laminate can leave the correct surface finish for adhesive and that the peel ply must only be removed immediately before applying the adhesive
- 19.5.3 Explain that blade manufacturer work instructions detail the surface finish requirements for adhesives
- 19.5.4 Explain and demonstrate where to find the mixing and curing requirements for different adhesive products
- 19.5.5 Demonstrate how to safely cut the sandwich panel in half and prepare the materials and tools required to bond the pieces together into a trailing edge section
- 19.5.6 Demonstrate how to apply the adhesive to the bond line to ensure the correct dimension and how to correctly apply clamps to the bond line to ensure that the adhesive wets out the two surfaces
- 19.5.7 Explain and demonstrate how to correctly cure adhesive

Delegate shall:

- 19.5.8 Be able to explain the differences between structural and non-structural adhesive



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- 19.5.9 Demonstrate the ability to cut the sandwich panel in half and to bond the two halves together to create a trailing edge section

## Lesson 20 - PAINTING

120 min.

The aim of the lesson is to give the Delegates the knowledge, skills and attitude to be able to paint a blade to a specific layer of thickness, safely and in accordance with a work instruction.

To successfully complete this lesson the delegates shall be able to:

- 1) Complete the blade build by applying the described paint layers (L2 - Skills)

### ELEMENT 20.1 - COMPLETION OF BLADE

Training staff shall:

- 20.1.1 Explain the function of the paint layers on a wind turbine blade and describe the materials from which paint products can be made
- 20.1.2 Explain the health and safety risks associated with paint products by considering the base and hardener materials and the solvents used to thin the paint
- 20.1.3 Explain the precautions to be adopted to mitigate the health and safety risks posed from paint products by considering the use of PPE and the type of filters required for a mask
- 20.1.4 Explain the term 'flash-off time' in the context of paint products
- 20.1.5 Explain why it is important to follow a blade manufacturer work instruction for painting a blade by considering correct surface finish for paint adhesion. Whether the paint requires one or two coats, the curing time for the paint, and the ambient humidity and temperature limits
- 20.1.6 Demonstrate how to calculate the amount of paint required for a given surface area and layer thickness
- 20.1.7 Demonstrate how to mask off an area of blade repair for painting
- 20.1.8 Demonstrate how to apply paint to a repair using a foam roller, and how to measure the layer thickness using a wet film gauge
- 20.1.9 Continually assess the delegate on their ability to apply the knowledge gained during the general safety module to the working environment to mitigate the risks associated with composite repair work

Delegate shall:

- 20.1.10 Demonstrate the ability to select the correct mask and filter for working with paint products



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- 20.1.11 Demonstrate the ability to safely apply paint to a blade surface to a specified layer thickness and to be able to measure the layer thickness with a wet film gauge. The trailing edge section built in lesson 19 can be used for this

## Lesson 21 - BLADE INSPECTION

30 min.

The aim of the lesson is to give the delegate the knowledge, skills and attitude to be able to conduct an inspection and to conduct it using the appropriate methodology in accordance with a work instruction.

To successfully complete this lesson the delegate shall be able to:

- 1) Describe and categorise typical failures found in wind turbine blades (L1 - Knowledge)
- 2) Describe typical reactions to the different damage categories (L1 - Knowledge)
- 3) Demonstrate the ability to take focused photographs of damage with a scale to indicate size (L 3 - Skills)
- 4) Demonstrate the ability to perform a tap test to locate areas of delamination (L3 - Skills)
- 5) Explain the importance of lighting (intensity & angle) in terms of inspecting composite materials (L2 - Knowledge)
- 6) Explain the different inspection tools and methods (L2 - Knowledge)
- 7) Demonstrate the ability to locate different types of damage on various blade types (L2 - Skills)

### ELEMENT 21.1 - TYPICAL FAILURES

Training staff shall:

- 21.1.1 Show examples of and describe typical failures and defects in wind turbine blades covering:
- a. erosion
  - b. impact damage
  - c. holes
  - d. cracks and delamination in the leading edge
  - e. blade surface and trailing edge
  - f. trailing edge bond line failures
  - g. lightning damage
- 21.1.2 Explain how to categorize those defects and failures on a scale from 1 to 5, with 1 being minor damage and 5 being serious structural failure. Show examples of typical failures in each category



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- 21.1.3 Explain the importance of consulting blade manufacturer documentation to obtain the manufacturer specific damage categories for accurate reporting of blade damage
- 21.1.4 Demonstrate the ability to recognise typical defects and failures found in wind turbine blades and correctly identify which damage category each failure or defect falls under

## ELEMENT 21.2 - REACTIONS TO DAMAGE CATEGORIES

Training staff shall:

- 21.2.1 Highlight the importance of consulting blade manufacturer specific documentation. This is for guidance on how to react to the various categories of blade damage
- 21.2.2 Outline the following typical reactions to damage categories:
  - a. **1.** no action required - turbine can run
  - b. **2.** follow-up inspection required - turbine can run
  - c. **3.** repair required within a time frame - turbine can run
  - d. **4.** repair required within a short time frame - turbine can run
  - e. **5.** repair required immediately - stop the turbine
- 21.2.3 Describe the lost production implications of stopping a turbine

Delegate shall:

- 21.2.4 Be able to describe typical reactions to the different damage categories and recall where to find manufacturer specific information about reactions to blade damage

## ELEMENT 21.3 - FOCUSED AND SCALED PHOTOGRAPHS

Training staff shall:

- 21.3.1 Explain the reasons for including photographs in a blade inspection or repair report. Give examples of photographs that are required in a blade inspection or repair report, e.g. blade data plate
- 21.3.2 Compare examples of poorly focused and well-focused photographs of blade damage. Explain the advantages of well-focused photographs
- 21.3.3 Show examples of photographs with no indication of scale and photographs with an indication of scale. Explain the advantages of including scale in the photograph when of identifying the size of the damage
- 21.3.4 Demonstrate how to adjust a camera focus setting to 'spot focus' and explain why this setting is preferred for long distance photographs
- 21.3.5 Demonstrate how to take focused photographs of blade damage both at a long and short distance, including a scale to indicate the size of the damage on short distance photographs



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- 21.3.6 Demonstrate the ability to take focused photographs of blade damage from long and short distances, including a scale to indicate the size of the damage on short distance photographs

#### ELEMENT 21.4 - TAP TEST

Training staff shall:

- 21.4.1 Show examples of a delaminated fibre reinforced composite material and explain possible causes of delamination such as impact damage
- 21.4.2 Demonstrate how to locate the outer edges of an area of delamination by performing a tap test with an appropriate tool

Delegate shall:

- 21.4.3 Describe possible causes of delamination in a blade
- 21.4.4 Demonstrate the ability to perform a tap test to identify the extent of areas of delamination in a fibre reinforced composite structure

#### ELEMENT 21.5 - LIGHTING

Training staff shall:

- 21.5.1 Explain how the intensity and the angle of the light source used for inspecting a laminate structure can affect the visibility of defects within the laminate
- 21.5.2 How the incorrect lighting can hide defects

Delegate shall:

- 21.5.3 Demonstrate the ability to adjust the light intensity and angle to correctly identify difficult to see damage in a laminate structure

#### ELEMENT 21.6 - INSPECTION TOOLS AND METHODS

Training staff shall:

- 21.6.1 Describe situations when blade inspections are required by considering installation, periodic maintenance, end of warranty inspections and when damage is suspected following an incident such as a bird strike
- 21.6.2 Explain condition for accessing a blade for inspection or repair such as: platforms, rope access, if the blade is on the ground, inspecting a blade from a distance and the inspection methods that can be used in each situation
- 21.6.3 Explain which tools can be used for inspecting a blade from a distance by considering telescopes, cameras, drones, the limitations and advantages of each tool



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Delegate shall:

- 21.6.4 Demonstrate the ability to locate, identify, categorise and document damage on a wind turbine blade. Both on the blade itself and from a distance using visual inspection, tap testing, a telescope and camera with a zoom lens

## ELEMENT 21.7 - TYPES OF DAMAGE

Training staff shall:

- 21.7.1 Create an exercise where the delegate must locate, identify and categorise the damage to a wind turbine blade. The damage must include the following: an area of delamination, cracks in the surface layers of gelcoat and paint, cracks in the laminate and holes through to the core material
- 21.7.2 The areas of damage must cover different categories of damage and must include a damage which can only be found by using a specific angle of lighting
- 21.7.3 Create an exercise where the delegate must inspect and identify damage on a wind turbine blade from a distance using a telescope and camera with a zoom lens. Demonstrate the use of those tools to perform a blade inspection

Delegate shall:

- 21.7.4 Describe situations when a blade inspection might be required and the methods that can be utilised to access a blade and the methods that can be used to perform a blade inspection
- 21.7.5 Demonstrate the ability to locate, identify, categorise and document damage on a wind turbine blade. Both on the blade itself and from a distance using visual inspection, tap testing, telescope and camera with a zoom lens

## Lesson 22 - INSPECTING LIGHTENING PROTECTION SYSTEM

50 min.

