Level 3 Certificate in Engineering

Optional Units

2800

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Unit 015 Manual metal arc welding

Rationale
This unit is concerned with the technology and practices involved in the application of manual metal arc welding. The unit is demanding in terms of technological content and the complexity of the welding that candidates are expected achieve. The unit is broadly divided into health and safety, welding equipment, welding consumables (ie electrodes) and the practicalities of producing a welded joint in relation to a welding procedure specification (WPS) and a quality specification.

Outcomes
There are four outcomes to this unit. The candidate will be able to
1 identify the health and safety aspects of manual metal arc welding
2 prepare the equipment for manual metal arc welding
3 identify the characteristics of welding consumables for manual metal arc welding
4 produce welded joints that conform to welding procedure specification (WPS).

Connection with other awards
It relates to City & Guilds Level 3 NVQ in Fabrication & welding (1681)
Units: 004, 008, 009, 031, 046

It also relates to the OSC*Eng* ECS 3.09.

Assessment
The outcomes from this unit will be assessed using evidence from an assignment which will cover both practical activities and underpinning knowledge.

Outcome 1 Identify the health and safety aspects of manual metal arc welding

Practical Activities

The candidate will be able to
1. investigate hazards and risks in a welding environment
2. refer to the health and safety regulations that apply to welding
3. recommend safety precautions, procedures and PPE to overcome welding hazards
4. observe safe working practices

Underpinning knowledge

The candidate will be able to
1 identify the implications of health and safety legislation in relation to welding process
- a Health & Safety At Work Act (1974) (HSaW)
- b Control Of Substances Hazardous To Health (1988) (COSHH)
  - i risk assessment
  - ii consumable data sheets
  - iii training and awareness
  - iv safe working procedures
  - v hierarchy of control
- c Provision And Use Of Work Equipment (1998) (PUWER)
  - i scope within the welding environment
- d Reporting Of Injuries, Diseases And Dangerous Occurrences Regulations (1995) (RIDDOR)
  - i application to welding process
    - A major injuries
    - B over three day injuries
    - C diseases
    - D dangerous occurrences
- e Management Of Health And Safety At Work Regulations (1999) (MHSWR)
  - i risk assessment
  - ii five steps to risk assessment
  - iii training and awareness
  - iv safe working procedures

- f Personal Protective Equipment At Work Regulations (1992) (PPE)
  - i application to welding process
  - ii employers' duties
  - iii employees' duties
  - iv protection against hazards
  - v fumes
  - vi airborne particles
  - vii arc radiation
  - viii hot metal
  - ix sparks
  - x falling objects
  - xi factors render PPE provided as protection against the above ineffective or unsafe
- g Noise at Work Regulations (1989)
  - i noise levels – action to be taken at
    - A first level 85dB(A)
    - B second level 90 dB(A)
    - C third level 140 dB(A)

2 describe the effects of welding fume

- a types of fume
  - i visible (particulate)
  - ii composition of fume
    - A occupational exposure standard (OES)
    - B time weighted average (TWA)
    - C short term exposure limit (STEL)
    - D maximum exposure limit (MEL)
  - iii invisible (gaseous)
    - A composition of fume
- b hazards to health from fume
- c control measures to reduce exposure
  - i extraction
    - A background
    - B local
  - ii natural ventilation (eg on-site)
  - iii air-fed headshields
  - iv respirator
  - v breathing apparatus
  - vi monitoring the effectiveness of control measures

3 identify the fire hazards associated with the process
- a sources of combustion
- b identification of hazards
- c methods of reducing risks
- d identification of suitable extinguishers

4 identify the hazards from electricity
- a shock
- b fire
- c burns
- d methods of avoiding shock hazards
- e emergency procedures in the event of an electric shock
- f use of fuses
- g use of earthing
  - i workpiece (welding)
  - ii plant

5 explain the hazards from arc radiation
- a visible light
- b infra-red
- c ultra-violet
- d effects of a-c.
  - i stain burns
  - ii arc eye
- e methods of protection from effects in d.
  - i PPE
  - ii screening
  - iii warnings
    - A verbal
    - B notices

6 identify the hazards from hot metal/slag

7 identify means of avoiding hazards

8 describe safe start-up and shutdown procedures

Outcome 2 Prepare the equipment for manual metal arc welding

Practical Activities

The candidate will be able to
1 select the welding equipment for a given application
2 prepare the welding equipment for a given application

Underpinning knowledge

The candidate will be able to
1 describe the supply of power for arc welding
    a from distribution grid
    b single phase
    c three phase
    d power factors

2 describe types of a welding power source
    a output
        i alternating current (ac)
        ii direct current (dc)
    b transformer
        i function
        ii winding ratio
        iii input/output ratio
        iv construction
    c transformer/rectifier
        i function of a rectifier
        ii operation of a rectifier
        iii construction of a rectifier
            A diode
            B thyristor
        iv function of smoothing capacitors
    d inverter
        i function
        ii operation
        iii construction
    e generator
        i fuel driven
            A function
            B operation
            C construction
            D motor driven
            E function
            F operation
            G construction
        ii rated output (duty cycle)

f measurement of electrical output and continuity
  i voltage – use of voltmeter/multi-meter
  ii current – use of ammeter/shunts/coils
  iii continuity – use of continuity tester/ohmmeter

3 describe methods of current regulation
- a tapped reactor
- b moving core
- c moving coil
- d moving shunt
- e saturable reactor
- f variable resistance

4 describe the power source characteristics
- a volt/ampere graph
- b drooping characteristic
- c constant current output

5 describe leads used
- a welding
- b return
- c earth
- d construction
- e rated output (duty cycle)

6 describe electrode holders used
- a types
- b fully insulated
- c partially insulated

7 describe return clamps used
- a types
- b clamping mechanisms

8 describe cleaning equipment used
- a grinders
- b chipping hammer
- c wire brushes
- d hammer and chisel

Outcome 3 Identify the characteristics of welding consumables for manual metal arc welding

Practical Activities

The candidate will be able to
1 select the welding consumables for a given application
2 identify welding consumables by their classification

