# Scope

The Borescope Inspection micro-credential sets the minimum requirements for a person to demonstrate knowledge of gearboxes and competence in safely performing borescope inspections within the wind industry.

# MICRO-CREDENTIAL Borescope Inspection

## Borescope Inspection: Tower and Nacelle Safety

### Does the trainee demonstrate knowledge and skills related to hazards, avoidance, and protection in the course of safely accessing equipment in the wind turbine nacelle?

#### Trainee MUST

1. Perform a hazard assessment for the area in which they are to demonstrate borescope inspection(s)
   1. Dropped objects
   2. Rotating equipment
   3. Chemical exposure to hot lubricating oil and vapors using SDS for specific lubricants encountered
   4. Work at heights
   5. Electrical hazards
   6. Pinch points
   7. Wind speed limits for rotor and shaft locks and maximum nacelle access wind speed
   8. Heat exhaustion
   9. Hypothermia
   10. Dehydration
2. Fill out Job Safety Analysis (JSA) worksheet based upon hazard assessment
3. Demonstrate the ability to safely rig, lift, and unload haul bags with borescope inspection equipment
   1. Use of hand signals for lifting
   2. Use of haul bags
   3. Use of lanyards
   4. Personnel positioning out of drop zone during lifting
   5. Knowledge of lift capacities and load snag points
4. Set up equipment and supplies in a secure location to prevent tripping and/or dropping
5. Demonstrate knowledge and ability for lock out and tag out (LOTO) of rotating and/or energized equipment

## Borescope Inspection Safety

### Does the trainee demonstrate knowledge and skills to safely perform borescope inspection? Note: turbine-specific control may be performed by a qualified wind turbine technician, but MUST BE commanded by the trainee

#### Trainee MUST

1. Disable rotor energy before accessing equipment
   1. Feather blades
   2. Engage High-speed (HS) hydraulic brake
2. Perform controlled rotation of the rotor to predetermined azimuth for access to specific inspection items such as bearings, rollers, windings, etc.
   1. Clear equipment from inspection ports
   2. Clear personnel from rotating equipment
   3. Rotor lock removal (if engaged)
   4. Hydraulic brake release
   5. Controlled free roll with blades near feather and proper yaw orientation into the wind or slow roll with turning the gear
   6. Hydraulic brake activation
   7. Engage HS or Low-speed (LS) rotor shaft lock per site or WT OEM protocol
3. Yaw nacelle out of wind per site or WT OEM protocol
4. Allow equipment to cool sufficiently to
   1. Protect from skin burns from heat
   2. Protect inspection equipment
   3. Reduce oil mist to improve borescope image quality
5. Shut off oil pumps
6. Identify slip, trip, and entanglement hazards, and avoid, eliminate, or protect against
7. Demonstrate the use of tool lanyards, magnetic trays, clamps
8. Identify all inspection ports and remove covers

#### Trainee MUST NOT

1. Pass unsecured tools or supplies over an open inspection port
2. Damage inspection cover gaskets
3. Allow debris from or near inspection covers to drop into equipment

## Borescope Inspection Fundamentals

### Does the trainee demonstrate knowledge of HS and LS brake limitations?

#### Trainee MUST

1. Understand the limitations of HS brakes
   1. Backlash accumulates from highest to lowest stage of the gearbox, i.e., from HS shaft to planetary section.
   2. Awareness of unexpected brake release in certain WT models.
   3. Awareness of non-functional E-stop in certain WT models.
   4. Abnormal conditions: Brake pressure source may be defective i.e. low accumulator precharge, brake pad wear may be excessive, lock-out mechanism may be damaged.
2. Understand the limitations of LS brakes
   1. Low maximum wind speed limit.
   2. Difficult to line up pin and hole.
   3. Planet bearing access may not be optimal or possible due to the limited number of stop positions.

### Does the trainee exhibit awareness of ergonomics?

#### Trainee MUST

1. Demonstrate the ability to position body and equipment during inspection to reduce back and neck strain and arm fatigue

### Does the trainee demonstrate knowledge of electrical hazards for generator inspection?

#### Trainee MUST

1. Identify exposed conductors.
2. Identify shock risk and perform pre-inspection voltage checks
3. Verify generator grounding

### Does the trainee demonstrate knowledge of borescope terminology?

#### While there is no industry standard terminology, trainee MUST

1. Identify and explain the function of
   1. Insertion tube
      1. Nominal diameter and advantages/disadvantages of each
      2. Length and advantages/disadvantages of various lengths
      3. Distal end (tip end)
   2. Optical tip adapter (lens or tip)
   3. Articulating section
   4. Articulation lock
   5. Joystick
   6. LCD screen
   7. Monitor
   8. Control handle
2. Demonstrate the understanding of lens and image processor parameters
   1. Focal length or depth of field
   2. Field of view
   3. Barrel distortion
   4. Exposure
      1. Overexposure – loss of information due to excess brightness.
      2. Underexposure – loss of information due to inadequate light levels.
   5. Gain

### Demonstrate the ability to change tips

#### Trainee MUST

1. Clean hands
2. Prepare the area to prevent dropping/losing lens
3. Clean the installed tip first, check image clarity with known target, then remove tip
4. Check o-ring on insertion tube distal end by threads for security and damage
5. Check image clarity of distal end without tip adapter installed to verify clarity of image
6. Thread replacement tip without cross threading or touching distal end lens
7. Clean lens using borescope OEM approved solution with cotton swabs and/or wipes
8. Make sure cleaning solution has evaporated from the lens
9. Check image clarity with known target