The aim of the lesson is to give the delegate the knowledge, skills and attitude of how lightning receptors can be measured and how damage can be identified.

To successfully complete this lesson the delegate shall be able to:

- 1) Explain the function of typical surface components of a lightning protection system (L2 - Knowledge)
- 2) Demonstrate the ability to safely measure the conductivity and resistance of a typical lightning protection system using a megohmmeter (L2 - Skills)
- 3) Demonstrate the ability to complete the visual and conductivity inspection of the system (L2 - Skills)



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## ELEMENT 22.1 - SURFACE COMPONENTS

Training staff shall:

- 22.1.1 Explain the reasons for having a lightning protection system in a blade by considering the effects of lightning current on fibre reinforced composites and by showing examples of damage caused to a blade by lightning current
- 22.1.2 Describe typical components in a lightning protection system such as lightning receptors, lightning cable and the connection to the hub
- 22.1.3 Explain how the lightning receptors connect to the lightning cable and how they conduct lightning current from the surface of the receptor to the lightning cable and out of the blade

Delegate shall:

- 22.1.4 Explain the function of the lightning receptors in a wind turbine blade. Describe how lightning current is conducted from the surface of the receptor through the lightning cable and out of the blade

## ELEMENT 22.2 - VISUAL AND CONDUCTIVITY INSPECTION

Training staff shall:

- 22.2.1 Show examples of damaged lightning protection system components
- 22.2.2 Demonstrate how to carry out a visual inspection of the lightning protection system

Delegate shall:

- 22.2.3 Demonstrate the ability to identify damaged components of the lightning protection system by conducting a visual inspection

## ELEMENT 22.3 - MEASURE RESISTANCE

Training staff shall:

- 22.3.1 Describe the tools required for measuring the resistance of the lightning protection system
- 22.3.2 Explain the safety precautions to be adopted for using a megohmmeter
- 22.3.3 Demonstrate how to safely use a megohmmeter to measure the resistance in the entire lightning protection system
- 22.3.4 Demonstrate how to safely use the megohmmeter to identify which lightning receptor or section of cable is defect

Delegate shall:



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- 22.3.5 Demonstrate the ability to safely use a megohmmeter to measure the resistance of the lightning protection system
- 22.3.6 Demonstrate the ability to safely use a megohmmeter to identify a defect lightning receptor

## Lesson 23 - GRINDING SKILLS

45 min.

The aim of the lesson is to give the delegate the knowledge, skills and attitude of how to choose the correct PPE, equipment and method to grind safely and effectively.

To successfully complete this lesson the delegate shall be able to:

- 1) Demonstrate the ability to accurately grind composite materials to reveal the fibre orientation and create overlaps to existing material prior to applying repair layers (L2 - Skills)

### ELEMENT 23.1 - GRINDING

Training staff shall:

- 23.1.1 Explain the health and safety risks associated with working with a grinder by considering the ergonomic implications including vibration, the dust produced, the electrical hazard, flying debris, noise and the risks posed by high speed rotating tools
- 23.1.2 Demonstrate how to mitigate those risks through body positioning, adequate breaks, correct PPE, pre-use tool inspection and electrical safety devices such as residual current device
- 23.1.3 Explain the different grades of grinding disc available
- 23.1.4 Demonstrate how to recognise and replace a worn grinding disc
- 23.1.5 Demonstrate how to safely use a grinder to accurately grind a composite structure to reveal the fibre orientation and create overlaps of the correct dimensions in each layer of laminate

Delegate shall:

- 23.1.6 Demonstrate the ability to select and correctly use the appropriate PPE for the task and perform a pre-use tool inspection before working with a grinder
- 23.1.7 Demonstrate the ability to recognise and replace a worn-out grinding disc
- 23.1.8 Demonstrate the ability to safely use a grinder to accurately grind composite materials to reveal the fibre orientation and the create overlaps of the correct dimensions in each layer of laminate

**NOTE:** These skills shall be assessed in each of the following repair exercises.



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## Lesson 24 - SANDING SKILLS

45 min.

The aim of the lesson is to give the delegate the knowledge, skills and attitude of how to choose the correct PPE, equipment and method to sand safely and effectively.

To successfully complete this lesson the delegate shall be able to:

- 1) Demonstrate the ability to sand filler material to match the surrounding aerodynamic profile following a repair and achieve the correct surface finish for paint adhesion (L2 - Skills)

### ELEMENT 24.1 - SANDING

Training staff shall:

- 24.1.1 Explain the health and safety risks associated with working with a sander by considering the ergonomic implications including vibration, the dust produced, the electrical hazard, flying debris, noise and the risks posed by high speed rotating tools. Demonstrate how to mitigate those risks through body positioning, adequate breaks, correct PPE, pre-use tool inspection and electrical safety devices such as RCD's
- 24.1.2 Outline how the surface profile affects the aerodynamic performance of the blade. Explain how blade repair work can change the surface profile leading to reduced performance and loss of production
- 24.1.3 Explain how the surface finish affects the adhesion of subsequent repair layers such as filler and paint. Indicate that the surface finish varies for different products and that the required finish is detailed in manufacturer work instructions and the technical data sheet for the product
- 24.1.4 Explain the different grades of sanding disc available
- 24.1.5 Demonstrate how to recognise and replace a worn sanding disc
- 24.1.6 Demonstrate how to safely use a sander and select an appropriate sanding disc firstly to remove excess filler to match the surrounding aerodynamic profile of the blade and secondly to create the correct surface finish for adhesion of subsequent repair layers

Delegate shall:

- 24.1.7 Describe how the surface profile of a repair affects the aerodynamic performance of a blade and explain how surface finish affects the adhesion of subsequent repair layers
- 24.1.8 Demonstrate the ability to recognise and replace a worn sanding disc
- 24.1.9 Demonstrate the ability to safely operate a sander to remove excess filler to match the surrounding aerodynamic profile and to create the correct surface finish for adhesion of subsequent repair layers



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**NOTE:** These skills shall be assessed in each of the following repair exercises.

## Lesson 25 - LAMINATE REPAIRS

600 min.

The aim of the lesson is to give the delegate the knowledge, skills and attitude to describe different methods, actively remove damaged laminate, prepare for the repair, conduct the repair itself safely and effectively.

To successfully complete this lesson the delegate shall be able to:

- 1) Apply the knowledge gained during the general safety module to the working environment to minimise the risks associated with composite repair work (L3 - Skills)
- 2) Demonstrate the ability to safely remove damaged material and properly clean a composite laminate prior to repair activities (L3 - Skills)
- 3) Demonstrate the ability to identify the existing fibre directions in a composite laminate after grinding to remove damaged material (L3 - Skills)
- 4) Demonstrate the ability to prepare the repair area in terms of reinforcement material overlaps and matrix adhesion (L3 - Skills)
- 5) Demonstrate the ability to calculate, weigh out and mix matrix material for a given repair using both epoxy and polyester resin systems (L3 - Skills)
- 6) Demonstrate the ability to apply the repair layers in the correct order and orientation while maintaining the specified overlaps and fibre straightness (L3 - Skills)
- 7) Demonstrate the ability to wet out all the fibres with matrix using appropriate tools (L3 - Skills)
- 8) Demonstrate the ability to wet out the fibres of the reinforcement material with matrix using both epoxy and polyester resin systems material (L3 - Skills)
- 9) Demonstrate the ability to apply vacuum consumables and achieve the specified vacuum levels to the repair (L3 - Skills)
- 10) Demonstrate the ability to correctly cure the repair using heating blankets and record the curing temperature (L3 - Skills)
- 11) Demonstrate the ability to use a barcol/ shore D hardness tester to verify that the repair has cured correctly (L3 - Skills)
- 12) Demonstrate the ability to record the ambient temperature and humidity throughout the process using a data logger (L3 - Skills)