Underpinning knowledge

The candidate will be able to
1 describe electrode coverings to BS EN 499 (1994)– classification of covered electrodes for the manual metal arc welding of non-alloy and fine grain steels
  a compulsory sections – 1 to 5
  b optional sections – 6 to 8
  c designations
    i product/process used
    ii strength and elongation of the weld metal
    iii impact properties of the weld metal
    iv chemical composition of the weld metal
    v type of the electrode covering
    vi recovery rate and current type
    v welding position
    vi hydrogen content of the deposit

2 describe electrodes by their covering type
  a cellulosic
  b rutile
  c basic
  d acid
  e iron powder
  f composition of a-e
  g applications of a-e
  h storage conditions of a-e
  i baking requirements for basic electrodes
  j levels of hydrogen content of a-c
  k determination of electrode efficiency of e
  l function of coverings
    i facilitates arc striking
    ii stabilises and directs the arc
    iii assists control of the size and frequency of filler metal globules/droplets
    iv protects filler metal from atmospheric contamination during transfer
    v protects deposited metal from contamination
    vi provides appropriate weld contour
    vii prevents rapid cooling of weld metal (thermal blanket effect)
    viii provides a flux for the molten pool to remove oxides and impurities
    ix supplies additional metal to weld pool (including alloying elements)

3 describe electrodes by their core wire composition

- a carbon steel
- b low alloy steel
- c stainless steel
- d non-ferrous metals
- e cast iron

4. describe electrode coverings to American classification AWS A5.1-91 (specification for carbon steel electrodes for shielded metal arc welding) and AWS A5.5-96 (specification for low alloy steel electrodes for shielded metal arc welding)

- a minimum tensile strength
- b minimum yield strength
- c minimum percentage elongation
- d position
- e usability
- f suffix

Outcome 4 Produce welded joints that conform to welding procedure specification (WPS)

Practical Activities

The candidate will be able to
1 produce a welding procedure specification for joints to be welded in a given application
2 produce welded joints in carbon steel, low alloy steel or stainless steel to a given welding procedure specification and quality specification in lap, tee, corner and butt joints in the flat, horizontal/vertical, vertical and overhead positions

Underpinning knowledge

The candidate will be able to
1 define the welding process on a WPS

2 identify the parent metal on a WPS

3 specify consumables on a WPS

4 describe pre welding activities
   a cleaning
   b edge preparation
   c assembly
   d pre-heat

5 define welding parameters on a WPS for a given application

6 identify welding positions on a welding procedure specification (BS EN 287 part 1: 1992 – approval testing of welders for fusion welding – steels) (BS EN ISO 9606-1. approval testing of welders. fusion welding. part 1. steel)

7 specify the number and arrangement of runs to fully fill/weld a joint

8 specify electrode sizes for joint thicknesses

9 describe the techniques used when welding with electrodes
   a cellulosic (including stovepipe)
   b rutile
   c basic
   d iron powder

10 specify the electrical conditions required
- a type of current
  - i alternating (ac)
  - ii direct (dc)
- b electrode polarity
  - i positive
  - ii negative
- c welding current ranges
  - i voltage
    - A open circuit
    - B arc

11 outline control of heat input

12 outline interpass/run cleaning/back gouging methods

13 explain the implications of quality specifications used to determine the integrity of welded joints (BS EN 25817: 1992 – arc welded joints in steel -guidance on quality levels for imperfections)

14 describe post welding activities
- a cleaning
  - i slag removal
  - ii spatter removal
  - iii wiring brushing
  - iv removal of excess weld metal where required
- b visual checks carried out by welding personnel
  - i qualitative
    - A defect levels
    - B appearance
  - ii quantitative
    - A extent
    - B size
    - C dimensional accuracy
- c post-weld heat treatment
  - i normalising
  - ii stress relief

Unit 016 Metal inert/active gas (MIG/MAG) welding

Rationale
This unit is concerned with the technology and practices involved in the application of metal inert gas (MIG) welding. The unit is demanding in terms of technological content and the complexity of the welding that candidates are expected achieve. The unit is broadly divided into health and safety, welding equipment, welding consumables (ie electrodes wires, shielding gases) and the practicalities of producing a welded joint in relation to a welding procedure specification (WPS) and a quality specification.

Outcomes
There are four outcomes to this unit. The candidate will be able to
1 identify the health and safety aspects of metal inert gas (MIG) welding
2 prepare the equipment for metal inert gas (MIG) welding
3 identify the characteristics of welding consumables for metal inert gas (MIG) welding
4 produce welded joints that conform to welding procedure specification (WPS).

Connection with other awards
It relates to City & Guilds 1681 in Fabrication and Welding Engineering. Units 005, 008, 009, 010, 031 and 046.
It also relates to the *OSCEng ECS* 3.09.

Assessment
The outcomes from this unit will be assessed using evidence from an assignment which will cover both practical activities and underpinning knowledge.

Outcome 1 Identify the health and safety aspects of metal inert gas (MIG) welding

Practical Activities

The candidate will be able to
1 investigate hazards and risks in a welding environment
2 refer to the health and safety regulations that apply to welding
3 recommend safety precautions, procedures and PPE to overcome welding hazards
4 observe safe working practices

Underpinning knowledge

The candidate will be able to
1 identify the implications of health and safety legislation in relation to welding process
  - a Health & safety at work act (1974) (HSaW)
  - b Control Of Substances Hazardous To Health (1988) (COSHH)
    - i risk assessment
    - ii consumable data sheets
    - iii training and awareness
    - iv safe working procedures
    - v hierarchy of control
  - c Provision And Use Of Work Equipment (1998) (PUWER)
    - i scope within the welding environment
  - d Reporting Of Injuries, Diseases And Dangerous Occurrences Regulations (1995) (RIDDOR)
    - i application to welding process
      - A major injuries
      - B over three day injuries
      - C diseases
      - D dangerous occurrences
  - e Management Of Health And Safety At Work Regulations (1999) (MHSWR)
    - i risk assessment
    - ii five steps to risk assessment
    - iii training and awareness
    - iv safe working procedures
  - f Personal Protective Equipment At Work Regulations (1992) (PPE)
    - i application to welding process
    - ii employers' duties
    - iii employees' duties
    - iv protection against hazards
      - A fumes
      - B gases
      - C noise
      - D airborne particles
      - E arc radiation
      - F hot metal
      - G sparks
      - H falling objects
      - I factors render PPE provided as protection against the above ineffective or unsafe

g Noise at Work Regulations (1989)
- i noise levels – action to be taken at
  - A first level 85dB(A)
  - B second level 90 dB(A)
  - C third level 140 dB(A)