### Does the trainee demonstrate knowledge of risks and loss prevention during borescope inspection?

#### Trainee MUST

1. Identify risks to insertion tube and optical tips
   1. Crushing
   2. Sticking
   3. Over-articulation and/or failure to constantly release articulation lock
   4. Over temperature
   5. Immersion
2. Identify most common risk exposures and methods to prevent loss
   1. Crushing
      1. Full complement planet bearings-eliminate gear train backlash or do not insert tip beyond initial row of rollers
   2. Sticking
      1. Full complement planet bearing inner rows and furthest rows back from insertion point-do not insert tip beyond initial row of rollers
      2. Tight clearances between parallel section bearings and housings-do not push insertion tube into rollers if initial insertion begins at high articulation angle
   3. Over-articulation/articulation lock
      1. Habitual articulation past 90 degrees
      2. Habitual failure to release articulation lock while removing insertion tube at high articulation angles
   4. Over temperature
      1. Exceeding borescope OEM temperature limits may damage lens adhesives in tip adapter and damage the lens. The trainee should demonstrate the use of internal temperature sensor or external thermal measurement device such as IR thermometer to monitor tip temperatures.
   5. Immersion
      1. Extreme reduction of image quality
      2. Extended immersion may allow lubricant to seep into distal end under tip adapter requiring additional cleaning after tip removal

### Does the trainee exhibit proper use of guide tubes?

#### Trainee MUST

1. Demonstrate the use of guide tube to stabilize and protect the insertion tube.
   1. Methods to prevent dropping guide tube into equipment internals
   2. Appropriate length for inspection
   3. Fixtures may be preferred to stabilize and secure the guide tube in order to improve image quality by reducing blur from hand shaking or insertions with extended distances from inspection port
   4. Cleanliness of guide tube, internally to protect optical tip, and externally to prevent contamination of inspected equipment

### Does the trainee demonstrate the ability to capture images that accurately document equipment condition?

#### Trainee MUST

1. Demonstrate the ability to select tip appropriate to the inspection item
2. Demonstrate the ability to control distal end of the borescope to target
3. Demonstrate the knowledge of objects seen on the LCD monitor
4. Demonstrate the ability to capture high quality still images of the target from several angles and distances
   1. Image freeze
   2. Image light level
   3. Image gain
   4. Image white balance
   5. Use of pre-programmed annotations (if equipped)
   6. Video capture (if equipped)
   7. Voice annotation (if equipped)
   8. Stereo measurement (if equipped)
5. Demonstrate the use of borescope functions to label and store images
   1. Screen annotation
   2. Image storage folder location
   3. Image freeze
6. Demonstrate the ability to download images to a backup storage

## Gearbox Fundamentals

### Does the trainee exhibit knowledge of gearbox operation and kinematics?

#### Trainee MUST

1. Demonstrate knowledge of basic gearbox function
   1. Purpose of gearbox
   2. Torque in relation to gearbox stage
   3. Mounting configuration and effect on loading
      1. Three point – gearbox LS section reacts rotor non-torque loads
      2. Four point – two-bearing main shaft reacts non-torque loads
      3. Integrated – gearbox reacts torque and non-torque loads with integrated, oil lubricated main bearing
   4. Gearbox load paths
      1. External
      2. Internal
   5. Lubrication
      1. Wet sump
      2. Dry sump
      3. Forced lubrication
      4. Splash lubrication
      5. Oil filtration, on-line and off-line
   6. Planetary v. parallel gear arrangements and reasons for each
2. Demonstrate knowledge of gear tooth nomenclature per AGMA 6006
   1. Flank
   2. Addendum
   3. Dedendum
   4. Pitch line
   5. Root
   6. Top land
   7. Tip relief
   8. Loaded face or Drive v. Coast face
   9. Sliding v. Rolling
3. Demonstrate knowledge of bearing nomenclature and purpose of each
   1. Main parts: Inner ring, outer ring, rollers (AKA rolling elements), cage.
   2. Main features: Raceways, ribs, bore and OD (Outside Diameter).
   3. Minor features: Radius, undercut, chamfer, end faces.
   4. Cylindrical roller bearings (CRBs)
   5. Taper(ed) roller bearings (TRBs)
   6. Ball bearings (BBs)
   7. Spherical roller bearings (SRBs)
4. Demonstrate knowledge of basic gear arrangements
   1. Parallel shaft arrangements
      1. Gear shaft assemblies – journals, keys, spacers, shoulders, axial retention
   2. Solid and hollow shafts
   3. Planetary arrangements
      1. Carrier and carrier bearings
      2. Planet pins (fixed to carrier)
      3. Annulus AKA ring gear
      4. Planet gears and bearings
      5. Sun pinion
5. Demonstrate knowledge of bearing load zones
   1. Parallel bearing load zones
   2. Planetary and carrier bearing load zones
6. Demonstrate knowledge of gear and bearing location nomenclature
   1. Gear shaft nomenclature
      1. High speed (HS)
      2. High speed intermediate (HIS)
      3. Low speed intermediate (LSI)
      4. Low speed (LS)
   2. Bearing nomenclature
      1. Rotor side (RS)
      2. Generator side (GS)
      3. RR, RS, GR, GG (Full complement bearings only)