### ELEMENT 25.1 - MINIMISE RISKS ASSOCIATED WITH COMPOSITE FIBRE WORK

Training staff shall:



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- 25.1.1 Continually assess the delegate on their ability to apply the knowledge gained during the general safety module to the working environment to mitigate the risks associated with composite repair work

Delegate shall:

- 25.1.2 Demonstrate the ability to apply the knowledge gained during the general safety and chemical safety modules to their working environment by correctly selecting and using PPE appropriate to the task in hand and to work in a safe manner with the materials and tools required for each process

## ELEMENT 25.2 - SAFE REMOVAL OF DAMAGED MATERIAL

Training staff shall:

- 25.2.1 Create a small area of damage in the trailing edge section produced in lesson 18, with the damage limited to the laminate structure
- 25.2.2 Demonstrate how to correctly document the initial damage with photographs
- 25.2.3 Demonstrate how to use a grinder to remove all the damaged laminate material without damaging the underlying core material and to evaluate the extent of the damage
- 25.2.4 Demonstrate how to clean the surface in preparation for lamination using a vacuum cleaner, tacky rags and isopropyl alcohol
- 25.2.5 Demonstrate how to protect the cleaned surface if the lamination cannot be performed immediately

Delegate shall:

- 25.2.6 Demonstrate the ability to safely remove damaged laminate with a grinder without damaging the underlying core material. Assess the extent of the damage and how to properly clean the surface in preparation for lamination. How to document each stage of the repair
- 25.2.7 Explain methods that can be used to protect the cleaned surface if the lamination cannot be performed immediately

## ELEMENT 25.3 - IDENTIFYING FIBRE DIRECTION

Training staff shall:

- 25.3.1 After removing damaged material, demonstrate how to safely use a grinder to remove existing layers of laminate to reveal the fibre orientation in each layer of damaged fibre

Delegate shall:

- 25.3.2 Demonstrate the ability to safely use a grinder to remove existing layers of laminate to reveal the fibre orientation in each layer of damaged fibre



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## ELEMENT 25.4 - REINFORCEMENT OVERLAPS AND MATRIX ADHESION

Training staff shall:

- 25.4.1 Explain the importance of repairing each layer of laminate that is damaged with the same type and weight of glass as the original
- 25.4.2 Demonstrate how to measure out and mark the overlaps for each repair layer
- 25.4.3 Demonstrate how to safely use a grinder to create overlaps of the correct dimension in each layer of existing fibre
- 25.4.4 Demonstrate how to use the created overlaps to measure and cut the required glass fibre mats for each repair layer

Delegate shall:

- 25.4.5 Demonstrate the ability to correctly measure and mark the overlaps for each repair layer
- 25.4.6 Demonstrate the ability to grind the existing laminate to create overlaps of the correct dimension for each repair layer, that they have the correct surface finish for adhesion of the repair laminates
- 25.4.7 Demonstrate the ability to measure the created overlaps and cut repair glass fibre mats of the correct size and areal weight for each repair layer

## ELEMENT 25.5 - MIXING

Training staff shall:

- 25.5.1 Assess the delegate on their ability to calculate the amount of matrix material and the quantities of each component required for the repair

Delegate shall:

- 25.5.2 Demonstrate the ability to correctly calculate the total amount of matrix required and the quantities of each component of the matrix
- 25.5.3 Demonstrate the ability to correctly mix the matrix material

## ELEMENT 25.6 - REPAIR LAYERS

Training staff shall:

- 25.6.1 Demonstrate how to apply the repair layers, focusing on the correct order, maintaining the required overlaps and fibre orientation to the existing layers and ensuring that the fibres are straight

Delegate shall:



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- 25.6.2 Demonstrate the ability to correctly calculate the total amount of matrix required, the quantities of each component of the matrix and to correctly mix the matrix material

#### ELEMENT 25.7 - WETTING OUT FIBRES USING APPROPRIATE TOOLS

Training staff shall:

- 25.7.1 Demonstrate how to use a bolt roller to wet out all the fibres with matrix and to keep the fibres straight during lamination processes
- 25.7.2 Demonstrate how to avoid cross contaminating adjacent work areas through control of contaminated tools and how to clean a bolt roller after use

Delegate shall:

- 25.7.3 Demonstrate the ability to use a bolt roller to completely wet out all the fibres with matrix material and avoid cross contamination of adjacent work areas

#### ELEMENT 25.8 - WET OUT OF FIBRES WITH MATRIX MATERIAL

Training staff shall:

- 25.8.1 Demonstrate how to use a brush to apply the matrix material to the repair and how to use a bolt roller to wet out all the fibres in each layer while maintaining the correct overlaps and keeping the fibres straight in each layer

Delegate shall:

- 25.8.2 Demonstrate the ability to use appropriate tools to apply the matrix material to the repair and wet out all the fibres while maintaining the correct overlaps and keeping the fibres straight in each layer of the repair

#### ELEMENT 25.9 - VACUUM CONSOLIDATION

Training staff shall:

- 25.9.1 Explain the challenges that can arise from creating a vacuum in a repair setting by considering the surface finish of the blade, the porosity of the laminate, core material in the blade and the distance from the repair to the vacuum pump. Discuss ways in which to mitigate against these challenges
- 25.9.2 Demonstrate how to apply vacuum consumables to a repair to achieve the specified vacuum levels as stated in a work instruction
- 25.9.3 Demonstrate the application of flash tape and tacky tape prior to applying resin to ensure that the flash tape and tacky tape will adhere to the surface. Demonstrate how to prevent contamination of the tape by using masking tape



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25.9.4 Demonstrate how to record and document the vacuum level using a vacuum gauge

Delegate shall:

25.9.5 Demonstrate the ability to apply vacuum consumables to the repair in the correct order and achieve the correct vacuum levels in accordance with a work instruction

25.9.6 Demonstrate the ability to read a vacuum gauge to verify and to be able to document the vacuum level applied to the repair

## ELEMENT 25.10 - CURING THE REPAIR USING HEATING BLANKETS

Training staff shall:

25.10.1 Explain how to safely use a heating blanket and how to adjust and control the heating blanket to the correct curing temperature as displayed on the temperature gauge. How to document the curing temperature

Delegate shall:

25.10.2 Demonstrate the ability to find the correct curing temperature and duration for the lamination resin being used for the repair

25.10.3 Demonstrate the ability to adjust and control the heating blanket to the correct curing temperature as displayed on the temperature gauge

25.10.4 Demonstrate the ability to document the curing temperature throughout the curing process

## ELEMENT 25.11 - VERIFYING THE CURING

Training staff shall:

25.11.1 Explain the requirement to record and document the hardness of the cured laminate

Delegate shall:

25.11.2 Apply the knowledge gained in lesson 16 (lamination skills) by demonstrating the ability to use a barcol/ shore D hardness tester to verify that the laminate has cured to the correct hardness level. How to document this reading

## ELEMENT 25.12 - RECORDING THE AMBIENT TEMPERATURE AND HUMIDITY

Training staff shall:

25.12.1 Remind the delegate of the requirement to record and document the ambient temperature and humidity throughout the entire repair process

Delegate shall:



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- 25.12.2 Apply the knowledge gained in lesson 16 (lamination skills) by demonstrating the ability to use a data logger to record and document the ambient temperature and humidity throughout the entire repair process

## Lesson 26 - FILLING

180 min.

The aim of the lesson is to give the delegate the knowledge, skills and attitude of how to apply filling safely and effectively.

To successfully complete this lesson the delegate shall be able to:

- 1) Locate areas in need of filling and apply filler material to gaps/pinholes (L2 - Skills)

### ELEMENT 26.1 - FILLER

Training staff shall:

- 26.1.1 Describe how pinholes and surface defects degrade the aerodynamic performance of the blade
- 26.1.2 Explain the limitations of using filler by considering the short pot life of some fillers, how ambient temperature and humidity can affect the pot life and limitations layer thickness
- 26.1.3 Demonstrate which tools to use and how to apply filler to fill small gaps and pinholes in the surface of a blade while maintaining the correct profile shape of the blade

Delegate shall:

- 26.1.4 Explain the limitations of using filler in terms of short pot life and layer thickness
- 26.1.5 Demonstrate the ability to apply filler with the correct tools to fill pinholes and small defects in the surface of a wind turbine blade

## Lesson 27 - SURFACE REPAIRS

180 min.