2 describe the effects of welding fume
- a types of fume
  - i visible (particulate)
  - ii composition of fume
    - A occupational exposure standard (OES)
    - B time weighted average (TWA)
    - C short term exposure limit (STEL)
    - D maximum exposure limit (MEL)
  - iii invisible (gaseous)
    - A composition of fume
- b hazards to health from fume
- c control measures to reduce exposure
  - i extraction
    - A background
    - B local
  - ii natural ventilation (eg on-site)
  - iii air-fed headshields
  - iv respirator
  - v breathing apparatus
  - vi monitoring the effectiveness of control measures

3 identify the fire hazards associated with the process
- a sources of combustion
- b identification of hazards
- c methods of reducing risks
- d identification of suitable extinguishers

4 explain the hazards from arc radiation
- a visible light
- b infra-red
- c ultra-violet
- d effects of a-c
  - i skin burns
  - ii arc eye
- e methods of protection from effects in d
  - i PPE
  - ii screening
  - III warnings
    - A verbal
    - B notices

5 identify the hazards from hot metal
   a means of avoiding hazards from hot metal

6 identify hazards from gas cylinders
   a safe storage conditions
   b safe handling/moving
   c safe use

7 describe safe start-up and shutdown procedures

Outcome 2 Prepare the equipment for metal inert gas (MIG) welding

Practical Activities

The candidate will be able to

1 select the welding equipment for a given application
2 prepare the welding equipment for a given application

Underpinning knowledge

The candidate will be able to

1 describe the supply of power for arc welding
  a from distribution grid
  b single phase
  c three phase
  d power factors

2 describe types of a welding power source
  a output
    i alternating current (ac)
    ii direct current (dc)
  b transformer
    i function
    ii winding ratio
    iii input/output ratio
    iv construction
  c transformer/rectifier
    i function of a rectifier
    ii operation of a rectifier
    iii construction of a rectifier
      A diode
      B thyristor
    iv function of smoothing capacitors
  d inverter
    i function
    ii operation
    iii construction
  e generator
    i fuel driven
      A function
      B operation
      C construction
    ii motor driven
      A function
      B operation
      C construction
  f rated output (duty cycle)

g measurement of electrical output and continuity
    i voltage – use of voltmeter/multi-meter
    ii current – use of ammeter/shunts/coils
    iii continuity – use of continuity tester/ohmmeter

3 describe methods of current regulation
  a saturable reactor
  b variable resistance

4 describe the power source characteristics
  a volt/ampere graph
  b flat characteristic
  c constant voltage output

5 explain the function of induction
  a principle
  b effect
  c fixed
  d stepped
  e variable control

6 describe guns used for welding
  a water cooled
  b air cooled
  c contactor
  d construction
  e push type
  f pull type
  g reel-on-gun type
  h swan neck design
  i pistol design
  i flux cored self-shielded variation
  j connections
  k nozzles
    i dip
    ii spray
  l contact tip
    i functions
    ii material
    iii sizes
    iv clearing a burn-back

7 describe leads used
- a welding
  - i water cooled
  - ii air cooled
  - iii harness
- b return
- c earth
- d construction
- e rated output (duty cycle)

8 describe return clamps used
- a types
- b clamping mechanisms

9 describe the gas supply and distribution
- a cylinders
- b manifold system
- c regulators
  - i fixed
  - ii single-stage
  - iii two-stage

10 describe gas flow meters
- a gas tubes and connectors
- b use of solenoid valves
- c heaters for CO_2

11 describe the wire feed unit
- a direct control of wire feed rate
  - i variable speed motor
- b indirect control of welding current
- c contactor leads
  - i solenoid valves
    - A control of gas flow rate
    - B control of water cooling
  - ii relay for electrical power
- d jog-feed control
- e gas purge control
- f burn-back control

12 identify cleaning equipment used
- a grinders
- b linishers
- c wire brushes
- d oxide removal
- e degreasing

Outcome 3 Identify the characteristics of welding consumables for metal inert gas (MIG) welding

Practical Activities

The candidate will be able to
1 identify MIG welding consumables
2 select welding consumables for a given application
3 prepare consumables for welding

Underpinning knowledge

The candidate will be able to
1 describe electrode wires used for MIG welding
    a BS EN 440:1995 – Welding consumables. Wire electrodes and deposits for gas shielded metal arc welding of non alloy and fine grain steels. Classification
    b BS EN 12072:2000 – Welding consumables. Wire electrodes, wires and rods for arc welding of stainless and heat-resisting steels. Classification
    c BS EN 758:1997 – Welding consumables. Tubular cored electrodes for metal arc welding with and without a gas shield of non-alloy and fine grain steels. Classification
        i sizes
            A diameters
            B reel sizes available
        ii strength and elongation of the weld metal
        iii impact properties of the weld metal
        iv chemical composition of the weld metal
        v deoxidisers
        vi function of copper coating
        vii protection of bare wires
        viii construction of cored wire electrodes
            A flux cored
            B iron cored
            C flux types
                1 rutile
                2 basic
                3 basic/fluoride
                4 fast-freezing slag
                5 slow freezing slag
                6 welding position(s)
                7 hydrogen content of deposited weld metal
            D type of seam
    d non-ferrous metals
        i types
        ii availability
        iii typical sizes

e storage
   i handling
   ii identification
   iii segregation
      A classification
      B size
f preparation for welding
g application

2 explain the purpose of gas shielding for MIG welding
   a implications of BS EN 439:1994 – Welding consumables. Shielding gases for arc welding and cutting
   b effects of shielding gases/ gas mixtures upon
      i weld pool/arc area protection
      ii heat input
      iii weld geometry
      iv penetration profile
      v travel speed
      vi mode of metal transfer
   c applications for shielding gases/gas mixtures
      i argon
      ii helium
      iii argon/helium mixtures
      iv carbon dioxide
      v argon/carbon dioxide mixtures
      vi argon/oxygen/carbon dioxide mixtures
      vii argon/oxygen mixtures
      viii helium/argon/oxygen/carbon dioxide mixtures
   d gas pressure requirements
   e flow rates for applications

Outcome 4 Produce welded joints that conform to welding procedure specification (WPS)

Practical Activities

The candidate will be able to
1 produce a welding procedure specification for joints to be welded in a given application
2 produce welded joints in carbon steel, aluminium or stainless steel to a given welding procedure specification and quality specification in lap, tee, corner and butt joints in the flat, horizontal/vertical, vertical and overhead positions.

Underpinning knowledge

The candidate will be able to
1 define the welding process on a WPS

2 identify the parent metal on a WPS

3 specify consumables on a WPS

4 describe pre welding activities
   a cleaning
   b edge preparation
   c assembly
   d pre-heat

5 define welding parameters on a WPS for a given application

6 identify welding positions on a welding procedure specification (BS EN 287 part1: 1992 – approval testing of welders for fusion welding – steels) (BS EN ISO 9606-1. approval testing of welders. fusion welding. part 1. steel)

7 specify the number and arrangement of runs to fully fill/weld a joint

8 specify electrode wire sizes for joint thicknesses

9 describe the techniques used when MIG welding

10 describe modes of metal transfer
- a dip (short-circuiting)
- b globular
- c spray
- d pulse
- e synergic pulse
- f factors that influence mode
  - i voltage/current ranges (a-c)
  - ii shielding gas
  - iii power source (d-e)

11 specify the electrical conditions required
- a type of current
  - i direct (dc)
- b electrode polarity (electrode positive)
- c voltage
  - i open circuit
  - ii arc
- d wire feed speed ranges
- e inductance

12 outline control of heat input

13 outline interpass/run cleaning/back gouging methods

14 explain the implications of quality specifications used to determine the integrity of welded joints (BS EN 25817: 1992 – arc welded joints in steel -guidance on quality levels for imperfections)

15 describe post welding activities
- a cleaning
  - i wiring brushing
  - ii removal of excess weld metal where required
  - iii slag removal
  - iv spatter removal
- b visual checks carried out by welding personnel
  - i qualitative
    - A defect levels
    - B appearance
  - ii quantitative
    - A extent
    - B size
    - C dimensional accuracy
- c post-weld heat treatment
  - i normalising
  - ii stress relief

Unit 017 Tungsten inert gas (TIG) welding

Rationale
This unit is concerned with the technology and practices involved in the application of tungsten inert gas (TIG) welding. The unit is demanding in terms of technological content and the complexity of the welding that candidates are expected achieve. The unit is broadly divided into health and safety, welding equipment, welding consumables (ie electrodes, filler wires, shielding gases) and the practicalities of producing a welded joint in relation to a welding procedure specification (WPS) and a quality specification.

Outcomes
There are four outcomes to this unit. The candidate will be able to
1. identify the health and safety aspects of tungsten inert gas (TIG) welding
2. prepare the equipment for tungsten inert gas (TIG) welding
3. identify the characteristics of welding consumables for tungsten inert gas (TIG) welding
4. produce welded joints that conform to welding procedure specification (WPS).

Connection with other awards
It relates to the NVQ 1681 Fabrication and Welding Engineering. Units 006, 008, 009, 016, 031 and 046.
It also relates to the *OSCEng ECS* 3.09.

Assessment
The outcomes from this unit will be assessed using evidence from an assignment which will cover both practical activities and underpinning knowledge.

Outcome 1 Identify the health and safety aspects of tungsten inert gas (TIG) welding

Practical Activities

The candidate will be able to
1 investigate hazards and risks in a welding environment
2 refer to the health and safety regulations that apply to welding
3 recommend safety precautions, procedures and PPE to overcome welding hazards
4 observe safe working practices

Underpinning knowledge

The candidate will be able to
1 identify the implications of health and safety legislation in relation to welding process
- a Health & Safety At Work Act (1974 (HSaW)
- b Control Of Substances Hazardous To Health (1988 (COSHH)
  - i risk assessment
  - ii consumable data sheets
  - iii training and awareness
  - iv safe working procedures
  - v hierarchy of control
- c Provision And Use Of Work Equipment (1998) [PUWER]
  - i scope within the welding environment
- d Reporting Of Injuries, Diseases And Dangerous Occurrences Regulations (1995) [RIDDOR]
  - i application to welding process
    - A major injuries
    - B over three day injuries
    - C diseases
    - D dangerous occurrences
- e Management Of Health And Safety At Work Regulations (1999) [MHSWR]
  - i risk assessment
  - ii five steps to risk assessment
  - iii training and awareness
  - iv safe working procedures
- f personal protective equipment at work regulations (1992) [PPE]
  - i application to welding process
  - ii employers' duties
  - iii employees' duties

- iv protection against hazards
  - A fumes
  - B gases
  - C airborne particles
  - D arc radiation
  - E hot metal
  - F sparks
  - G falling objects
- v factors render PPE provided as protection against the above ineffective or unsafe

g Noise at Work Regulations (1989)
- i noise levels – action to be taken at
  - A first level 85dB(A)
  - B second level 90 dB(A)
  - C third level 140 dB(A)

2. describe the effects of welding fume
   - a types of fume
     - i visible (particulate)
       - A composition of fume
       - B occupational exposure standard (OES)
         - 1 time weighted average (TWA)
         - 2 short term exposure limit (STEL)
       - C maximum exposure limit (MEL)
     - ii invisible (gaseous)
       - A composition of fume
   - b hazards to health from fume
     - i extraction
       - A background
       - B local
     - ii natural ventilation (eg on-site)
     - iii air-fed headshields
     - iv respirator
     - v breathing apparatus
     - vi monitoring the effectiveness of control measures

3. identify the fire hazards associated with the process
   - a sources of combustion
   - b identification of hazards
   - c methods of reducing risks
   - d identification of suitable extinguishers