The aim of the lesson is to give the delegate the knowledge, skills and attitude of how to repair small damage in the surface of the wind turbine blade safely and effectively.

To successfully complete this lesson the delegate shall be able to:

- 1) Apply the knowledge gained during the general safety lessons to the working environment to minimise the risks associated with composite repair work (L3 - Skills)



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- 2) The knowledge gained during lesson 17 (basic lamination) (L3 - Skills)
- 3) The ability to prepare the repair area in terms of filler adhesion (L3 - Skills)
- 4) The ability to reproduce the surface profile shape using filler (L2 - Skills)
- 5) The ability to prepare the repair area in terms of paint adhesion (L3 - Skills)
- 6) The ability to measure the layer thickness of the paint using a wet film gauge (L3 - Skills)
- 7) The ability to record the ambient temperature and humidity throughout the process using a data logger (L3 - Skills)
- 8) The ability to classify the repair needed by inspecting the damaged area and subsequently documenting it (L2 - Skills)

### ELEMENT 27.1 - MINIMISE RISKS ASSOCIATED WITH COMPOSITE FIBRE WORK

Training staff shall:

- 27.1.1 Continually assess the delegate on their ability to apply the knowledge gained during the general safety module to the working environment to mitigate the risks associated with composite repair work

Delegate shall:

- 27.1.2 Demonstrate the ability to apply the knowledge gained during the general safety and chemical safety modules to their working environment by correctly selecting and using PPE appropriate to the task in hand and to work in a safe manner with the materials and tools required for each process

### ELEMENT 27.2 - FILLER ADHESION

Training staff shall:

- 27.2.1 Demonstrate how to safely use a small grinder and a sander to remove surface damage such as pin holes, scratches, cracks and how to create the correct surface finish for the adhesion of subsequent repair layers

Delegate shall:

- 27.2.2 Demonstrate the ability to safely use a small grinder and a sander to remove small areas of surface damage like pin holes, scratches, cracks and how to create the correct surface finish for the adhesion of subsequent repair layers

### ELEMENT 27.3 - REPRODUCE SURFACE PROFILE

Training staff shall:



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- 27.3.1 Demonstrate how to apply thin layers of filler to a surface repair to match the surrounding profile shape of the blade

Delegate shall:

- 27.3.2 Demonstrate the ability to apply thin layers of filler to match the surrounding profile shape of the blade

#### ELEMENT 27.4 - PAINT ADHESION

Delegate shall:

- 27.4.1 Apply the knowledge gained in lesson 24 (sanding skills) by demonstrating the ability to create the correct surface finish for the adhesion of the paint layer

#### ELEMENT 27.5 - LAYER THICKNESS

Delegate shall:

- 27.5.1 Apply the knowledge gained in lesson 21 (painting) by demonstrating the ability to determine the correct layer thickness for paint using a work instruction

#### ELEMENT 27.6 - APPLY PAINT WITH ROLLER

Delegate shall:

- 27.6.1 Apply the knowledge gained in lesson 21 (painting) by demonstrating the ability to apply paint to surface repairs using a roller

#### ELEMENT 27.7 - LAYER THICKNESS WITH WET FILM

Delegate shall:

- 27.7.1 Apply the knowledge gained in lesson 20 (painting) by demonstrating the ability to measure the layer thickness of paint using a wet film gauge

#### ELEMENT 27.8 - RECORD AMBIENT TEMPERATURE AND HUMIDITY

Delegate shall:

- 27.8.1 Apply the knowledge gained in lesson 17 (lamination skills) by demonstrating the ability to record and document the ambient temperature and humidity throughout the entire repair process

#### ELEMENT 27.9 - INSPECTION AND DOCUMENTATION



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Delegate shall:

- 27.9.1 Apply the knowledge gained in lesson 22 (blade inspection) by demonstrating the ability to inspect a blade surface and identify typical surface defects such as pinholes, scratches and cracks

## Lesson 28 - TRAILING EDGE REPAIRS

440 min.

The aim of the lesson is to give the delegate the knowledge, skills and attitude to conduct a laminate repair on the trailing edge area of a wind turbine blade safely and in accordance with a work instruction.

**NOTE:** Trailing edge repairs must be carried out in accordance with a blade manufacturer work instruction, where these are impossible to obtain then the training provider shall create a work instruction.

To successfully complete this lesson the delegate shall be able to:

- 1) Apply the knowledge gained during the general safety lessons to the working environment to minimise the risks associated with composite repair work. (L3 - Skills)
- 2) Apply the knowledge gained during lesson 25 (laminate repairs) to the repair task (L3 - Skills)
- 3) Demonstrate the ability to repair an open trailing edge in accordance with a work instruction (L3 - Skills)
- 4) Demonstrate the ability to repair cracks running parallel to the trailing edge in accordance with a work instruction (L3 - Skills)
- 5) Demonstrate the ability to recreate the trailing edge profile using filler (L3 - Skills)
- 6) Demonstrate the ability to record the ambient temperature and humidity throughout the process using a data logger. (L3 - Skills)

### ELEMENT 28.1 - MINIMISE RISKS ASSOCIATED WITH COMPOSITE FIBRE WORK

Training staff shall:

- 28.1.1 Continually assess the delegate on their ability to apply the knowledge gained during the general safety module to the working environment to mitigate the risks associated with composite repair work

Delegate shall:



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- 28.1.2 Demonstrate the ability to apply the knowledge gained during the general safety and chemical safety modules to their working environment by correctly selecting and using PPE appropriate to the task in hand and to work in a safe manner with the materials and tools required for each process

#### ELEMENT 28.2 - REPAIR TASK

Training staff shall:

- 28.2.1 Assess the delegate on their ability to apply the lamination and curing skills gained in lesson 25 (laminare repairs) to laminare repairs on the trailing edge

Delegate shall:

- 28.2.2 Apply the lamination and curing skills gained in lesson 25 (laminare repairs) by demonstrating the ability to carry out laminare repairs (with minimal help from the training staff), to repairs on the trailing edge

#### ELEMENT 28.3 - TRAILING EDGE REPAIR

Training staff shall:

- 28.3.1 Explain the requirement to perform repairs in accordance with an approved work instruction by considering the safety and quality implications of repair work on the trailing edge
- 28.3.2 Using the trailing edge section created in the sandwich panel lessons to create an open trailing edge failure
- 28.3.3 Demonstrate how to measure and document the initial damage
- 28.3.4 Demonstrate how to carefully insert thin wedges into the damage to open it sufficiently to allow access to clean the area, without extending the length of the open trailing edge
- 28.3.5 Demonstrate how to remove debris from and clean the surfaces prior to bonding using appropriate tools and isopropyl alcohol
- 28.3.6 Demonstrate how to apply structural adhesive to the repair and how to apply clamps to the repair

Delegate shall:

- 28.3.7 Demonstrate the ability to repair an open trailing edge in accordance with a work instruction

#### ELEMENT 28.4 - CRACK REPAIRS

Training staff shall:

- 28.4.1 Explain the requirement to perform repairs in accordance with an approved work instruction by considering the safety and quality implications of repair work on the trailing edge



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- 28.4.2 Using the trailing edge section created in the sandwich panel topic create a crack running parallel to the trailing edge that extends through both sides of the trailing edge section but allows sufficient undamaged material at either end of the crack to allow the correct overlaps for the laminate repair
- 28.4.3 Demonstrate how to remove the damaged material from the trailing edge
- 28.4.4 Demonstrate how to create a temporary hardback repair on one side of the trailing edge and explain that this is temporary and to support the lamination of the other side of the trailing edge
- 28.4.5 Demonstrate how to laminate and cure one side of the trailing edge using the temporary hardback repair as a support for the lamination
- 28.4.6 Demonstrate how to remove the temporary hardback repair, laminate and cure the remaining side of the trailing edge

Delegate shall:

- 28.4.7 Demonstrate the ability to repair cracks running parallel to the trailing edge by using a temporary hardback repair to support the laminate repair on one side of the trailing edge and then removing the temporary hardback and completing the repair by laminating the remaining side of the trailing edge

## ELEMENT 28.5 - RECREATING BLADE PROFILE

Training staff shall:

- 28.5.1 Explain the importance of recreating the aerodynamic profile of the blade
- 28.5.2 Demonstrate how to apply filler to the repair to cover the repair and to approximately match the surrounding aerodynamic profile of the trailing edge
- 28.5.3 Demonstrate how to use a sander to shape the filler to match the surrounding aerodynamic profile and create the correct surface finish for the adhesion of the paint layer

Delegate shall:

- 28.5.4 Demonstrate the ability to use filler to cover the repair and to match the surrounding aerodynamic profile of the blade
- 28.5.5 Demonstrate the ability to use a sander to shape the filler to match the surrounding aerodynamic profile and create the correct surface finish for the adhesion of the paint layer

## ELEMENT 28.6 - RECORD AMBIENT TEMPERATURE AND HUMIDITY

Delegate shall:

- 28.6.1 Without help from the training staff, demonstrate the ability to record and document the ambient temperature and humidity throughout the entire trailing edge repair process



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**NOTE:** Where the delegate must perform an action without help from the training staff, the training staff must assess and document this using the delegate assessment form.