4. explain the hazards from arc radiation
   a visible light
   b infra-red
   c ultra-violet
   d effects of a.-c.
   e methods of protection from effects in d.
      i PPE
      ii screening
      iii warnings
         A verbal
         B notices

5. identify the hazards from hot metal

6. identify the means of avoiding hazards from hot metal

7. identify hazards from gas cylinders
   a safe storage conditions
   b safe handling/moving
   c safe use

8. describe safe start-up and shutdown procedures

Outcome 2 Prepare the equipment for tungsten inert gas (TIG) welding

Practical Activities

The candidate will be able to
1. select the welding equipment for a given application
2. prepare the welding equipment for a given application

Underpinning knowledge

The candidate will be able to
1. describe the supply of power for arc welding
   a from distribution grid
   b single phase
   c three phase
   d power factors

2. describe types of a welding power source
   a output
      i alternating current (ac)
      ii direct current (dc)
   b transformer
      i function
      ii winding ratio
      iii input/output ratio
      iv construction
   c transformer/rectifier
      i function of a rectifier
      ii operation of a rectifier
      iii construction a rectifier
         A diode
         B thyristor
      iv function of smoothing capacitors
   d inverter
      i function
      ii operation
      iii construction
   e generator
      i fuel driven
         A function
         B operation
         C construction
      ii motor driven
         A function
         B operation
      C construction
   f rated output (duty cycle)
   g measurement of electrical output and continuity
      i voltage – use of voltmeter/multi-meter
      ii current – use of ammeter/shunts/coils
      iii continuity – use of continuity tester/ohmmeter

3. describe methods of current regulation
   a tapped reactor
   b moving core
   c moving coil
   d moving shunt
   e saturable reactor
   f variable resistance

4. describe the power source characteristics
   a volt/ampere graph
   b drooping characteristic
   c constant current output

5. describe methods of arc ignition
   a scratch
   b high frequency
   c lift start
      i contactor
      ii foot pedal/current control

6. describe torches used for welding
   a water cooled
   b air cooled
   c pencil
   d construction
   e connections
   f contactor/switch
   g back caps
   h nozzles
   i collet
   j collet holder
   k gas lens
      i construction
      ii effects
      iii benefits
      iv limitations
      v applications

7. describe leads used
   a welding
      i water cooled
      ii air cooled
      iii harness
   b return
   c earth
   d construction
   e rated output (duty cycle)

8. describe return clamps used
    a types
    b clamping mechanisms

9. describe the gas supply and distribution
    a cylinders
    b manifold system
    c regulators
        i fixed
        ii single-stage
        iii two-stage
    d gas flow meters
    e gas tubes and connectors
    f use of solenoid valves

10. identify cleaning equipment used
    a grinders
    b linishers
    c wire brushes
    d oxide removal
    e degreasing

Outcome 3 Identify the characteristics of welding consumables for tungsten inert gas (TIG) welding

Practical Activities

The candidate will be able to
1. identify TIG welding consumables
2. select welding consumables for a given application
3. prepare consumables for welding

Underpinning knowledge

The candidate will be able to
1. describe electrodes used for TIG welding to BS EN 26848:1991 – Specification for tungsten electrodes for inert gas shielded arc welding and for plasma cutting and welding
    - a thoriated
    - b ceriated
    - c zirconiated
    - d compositions
    - e sizes
    - f identification
    - g applications

2. describe electrode preparation for welding
    - a cleaning
    - b grinding
        - i techniques
        - ii equipment
        - iii health and safety implications of grinding
            - A dust
            - B particulates
            - C extraction
            - D radioactivity (thoriated)

3. describe filler wires used for TIG welding
    - a BS EN 1668:1997 – Welding consumables. rods, wires and deposits for tungsten inert gas welding of non alloy and fine grain steels. Classification
    - b BS EN 12072:2000 – Welding consumables. Wire electrodes, wires and rods for arc welding of stainless and heat-resisting steels. Classification
        - i sizes
            - A diameters
            - B length
        - ii strength and elongation of the weld metal
        - iii impact properties of the weld metal
        - iv chemical composition of the weld metal
        - v deoxidisers
        - vi function of copper coating
    - c non-ferrous metals
        - i types
        - ii availability
        - iii typical sizes

- d storage
  - i handling
  - ii identification
  - iii segregation
    - A classification
    - B size
- e cleaning for welding
- f preparation for welding
- g application

4. explain the purpose of gas shielding for TIG welding
   - a implications of BS EN 439:1994 – Welding consumables. Shielding gases for arc welding and cutting
   - b effects of shielding gases/gas mixtures upon
     - i weld pool/arc area protection
     - ii heat input
     - iii weld geometry
     - iv penetration profile
     - v travel speed
   - c applications for shielding gases/gas mixtures
     - i argon
     - ii helium
     - iii argon/helium mixtures
     - iv helium/argon mixtures
     - v argon/hydrogen mixtures
     - vi nitrogen
     - vii argon/nitrogen mixtures
   - d gas pressure requirements
   - e flow rates for applications

Outcome 4 Produce welded joints that conform to welding procedure specification (WPS)

Practical Activities

The candidate will be able to
1. produce a welding procedure specification for joints to be welded in a given application
2. produce welded joints in carbon steel, aluminium or stainless steel to a given welding procedure specification and quality specification in lap, tee, corner and butt joints in the flat, horizontal/vertical, vertical and overhead positions

Underpinning knowledge

The candidate will be able to
1. define the welding process on a WPS

2. identify the parent metal on a WPS

3. specify consumables on a WPS

4. describe pre welding activities
   a cleaning
   b edge preparation
   c assembly
   d pre-heat

5. define welding parameters on a WPS for a given application

6. identify welding positions on a welding procedure specification (BS EN 287 part 1: 1992 – approval testing of welders for fusion welding – steels) (BS EN ISO 9606-1. approval testing of welders. fusion welding. part 1. steel)

7. specify the number and arrangement of runs to fully fill/weld a joint

8. specify electrode sizes for joint thicknesses

9. specify filler wire sizes for joint thicknesses

10. describe the techniques used when TIG welding (including autogenous)

11. specify the electrical conditions required
    a type of current (ac/dc)
        i effects upon heat input/distribution
        ii effects upon electrode
        iii effects upon weld bead profile
        iv effects upon penetration
    b electrode polarity
        i effects upon heat input/distribution
        ii effects upon electrode
        iii effects upon weld bead profile
        iv effects upon penetration
    c welding current ranges
    d voltage
        i open circuit
        ii arc
12. outline control of heat input

13. outline interpass/run cleaning/back gouging methods

14. explain the implications of quality specifications used to determine the integrity of welded joints (BS EN 25817: 1992 – arc welded joints in steel -guidance on quality levels for imperfections)

15. describe post welding activities
    a cleaning
        i wiring brushing
        ii removal of excess weld metal where required
    b visual checks carried out by welding personnel
        i qualitative
            A defect levels
            B appearance
        ii quantitative
            A extent
            B size
            C dimensional accuracy
    c post-weld heat treatment
        i normalising
        ii stress relief

Unit 018 Mechanised welding

Rationale
This unit is concerned with the technology and practices involved in the application of mechanised welding. The unit is demanding in terms of technological content and the complexity of the welding that candidates are expected achieve. The unit is broadly divided into health and safety, welding equipment, welding consumables (eg electrodes wires, shielding gases) and the practicalities of producing a welded joint in relation to a welding procedure specification (WPS) and a quality specification.

Outcomes
There are four outcomes to this unit. The candidate will be able to
1 identify health and safety aspects of mechanised welding
2 prepare the equipment for mechanised welding
3. identify the characteristics of welding consumables for mechanised welding
4. produce welded joints that conform to welding procedure specification (WPS).

Connection with other awards
It relates to the NVQ 1681 Fabrication and Welding Engineering. Units 006, 008, 009, 010, 016, 031 and 046.
It also relates to the *OSCEng ECS* 3.10.

Assessment
The outcomes from this unit will be assessed using evidence from an assignment which will cover both practical activities and underpinning knowledge.

Outcome 1 Identify the health and safety aspects of mechanised welding

Practical Activities

The candidate will be able to
1. investigate hazards and risks in a welding environment
2. refer to the health and safety regulations that apply to welding
3. recommend safety precautions, procedures and PPE to overcome welding hazards
   observe safe working practices

Underpinning knowledge

The candidate will be able to
1. identify the implications of health and safety legislation in relation to welding process
   a Health & Safety At Work Act (1974 (HSaW)
   b Control Of Substances Hazardous To Health (1988) (COSHH)
      i risk assessment
      ii consumable data sheets
      iii training and awareness
      iv safe working procedures
      v hierarchy of control
   c Provision And Use Of Work Equipment (1998) (PUWER)
      i scope within the welding environment

2 Reporting Of Injuries, Diseases And Dangerous Occurrences Regulations (1995) (RIDDOR)
   a application to welding process
      i major injuries
      ii over three day injuries
      iii diseases
      iv dangerous occurrences
   b management of health and safety at work regulations (1999) (MHSWR)
      i risk assessment
      ii five steps to risk assessment
      iii training and awareness
      iv safe working procedures
   c personal protective equipment at work regulations (1992)(PPE)
      i application to welding process
      ii employers' duties
      iii employees' duties
      iv protection against hazards
         A fumes
         B gases
         C noise
         D airborne particles
         E arc radiation
         F hot metal
         G sparks
         H falling objects

v factors render PPE provided as protection against the above ineffective or unsafe

d Noise at work regulations (1989)
- i noise levels – action to be taken at
  - A first level 85dB(A)
  - B second level 90 dB(A)
  - C third level 140 dB(A)

3 describe the effects of welding fume
- a types of fume
  - i visible (particulate)
  - ii composition of fume
    - A occupational exposure standard (OES)
      - I time weighted average (TWA)
      - II short term exposure limit (STEL)
    - B maximum exposure limit (MEL)
  - iii invisible (gaseous)
    - A composition of fume
- b hazards to health from fume
- c control measures to reduce exposure
  - i extraction
    - A background
    - B local
  - ii natural ventilation (eg on-site)
  - iii air-fed headshields
  - iv respirator
  - v breathing apparatus
  - vi monitoring the effectiveness of control measures

4 identify the fire hazards associated with welding
- a sources of combustion
- b identification of hazards
- c methods of reducing risks
- d identification of suitable extinguishers

5. identify the hazards from electricity
- a shock
- b fire
- c burns
- d methods of avoiding shock hazards
- e emergency procedures in the event of an electric shock
- f use of fuses
- g use of earthing
  - i workpiece (welding
  - ii plant
- h use of circuit breakers
- i use of earth leakage circuit breakers (ELCB)
- j double/reinforced insulation power sources

6. explain the hazards from arc radiation
    - a visible light
    - b infra-red
    - c ultra-violet
    - d effects of a.-c.
    - e methods of protection from effects in d.
        - i PPE
        - ii screening
        - iii warnings
            - A verbal
            - B notices

7. identify the hazards from hot metal
    - a means of avoiding hazards

8. identify hazards from gas cylinders
    - a safe storage conditions
    - b safe handling/moving
    - c safe use

9. describe safe start-up and shutdown procedures

Outcome 2 Prepare the equipment for mechanised welding

Practical Activities

The candidate will be able to
1. select the welding equipment for a given application
2. prepare the welding equipment for a given application

Underpinning knowledge

The candidate will be able to

1 describe the supply of power for arc welding
- a from distribution grid
- b single phase
- c three phase
- d power factors

2 describe types of a welding power source
- a output
  - i alternating current (ac)
  - ii direct current (dc)
- b transformer
  - i function
  - ii winding ratio
  - iii input/output ratio
  - iv construction
- c transformer/rectifier
  - i function of a rectifier
  - ii operation of a rectifier
  - iii construction of a rectifier
    - A diode
    - B thyristor
  - iv function of smoothing capacitors
- d inverter
  - i function
  - ii operation
  - iii construction
- e generator
  - i fuel driven
    - A function
    - B operation
    - C construction
  - ii motor driven
    - A function
    - B operation
    - C construction
- f rated output (duty cycle)

g measurement of electrical output and continuity
   i voltage – use of voltmeter/multi-meter
   ii current – use of ammeter/shunts/coils
   iii continuity – use of continuity tester/ohmmeter