## Lesson 29 - LEADING EDGE REPAIRS

440 min.

The aim of the lesson is to give the delegate the knowledge, skills and attitude to conduct laminate repairs on a leading edge safely and effectively.

To successfully complete this lesson the delegate shall be able to:

- 1) Apply the knowledge gained during the general safety lessons to the working environment to minimise the risks associated with composite repair work (L3 - Skill)
- 2) Apply the knowledge gained during lesson 25 (lamination skills) to the repair task (L3 - Skill)
- 3) Demonstrate the ability to repair delamination, holes and cracks running parallel to the leading edge in accordance with a work instruction (L3 - Skill)
- 4) Demonstrate the ability to recreate the leading-edge profile using filler (L3 - Skill)

### ELEMENT 29.1 - MINIMISE RISKS ASSOCIATED WITH COMPOSITE FIBRE WORK

Training staff shall:

- 29.1.1 Continually assess the delegate on their ability to apply the knowledge gained during the general safety module to the working environment to mitigate the risks associated with composite repair work

Delegate shall:

- 29.1.2 Demonstrate the ability to apply the knowledge gained during the general safety and chemical safety modules to their working environment by correctly selecting and using PPE appropriate to the task in hand and to work in a safe manner with the materials and tools required for each process

### ELEMENT 29.2 - REPAIR TASK

Training staff shall:

- 29.2.1 Create an exercise where the delegate must repair damage equivalent to cracks in the leading edge of a blade

Delegate shall:



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- 29.2.2 Apply the lamination and curing skills gained in lesson 26 (laminare repair) by demonstrating the ability to carry out laminate repairs, with minimal help from the training staff, to repairs on the leading edge

### ELEMENT 29.3 - LEADING EDGE REPAIR

Training staff shall:

- 29.3.1 Demonstrate how to use a grinder to safely remove damaged material from the leading edge of a blade

Delegate shall:

- 29.3.2 Demonstrate the ability to safely removed damaged material from the leading edge of a blade while creating overlaps and the correct surface finish for subsequent repair layers
- 29.3.3 Demonstrate the ability to lay-up and correctly cure with vacuum and heat a laminate repair on the leading edge with at least two layers of biax

### ELEMENT 29.4 - RECREATE LEADING EDGE

Training staff shall:

- 29.4.1 Demonstrate the tools and techniques that can be used to shape the filler to the approximate profile shape of the leading edge and explain that the final profile shape will be obtained by sanding

Delegate shall:

- 29.4.2 Demonstrate the ability to apply filler to a laminate repair on the leading edge and to shape the filler to approximately match the surrounding aerodynamic profile of the leading edge
- 29.4.3 Demonstrate the ability to shape the cured filler with a sander so that it accurately matches the surrounding aerodynamic profile of the leading edge and has the correct surface finish for the adhesion of paint

## Lesson 30 - SANDWICH PANEL REPAIR

180 min.

The aim of the lesson is to give the delegate the knowledge, skills and attitude to carry out laminate repairs on the inner and outer laminate of a sandwich panel safely and effectively.

To successfully complete this lesson the delegate shall be able to:

- 1) Apply the knowledge gained during the general safety module to the working environment to minimise the risks associated with composite repair work (L3 - Skills)



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- 2) Apply the knowledge gained during lesson 25 (laminare repair) to the repair task (L3 - Skills)
- 3) Demonstrate the ability to repair the inner and outer laminate of a sandwich panel in accordance with a work instruction (L3 - Skills)
- 4) Demonstrate the ability to correctly size and shapes the replacement core material in a sandwich panel repair (L3 - Skills)
- 5) Demonstrate the ability to classify the repair needed by inspecting the damaged area and subsequently documenting it (L2 - Skills)

### ELEMENT 30.1 - MINIMISE RISKS ASSOCIATED WITH COMPOSITE FIBRE WORK

Training staff shall:

- 30.1.1 Continually assess the delegate on their ability to apply the knowledge gained during the general safety module to the working environment to mitigate the risks associated with composite repair work

Delegate shall:

- 30.1.2 Demonstrate the ability to apply the knowledge gained during the general safety and chemical safety modules to their working environment by correctly selecting and using PPE appropriate to the task in hand and to work in a safe manner with the materials and tools required for each process without help from the training staff

### ELEMENT 30.2 - REPAIR TASK

Training staff shall:

- 30.2.1 Assess the delegate on their ability to apply the lamination and curing skills gained in lesson 25 (laminare repair) to laminare repairs

Delegate shall:

- 30.2.2 Without help from the training staff, apply the lamination and curing skills gained in lesson 25 (laminare repair) by demonstrating the ability to carry out laminare repairs, with minimal help from the training staff, to repairs on the trailing edge

### ELEMENT 30.3 - REPAIR INNER AND OUTER LAMINATE

Training staff shall:

- 30.3.1 Using the sandwich panel created in the sandwich panel topic create a small hole, approximately ten millimetres in diameter, that extends through both the outer and inner laminates



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- 30.3.2 Demonstrate how to remove the outer laminate and the core material to reveal the inner laminate
- 30.3.3 Demonstrate how to remove damaged material from the inner laminate
- 30.3.4 Demonstrate how to use hardback and non-structural adhesive to create a support to upon which to repair the inner laminate

Delegate shall:

- 30.3.5 Demonstrate the ability, in accordance with a work instruction, to create a support using hardback and to perform a laminate repair with the correct overlaps and fibre orientation on the inner laminate
- 30.3.6 Demonstrate the ability to repair the outer laminate with the correct overlaps and fibre orientation, after replacing the core material

#### ELEMENT 30.4 - REPLACEMENT CORE

Training staff shall:

- 30.4.1 Explain the requirement for the gap between the existing and replacement core material to be less than 2 millimetres
- 30.4.2 Demonstrate how to measure, cut and shape the replacement core material to match the profile of the surrounding core material
- 30.4.3 Demonstrate how to apply the replacement core material to the sandwich panel, how to bond it into place using lamination resin or structural adhesive and how to cure it using vacuum and heat
- 30.4.4 Demonstrate how to repair the outer laminate following replacement of the core material

Delegate shall:

- 30.4.5 Demonstrate the ability, in accordance with a work instruction, to correctly measure, cut and shape replacement core material so that it matches the profile shape of the surrounding core material with a gap of less than two millimetres on all sides
- 30.4.6 Demonstrate the ability, in accordance with a work instruction, to bond the replacement core material with either lamination resin or structural adhesive, and to correctly cure the chosen material with heat and vacuum

#### ELEMENT 30.5 - INSPECTION AND DOCUMENTATION

Delegate shall:

- 30.5.1 Demonstrate the ability to document, with photographs, all stages of the sandwich panel repair including the vacuum levels, curing temperatures, the ambient temperature, humidity and the batch numbers of all materials used



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## Lesson 31 - BOND LINE REPAIRS

180 min.

The aim of the lesson is to give the delegate the knowledge, skills and attitude to drill injection and verification holes and subsequently inject structural adhesive to repair the bond line safely and effectively.