3 describe methods of current regulation
   a saturable reactor
   b variable resistance

4 describe the power source characteristics
   a volt/ampere graph
   b flat characteristic
   c constant voltage output
   d constant current output
   e drooping characteristic

5 explain the function of induction
   a principle
   b effect
   c fixed
   d stepped
   e variable control

6 describe return clamps used
   a types
   b clamping mechanisms

7 identify cleaning equipment used
   a grinders
   b linishers
   c wire brushes
   d oxide removal
   e degreasing

8 describe mechanised welding processes
   a submerged arc
      i principles
      ii process description
      iii equipment
      iv identify types of power source available
      v wire feed method
      vi identify types of flux
         A fused
         B agglomerated
         C mixed
      vii applications
      vii benefits
      viii limitations

b electroslag
   i principles
   ii process description
   iii equipment
   iv identify types of power source used
   v wire feed method
   vi function
   vii damming
   viii applications
   ix benefits
   x limitations
   xi consumable guide variation of process
   xii multiple wire method
   xiii electrogas variation of process
c mechanised MIG
   i principles
   ii process description
   iii equipment
   iv identify types of power source used
   v wire feed method
   vi identify types of gases/gas mixtures
      A argon
      B helium
      C argon/helium mixtures
      D carbon dioxide
      E argon/carbon dioxide mixtures
      F argon/oxygen/carbon dioxide mixtures
      G argon/oxygen mixtures
      H helium/argon/oxygen/carbon dioxide mixtures
   vii describe modes of metal transfer
      A dip (short-circuiting
      B globular
      C spray
      D pulse
      E synergic pulse
      F factors that influence mode
         I voltage/current ranges (a-c)
         II shielding gas
         III power source (d-c)
   viii applications
   ix benefits
   x limitations

xi flux cored variation of process
  A identify types of fluxes
    I rutile
    II basic
    III basic/fluoride
    IV fast-freezing slag
    V slow freezing slag
    VI welding position(s
    VII hydrogen content of deposited weld metal
xii multiple head method
xiii narrow gap variation of process
xiv robotic applications

d mechanised TIG
  i principles
  ii process description
  iii equipment
  iv identify types of power source used
  v wire feed method
  vi autogenous
  vii identify types of gases/gas mixtures
    A argon
    B helium
    C argon/helium mixtures
    D helium/argon mixtures
    E argon/hydrogen mixtures
    F nitrogen
    G argon/nitrogen mixtures
  viii applications
  ix benefits
  x limitations
  xi orbital variation of process
  xii tube-to-tube plate variation of process
  xiii narrow gap variation of process
  xiv hot wire variation of process
e mechanised plasma arc
  i principles
  ii process description
  iii equipment
  iv identify types of power source used
  v wire feed method
  vi autogenous
  vii identify plasma and shielding gases/gas mixtures
    A argon
    B helium
    C argon/helium mixtures
    D helium/argon mixtures
    E argon/hydrogen mixtures
  viii applications
  ix benefits
  x limitations

Outcome 3 Identify the characteristics of welding consumables for mechanised welding

Practical Activities

The candidate will be able to
1 identify welding consumables for mechanised processes
2 select welding consumables for a given application
3 prepare consumables for welding

Underpinning knowledge

The candidate will be able to
1. describe electrode wires used for MIG welding
    a BS EN 440:1995 – Welding consumables. Wire electrodes and deposits for gas shielded metal arc welding of non alloy and fine grain steels. Classification
    b BS EN 12072:2000 – Welding consumables. Wire electrodes, wires and rods for arc welding of stainless and heat-resisting steels. Classification
    c BS EN 758:1997 – Welding consumables. Tubular cored electrodes for metal arc welding with and without a gas shield of non-alloy and fine grain steels. Classification
        i sizes
            A diameters
            B reels sizes available
        ii strength and elongation of the weld metal
        iii impact properties of the weld metal
        iv chemical composition of the weld metal
        v deoxidisers
        vi function of copper coating
        vii protection of bare wires
    d non-ferrous metals
        i types
        ii availability
        iii typical sizes
    e storage
        i handling
        ii identification
        iii segregation
            A classification
            B size
    f preparation for welding
    g application

Outcome 4 Produce welded joints that conform to welding procedure specification (WPS

Practical Activities

The candidate will be able to

1. produce a welding procedure specification for joints to be welded in a given application
2. produce welded joints in carbon steel, low alloy steel or stainless steel to a given welding procedure specification and quality specification in tee and butt joints in the flat, horizontal/vertical, positions on plate and either rotated or fixed – horizontal axis on pipe

Underpinning knowledge

The candidate will be able to

1 define the welding process on a WPS

2 identify the parent metal on a WPS

3 specify consumables on a WPS

4 describe pre welding activities
   - a cleaning
   - b edge preparation
   - c assembly
   - d pre-heat

5 define welding parameters on a WPS for a given application

6\. identify welding positions on a welding procedure specification (BS EN 287 part 1: 1992 – approval testing of welders for fusion welding – steels) (BS EN ISO 9606-1. approval testing of welders. fusion welding. part 1. steel)

7\. specify the number and arrangement of runs to fully fill/weld a joint

8\. specify electrode wire sizes for joint thicknesses

9\. describe the techniques used when welding (including autogenous)

10\. specify the electrical conditions required
   - a type of current
     - i direct (dc)
     - ii alternating (ac)
   - b electrode polarity
     - i electrode positive
     - ii electrode negative
   - c voltage
     - i open circuit
     - ii arc
   - d wire feed speed ranges
   - e inductance

11. outline control of heat input

12. outline interpass/run cleaning/back gouging methods

13. explain the implications of quality specifications used to determine the integrity of welded joints (BS EN 25817: 1992 – arc welded joints in steel -guidance on quality levels for imperfections)

14. describe post welding activities
    - a cleaning
        - i wiring brushing
        - ii removal of excess weld metal where required
        - iii slag removal
        - iv spatter removal
    - b visual checks carried out by welding personnel
        - i qualitative
            - A defect levels
            - B appearance
        - ii quantitative
            - A extent
            - B size
            - C dimensional accuracy
    - c post-weld heat treatment
        - i normalising
        - ii stress relief

Unit 019 Thick platework

Rationale

This unit is concerned with the underlying process technology associated with fabrication of thick plate work associated with plate fabrications from low carbon steel, low alloy steel, stainless steel and aluminium alloys.
It includes all types of bolted and welded fabrications, developed plate work, tubular node connection, boxed girder construction and pressure vessels.
It covers health and safety aspects of fabrication, necessary planning and template development lay outs, marking out, cutting and forming and joining for the production of thick plate fabrications.