To successfully complete this lesson the delegate shall be able to:

- 1) Demonstrate the ability to identify areas of debonding within a bond line (L3 - Skills)
- 2) Demonstrate the ability to inject adhesive into a de-bonded section of a bond line (L3 - Skills)
- 3) Demonstrate the ability to inject the applicable material in the trailing edge (L3 - Skills)

### ELEMENT 31.1 - DEBONDING

Training staff shall:

- 31.1.1 Define the term 'Bond line' and describe where bond lines are located on a blade
- 31.1.2 Explain the possible defects that can occur within a bond line on a blade
- 31.1.3 Demonstrate how to identify areas in a blade where a bond line has failed by using tap testing and visual inspection
- 31.1.4 Create an exercise where the delegate must identify areas where a bond line has failed

Delegate shall:

- 31.1.5 Demonstrate the ability to correctly identify and document areas on a blade where the bond line has failed

### ELEMENT 31.2 - INJECTION OF ADHESIVE

Training staff shall:

- 31.2.1 Explain the need for caution and to follow a blade manufacturer work instruction when repairing bond lines that are located above structural parts like the spar or webs of the blade
- 31.2.2 Demonstrate how to identify the laminate thickness from a blade drawing
- 31.2.3 Explain how to drill injection and verification holes through the laminate without damaging the underlying structural parts of the blade
- 31.2.4 Explain how to position the holes so that adhesive can be injected from one side and flow across the area of debonding
- 31.2.5 Explain how to inject structural adhesive into the area of debonding and how to verify that it has flowed across the de-bonded area



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### ELEMENT 31.3 - INJECTING MATERIAL IN THE TRAILING EDGE

Training staff shall:

- 31.3.1 Demonstrate how to determine the correct dimensions of the trailing edge bond line on a blade from a blade drawing or manufacturer work instruction
- 31.3.2 Demonstrate how to drill injection and verification holes along the trailing edge so that the spacing does not compromise the integrity of the trailing edge
- 31.3.3 Demonstrate how to inject structural adhesive into the trailing edge

Delegate shall:

- 31.3.4 Demonstrate the ability to determine the correct dimensions of the bond line in the trailing edge from a blade drawing or blade manufacturer work instruction
- 31.3.5 Demonstrate the ability to drill injection and verification holes in the trailing edge
- 31.3.6 Demonstrate the ability to inject adhesive into the trailing edge in accordance with a work instruction

## Lesson 32 - SUMMARY AND FINAL TEST

60 min.

The aim of the final test is to summarise the blade repair module and to assess the delegates understanding of key theoretical and safety related elements of the module.

To successfully complete this blade repair module delegates shall:

- 1) Pass the final test

### ELEMENT 32.1 - SUMMARY

Training staff shall:

- 32.1.1 Summarise the blade repair module referring to the learning objectives covered

### ELEMENT 32.2 - FINAL TEST

Training staff shall:

- 32.2.1 Introduce the final test and explain the criteria for the test with reference to the delegate performance assessment
- 32.2.2 Conduct the test in accordance with the delegate performance assessment criteria.



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- 32.2.3 Upon completion of the test check the delegates answers and give feedback to the delegates about the test result
- 32.2.4 In the case that a delegate does not pass the test, conduct an interview with the delegate in accordance with the delegate performance assessment

## Lesson 33 - EVALUATION

30 min.

The aim of this lesson is to enable the Delegates to reflect on and process their learning outcome and key takeaways from the module, aiming to achieve a high learning transfer from the module to his/her way of work. Additionally, the aim is to give the Delegates the opportunity to conduct an open-minded written and oral formative evaluation of the training.

To successfully complete this lesson of the Module, Delegates must:

- 1) Show commitment to avoid incidents while working with blade repair
- 2) Show commitment to act out this value by demonstrating a proactive approach
- 3) Participate in the formative evaluation of the module in a constructive manner

## Lesson 34 - REFLECTION SESSION

The Instructor shall:

- 34.1.1 Give the Delegates final feedback on the formal Delegate performance assessment and inform them whether they have passed (failed Delegates must be informed individually prior to the reflection session)
- 34.1.2 Help the Delegate to do a summative self-evaluation, i.e. mental overview and assort what is learned, identify key takeaways and bridge the gap between what is learned during the module and applying it in his/her way of work. This can be achieved e.g. by an individual reflection session, question session and/or class discussion
- 34.1.3 Re-present the overall aims and objectives of the course for the Delegates' comparison on their learning outcome and meeting of their previously stated expectations of the course
- 34.1.4 Give an overall feedback and feed forward on the Delegates' learning outcome
- 34.1.5 Encourage the Delegates to examine and grow awareness of what specific elements in their own WTG type/WTG environment differ from the training scenario environment (to visualize and enhance learning transfer) and to discuss with colleagues' blade repair methods and techniques under the local specific conditions identified after course completion



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## Lesson 35 - FORMATIVE EVALUATION

Delegates shall:

- 35.1.1 Conduct an online or written formative evaluation of the module, as a minimum

The Instructor shall:

- 35.1.2 Respond on relevant elements of any oral feedback from the Delegates



GLOBAL WIND  
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# Annexes





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## ANNEX 1 - EQUIPMENT LIST

Any equipment used during this GWO training module shall meet or exceed the minimum requirements of the national standards in the country where the training is taking place. When working in a country where there is no applicable national standard then the equipment shall meet or exceed the minimum requirements of the European standards.

### 1. DOCUMENTATION:

- 1) Safety data sheets for all materials used throughout the training module
- 2) Technical data sheets (where applicable) for materials used throughout the training module
- 3) Work instruction examples
- 4) Photocard
- 5) Blade inspection report
- 6) Risk assessment templates and examples (hand out)

### 2. MEASURING TOOLS (ENOUGH FOR EACH DELEGATE):

- 1) Ambient temperature & humidity data logger
- 2) Thermocouple temperature gauge and probes
- 3) Absolute pressure gauge (Vacuum gauge)
- 4) 0-150 mm rule
- 5) 0-300 mm rule
- 6) Tape measure
- 7) Weighing scale
- 8) Wet film thickness gauge

### 3. POWER TOOLS (ENOUGH FOR EACH DELEGATE)

- 1) Heating blankets
- 2) Vacuum pump
- 3) Electric orbital sanding machine
- 4) Electric grinding machine



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#### 4. HAND TOOLS (ENOUGH FOR EACH DELEGATE)

- 1) Scissors
- 2) Retractable blade knife
- 3) Clamps
- 4) Flat aluminium mould 1000x600
- 5) Caulking gun
- 6) Straight edge
- 7) Filling knife
- 8) Spatula
- 9) Glass fibre cutter
- 10) Chisel
- 11) Bolt roller
- 12) 1-ounce hammer (tap tester)

#### 5. TOOLS CONSUMABLES

- 1) Sufficient types and numbers of discs etc.
- 2) Painting rollers
- 3) Brushes
- 4) Cleaning cloth
- 5) Rags
- 6) Diamond cutting wheel
- 7) Marker pens
- 8) Duct tape
- 9) Mask tape
- 10) Plastic cover
- 11) Rubbish bag
- 12) Surface cleaner (preferably isopropyl alcohol)

#### 6. CONSUMABLE MATERIALS:

- 1) Unidirectional fibreglass material
- 2) Biaxial stitched mat fibreglass



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- 3) Triaxial stitched mat fibreglass
- 4) Core material (not honeycomb)
- 5) Epoxy gelcoat kit
- 6) Polyester gelcoat kit
- 7) Epoxy lamination resin kit
- 8) Polyester lamination resin kit
- 9) Paint
- 10) Polyurethane glue
- 11) Filler
- 12) Araldite 2021 (or similar non-structural adhesive)
- 13) Mixing pots
- 14) Mixing sticks
- 15) Vacuum foil
- 16) Breather fabric
- 17) Peelply
- 18) Release film
- 19) Vacuum hose
- 20) Sealant tape (tacky tape)
- 21) Polyurethane topcoat
- 22) Release agent
- 23) Vinyl ester

## 7. PERSONAL PROTECTIVE EQUIPMENT

- 1) Air fed mask
- 2) Filter
- 3) Safety glasses
- 4) Face shield
- 5) Dust suits
- 6) Lamination suits
- 7) Protective sleeves
- 8) Thin nitrile gloves



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- 9) Cotton inner gloves
- 10) Nitrile gloves
- 11) Handling gloves
- 12) Boot cover
- 13) Hearing protection
- 14) Face mask
- 15) Anti-vibration gloves
- 16) Safety boots

**NOTE:** All equipment shall be maintained and where appropriate, inspected and tested in accordance with current national standards/legislation and manufacturers' recommendations.



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## ANNEX 2 - PRACTICAL EXERCISE (EXAMPLE)

### 1. INTRODUCTION:

This exercise will enable the delegate to produce a sandwich panel which can be used for later repair exercises.

Exercise name	Sandwich Panel
PPE	Disposable Coverall Gloves (type dependant on materials used) Mask (type dependant on materials used) Eye protection Hearing protection
Materials	Mould release agent Flash tape Gelcoat Vacuum consumables Matrix material (epoxy) Fibreglass (size and weight as indicated by the instructor) 10 mm core material (pvc foam or balsa wood) Vacuum consumables Thermocouple temperature probe
Tools	Non-metallic scraper for mould surface Mixing pots Mixing sticks Brushes Rollers Scissors Bolt roller



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Vacuum pump (or supply from workshop)

Heating blanket

Documentation

SDS for materials used

TDS for materials used

## 2. EXERCISE 1 - MOULD PREPARATION

- 1) Carefully remove any debris from the mould surface using non-metallic tools.
- 2) Clean the surface of the mould using isopropyl alcohol.
- 3) Apply a thin layer of mould release agent to the mould surface and allow it to dry for 1 to 2 minutes.
- 4) Remove any excess release agent using a clean dry cloth.
- 5) Allow the release agent to dry for a further 15 minutes.
- 6) Apply flash tape to the mould surface according to the instructions given by the instructor.
- 7) Apply vacuum tape on top of the flash tape.

## 3. EXERCISE 2 - GELCOAT

- 1) Find the SDS for the gelcoat being used and identify the PPE required. Fill in the information in the table below.

Gloves required

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Mask required

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- 2) Find the TDS for the gelcoat and use this to calculate the amount of gelcoat required to cover the mould surface at a layer thickness of 0.8 mm. Enter the information in the table below:

Total amount of gelcoat

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Mixing ratio

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Amount of gelcoat base

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Amount of gelcoat hardener

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Curing time for gelcoat

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- 3) Carefully weigh out and thoroughly mix the gelcoat.
- 4) Apply the gelcoat to the mould surface and distribute evenly using a roller.
- 5) Allow the gelcoat to tack-off in accordance with the TDS.

#### 4. EXERCISE 3 - DRY MATERIAL PREPARATION

- 1) 1. Cut out the fibre glass mats and core material to the sizes indicated by the instructor.
- 2) 2. Shape the core material as directed by the instructor.

#### 5. EXERCISE 4 - MATRIX MATERIAL

- 1) Find the SDS for the matrix material being used and identify the PPE required for the matrix material being used. Enter this information in the table below:

Type of gloves required

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Type of mask required

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Type of mask filter required

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Other PPE required

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- 2) Find the TDS for the matrix material being used and use this to calculate the amount of matrix required for the panel. Enter the information in the table below:

Total amount of Matrix

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Mixing ratio

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Amount of Matrix base

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Amount of Matrix hardener

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Curing time for matrix

---

Curing temperature for matrix

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## 6. EXERCISE 5 - PANEL ASSEMBLY

- 1) Carefully weigh out and thoroughly mix the material.
- 2) Apply a thin layer of matrix material onto the gelcoat on the mould.
- 3) Apply the first layer(s) of glass fibre onto the gelcoat on the mould.
- 4) Apply matrix to the glass fibre and thoroughly wet out the glass using a bolt roller, ensuring the fibres are straight.
- 5) Apply the core material to the first layer of glass and apply a thin layer of matrix on top of the core material.
- 6) Place the subsequent layers of glass fibre onto the matrix and thoroughly wet out the glass fibre with matrix.

## 7. EXERCISE 6 - CURING

- 1) Apply peelply on top of the glass fibre and remove the air.
- 2) Apply release film onto the peelply.
- 3) Place thermocouple onto the release film.
- 4) Apply breather fabric onto the release film.
- 5) Insert vacuum hose and cover entire panel with vacuum foil. Ensure that the vacuum foil is sealed to the vacuum tape all the way around.
- 6) Apply vacuum to the panel, check for air leaks and fix air leaks.
- 7) Place a heating blanket onto the panel and adjust the temperature to the curing temperature in the TDS. Note the time that the blanket reaches the curing temperature.



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## ANNEX 3 - WORK INSTRUCTION (EXAMPLE)

**NOTE:** This annex includes a template which must be developed by the training provider into a work instruction for use during the blade repair training module. It details the required elements in a work instruction and some text as a suggestion of what should be included in each section.

The template is incomplete in some areas and is therefore **not** intended to be used as is.

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### SAFETY

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Work involving the repair of glass-fibre reinforced composite material carries risks to you and those around you. To limit these risks read and obey the warnings below!

 **WARNING**

Obey the manufacturer instructions when you use cleaning agents, resins, sealants, fillers and paints. These materials are hazardous to your health and if used incorrectly present a fire hazard.

Wear the correct personal protection equipment as specified in the safety data sheet for the materials that you are working with. The materials used in fibre-reinforced composite repair can cause life changing injuries or death.

Wear the correct personal protection equipment: eye protection, correct filter dust mask, hearing protection, disposable coverall and correct gloves for the task when you cut, abrade or drill fibre-reinforced composite materials. The dust from these materials can cause lung injuries, skin irritation. These activities create high levels of noise which can damage your hearing. Flying debris from these activities can damage your eyes.

### Environmental conditions

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The materials used in the repair of fibre-reinforced composite materials are sensitive to environmental conditions like ambient temperature and humidity. When these materials are used outside of their intended temperature and or humidity range they may not cure as the manufacturer intends leading to health risks from uncured material and a loss of material performance resulting in a failure of the repair. To limit these risks read and obey the warning below!

 **WARNING**

Obey the environmental conditions described in the Technical Data Sheet for all materials used.

The ambient temperature and humidity must be recorded using a suitable data logger for the entire duration of the repair process.

### Documentation of the repair

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During the repair process it is of utmost importance to document each stage of the repair with photographs and to include those in a repair report. The repair report must contain at a minimum:



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- Batch numbers and expiry dates of all materials used
- A record of ambient temperature and humidity throughout the repair process
- Curing temperature achieved
- Vacuum levels achieved
- References to documentation used during the repair
- Photographs, including the: size and location, site name, turbine ID number, blade serial number and technician, of:
  - The initial damage
  - The repair after damaged material has been removed
  - Each repair layer applied
  - Filler applied
  - Gelcoat and or paint applied

The photocard in annex 5 can be used for this purpose.

## **Documentation**

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### **Safety documentation**

The following safety documentation is required before commencing repair activities:

- Safety Data sheet for each material
- Company specific safety instructions
- Risk assessments

### **Reference documentation**

The following reference documentation is required before commencing repair activities:

- Technical Data sheet for each material
- Company specific repair instructions
- Blade drawings, if not included in the repair instruction

## **Personal Protection Equipment**

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The following Personal Protection equipment is the minimum anticipated for carrying out repair work, it must be supplemented with specifics from the Safety Data Sheet and company specific requirements.

- Disposable coverall
- Safety footwear
- Eye Protection
- Hearing Protection
- Cut resistant gloves
- Chemical resistant gloves (specific to the materials used)
- Nitrile gloves for general work
- Mask (with filters specific to the materials used)
- Dust mask

## **Tools**

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The following list of tools is the minimum anticipated for carrying out repair work, it must be supplemented with additional tools specific to the repair being performed.

- Knife with a retractable blade
- Tape measure (or equivalent)
- Chisels
- Hammer
- Photocard
- Grinding machine
- Sanding machine
- Vacuum pump
- Bolt roller
- Foam paint roller
- Vacuum gauge
- Data logger (for ambient temperature and humidity)
- Thermocouple temperature probe
- Resin trap
- Weighing scales
- Hardness tester (Barcol or ShoreD)
- Wet film gauge
- Plastic scrapers

## Materials

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### Consumable materials

The following list of consumable materials is the minimum anticipated for carrying out repair work, it must be supplemented with additional consumable materials specific to the repair being performed.

- Paint brushes
- Foam paint rollers
- 80 and 120 grit grinding discs
- 120 and 240 grit sanding discs
- 1" and 2" Masking tape
- Flash tape
- Vacuum sealant tape
- Mixing pots
- Mixing sticks
- Waste chemical bags
- General waste bags
- Vacuum hose
- Vacuum foil
- Breather fabric
- Release film
- Peel-ply
- Cleaning agent (like isopropyl alcohol)
- Cleaning rags



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## Repair materials

The following list of repair materials is the minimum anticipated for carrying out repair work and it is very general in nature considering all repair scenarios. It must be supplemented with specific and additional repair materials specific to the repair being performed.

- Glass-fibre mats
- Hardback material
- Core material
- Matrix material
- Non-structural adhesive (like araldite 2021)
- Structural adhesive
- Filler
- Gelcoat
- Paint

## Repair stage 1

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### Preparation

Gather all required documentation, tools and materials that are required for the inspection and repair task.

### Assessment and damage removal

1. Photograph the initial damage making sure to include scale in the photographs to indicate the size of the damage. Make a note of any relevant observations which might indicate the root cause of the damage.
2. Perform a tap test around the damage to identify the extent of underlying delamination. Mark this extent on the blade surface.



**NOTE:** If the laminate has been in prolonged contact with water it must be dried before commencing repair activities.

3. Carefully remove all the damaged material taking care to not damage underlying structural elements like spar caps.
4. Assess the size of the repair needed taking into consideration the overlaps required for each layer of laminate and the size of the core material (if required).



**NOTE:** During removal of the damaged material it may be found that the repair size exceeds the scope of the technician performing the repair. In this case work should stop and the OEM contacted for advice on how to proceed.

5. Carefully grind the existing laminate around the area being repaired to create overlaps in each layer of laminate being repaired.
6. Clean the repair area with a cleaning agent ensuring that you remove all dust, debris and oils.



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## Repair Stage 2

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### Preparation

1. Measure the extents of the overlaps and removed core material created above. Use these measurements to carefully cut and shape the repair pieces as required taking care to ensure the correct fibre orientation for each repair layer.

**i NOTE:** A fundamental principle of fibre-reinforced composite repair work is that you should replace what you take out. This holds in the case of blade repair work however you should consult OEM specific repair instructions and or blade drawings to identify which materials to use for the repair task.

2. Calculate the amount of resin required for each repair layer based upon the weight of the glass-fibre and the size of the core material being replaced. Note down the amount for each layer.

### Applying the repair

**⚠ WARNING:** Mixing large quantities of matrix materials can cause a runaway exothermic reaction and lead to a fire. Take precautions to avoid an exothermic reaction by only mixing sufficient quantities of matrix material for the repair being performed, and where large quantities are required dividing this into smaller quantities.

3. For the first repair layer weigh out and thoroughly mix the matrix material components.
4. Apply resin to the existing laminate with a paint brush and carefully apply the first glass-fibre repair layer, apply enough resin to fully wet out the glass-fibre mat. Carefully roll the mat with a bolt roller to ensure complete wet-out of the fibres with matrix and to remove any air bubbles.
5. For the next repair layer weigh out and thoroughly mix the matrix material components.
6. Apply the next repair layer and wet-out as described in step 4.
7. Continue step 5 and 6 until all repair layers are applied.

**i NOTE:** If the repair is small and only has a small number of layers it is possible to mix all the matrix material and apply all of the repair layers in one go. Consult the OEM specific instructions for the maximum number of layers that can be applied at a time.

### Vacuum bagging

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1. Clean the area around the repair and apply flash tape to the blade surface so that it surrounds the repair. Ensure that there are no creases or folds in the flash tape.
2. Apply vacuum sealant tape on top of the flash tape.
3. Apply peel ply on top of the last laminate repair layer and roll this to remove any air bubbles.
4. Apply the release film on top of the peelply.



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5. Apply the thermocouple probe on top of the release film, placing it to the side of the repair so that it does not cause an impression in the repair layers. Guide the wires from the thermocouple probe out from the repair and seal with vacuum sealant tape. Connect the wires to the temperature gauge.
6. Apply the breather fabric on top of the release film.
7. Cut two lengths of vacuum hose, one for the vacuum pump and one for the vacuum gauge the pieces should be long enough to reach the vacuum pump and gauge. Wrap the repair end of the vacuum hose pieces with breather fabric to ensure that they do not become clogged by vacuum film or resin.
8. Where the vacuum hoses cross the vacuum sealant tape, additional vacuum sealant tape should be applied on top of the hoses to ensure a seal.
9. Connect the vacuum gauge to one of the vacuum hoses and attach the other hose to the vacuum pump. Use a resin trap between the repair and the vacuum pump.
10. Apply the vacuum film on top of the repair and press it down onto the vacuum sealant tape.
11. Start the vacuum pump and check for air leaks around the repair. Consult the OEM specific instruction for the vacuum level to be achieved.

## Curing

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1. Consult the TDS for the matrix material to ascertain the correct curing temperature and time.
2. Place a heating blanket over the repair and switch it on. Adjust the temperature of the heating blanket until the temperature gauge reaches the correct curing temperature.
3. Make a note of the time that the temperature gauge reaches the correct temperature, this is the time at which the curing duration starts.
4. Allow the repair to cure for the time specified in the TDS.

 **WARNING:** The cured vacuum bagging consumables will have sharp edges.

5. After the specified curing time has elapsed carefully remove the vacuum bagging materials from the repair, leaving the peelply in place.
6. Verify that the matrix material has reached the specified hardness in the TDS using a Barcol or ShoreD tester.

## Filling

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1. Remove the peel ply from the repair and sand the surface to the required finish as stated in the TDS for the filler being used.
2. Weigh out and mix the filler (if using a two-component filler)



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3. Apply filler to the repair and shape using a plastic scraper so that it matches the surrounding blade profile shape.
4. Allow the filler to cure fully in accordance with the TDS.
5. After the filler has cured sand the filler using 120 grit paper so that it matches the surrounding blade profile as closely as possible.

### Paint or gelcoat

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1. Consult the OEM specific repair instruction to ascertain whether gelcoat or paint or both are required to finish the repair.
2. Clean the filler surface using an appropriate cleaning agent, allow any residual cleaning agent to fully evaporate before proceeding.

**i NOTE:** Steps 3 to 6 below will depend on the OEM requirements. Consult the OEM specific instructions. If the OEM demands both gelcoat and paint proceed with steps 3 to 6. If the OEM only requires paint omit steps 3 to 5.

3. Calculate and then weigh out and mix the required amount of gelcoat and apply this to the filler, distributing it evenly and to the specified layer thickness with a plastic scraper. Verify the layer thickness using a wet film gauge.
4. Allow the gelcoat to fully cure in accordance with the TDS.
5. Sand the gelcoat to the required surface finish in accordance with the TDS for the paint.
6. Calculate and then weigh out and mix the required amount of paint and apply this to the sanded gelcoat, distributing it evenly and to the specified layer thickness using a foam roller. Verify the layer thickness with a wet film gauge.



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## ANNEX 4 - PHOTOCARD

Below is an example of a photocard that can be used by the delegates during the blade repair and inspection exercises. This should be printed and laminated so that it can be written on and used in each photograph taken to ensure consistency.

1	2	3	4	5	6	7	8	9	10	11	12	Cm
2												17
3	<b>Date:</b>											16
4	<b>Site:</b>											15
5												14
6	<b>Company:</b>											13
7	<b>Technician:</b>											12
8												11
9	<b>Turbine ID:</b>											10
10	<b>Blade Serial number:</b>											9
11												8
12	<b>Radius:</b>				<b>Blade Side:</b>							7
13												6
14												5
15	<b>Photo No.:</b>				<b>Dist. From LE/TE:</b>							4
16												3
17												2
cm	12	11	10	9	8	7	6	5	4	3	2	1



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**ANNEX 5 - VERSION HISTORY**

<b>Amendment Date</b>	05/02/2019	<b>Approved by &amp; date</b>	<b>GWO SC 05/02/2019</b>
<b>Version</b>	<b>1</b>	<b>Description of changes</b>	
<b>Minor corrections since launch</b>			
<b>October 2019</b>			
- Section 9.2 duration updated to clarify meaning of contact time			
<b>First Edition</b>			
New Training Module created			