Outcomes

There are five outcomes to this unit. The candidate will be able to

1 identify health and safety aspects associated with thick plate fabrication
2 prepare and plan for effective thick plate fabrication
3 prepare and use equipment for cutting thick plate
4 prepare and use equipment to form and shape thick plate
5 apply assembly, joining and inspection techniques to thick plate fabrications.

Connection with other awards

This unit extends the knowledge contained in 6983 Applying Engineering Principles Level 2 Unit 032 Producing fabricated assemblies using thick plate, bar and sections.
It relates to Units 026-028, 031, 033, 035-042 & 045 of the City & Guilds NVQ in Fabrication & welding (1681)

It also relates to the *OSCEng ECS* 1.12, 1.13, 1.17, 1.18, 1.20, 2.01, 2.02-2.04, 2.06, 2.09, 2.10, 2.14-2.17, 3.03, 3.04, 3.09, 3.12, 3.13, 3.16, 4.08, 6.01, 6.02, 6.06, 7.04, 8.01 and 8.02.

Assessment

The outcomes from this unit will be assessed using evidence from an assignment which will cover both practical activities and underpinning knowledge.

Outcome 1 Identify health and safety aspects associated with thick plate fabrication

Practical activities

The candidate will be able to
1 refer to the health and safety regulations applied to fabrication
2 recommend safety precautions, procedures and PPE to meet specific requirements
3 promoting a safe and efficient preparation
4 observe safe working practices.

Underpinning knowledge

The candidate will be able to
1. describe the implications of the health and safety legislation relating to thick plate fabrication
   a Health and Safety at Work Act HaSW (1974)
   b Control of Substances Hazardous To Health (COSHH) (1988)
      i risk assessment
      ii consumable data sheets
      iii safe working practices
      iv training and awareness
   c Provision and Use of Work Equipment (PUWER (1988)
      i scope within a composite fabrication environment
   d Reporting Injuries, Diseases And Dangerous Occurrences Regulations (RIDDOR (1995)
      i application to fabrication processes
         A major injuries
         B over three day injuries
         C diseases
         D dangerous occurrences
   e Management of Health and Safety at Work Regulations (MHSWER)(1990)
      i risk assessment
      ii five steps to risk assessment
      iii training and awareness
      iv safe working procedures
   f Personal Protective Equipment at Work Regulations PPE (1992)
      i application to welding processes
      ii employees' duties
      iii employers' duties
      iv protection against hazards
         A fumes
         B airborne particles
         C arc radiation
         D hot metal
         E sparks
         F lifting, handling of material
         G falling objects
      v factors that render PPE provided as protection against the above ineffective or unsafe

g Noise at Work Regulations (1989
  i noise levels – action to be taken at
    A first level 85dB(A
    B second level 90 dB(A
    C third level 140 dB(A

2. explain the fire hazards associated with thick plate fabrication
   a sources of combustion
   b identification of hazards
   c methods of reducing risks
   d identification of suitable extinguishers

3. explain the hazards from arc radiation
   a visible light
   b infra-red
   c ultra-violet
   d effects of a – c
   e methods of protection from effects in d.
     i PPE
     ii screening
     iii warnings
       A verbal
       B notices

4. state hazards from hot metal or slag
   a thermal cutting process
   b arc cutting process
   c welding processes
   d grinding

5. describe safe start-up and shut down processes
   a thermal cutting
   b welding

Outcome 2 Prepare and plan for effective production of thick plate fabrication.

Practical activities

The candidate will be able to
1. interpret instructions and plan a logical sequence of operations for a given task
2 prepare templates for developed shapes, marking out plates, cutting out shapes
and checking formed plate
3 calculate cutting sizes using standard formula
4 extract information from working drawing and produce layouts of a component part
5. mark out plate in readiness for cutting, forming and bending
6. prepare flow charts

Underpinning knowledge

The candidate will be able to
1. describe a logical sequence of operations required to manufacture a thick plate fabrication, in terms of
   a economy of materials and labour
   b simplicity of construction
   c quantity required
   d use of production aids
   e dimensional accuracy
   f standard of finish

2. determine the optimum methods of
   a cutting
   b forming
   c joining

3. select machines and equipment required for 2

4. produce a flow chart for production to minimise handling

5. extract information from a working drawing and produce material cutting lists

6. describe the of layout of work
   a state the function of templates
   b state the function of a datum surface/line
   c list and state the function of marking out equipment
   d determine cutting dimensions by
      i extracting information from the working drawing
      ii calculation – use of standard formula
      iii applies the concept of the neutral surface for rolling, bending and forming operations
   e determine the position of joints with regard to
      i ease of forming
      ii function and strength
      iii distortion control
   f state the cause of cumulative error

7. describe methods of marking out thick plate with reference to
   a equipment required in handling thick plate
   b allowances for thickness of plate and variation in size
   c dimensional accuracy
   d quantity required
   e templates required
   f adequate cutting and forming instructions to avoid 'wrong hand' error
   g standard back marks, cross centres and pitch of holes
   h methods of locating welded and bolted fittings
   i explains the function of setting out points (sop)

Outcome 3 Prepare and use equipment to cut thick plate

Practical activities

The candidate will be able to
1. select cutting equipment for given thick plate applications
2. prepare cutting equipment for use
3. using templates, guidance systems for cutting thick plate
4. produce component to correct to size and shape

Underpinning knowledge

The candidate will be able to
1. describe principles, applications for cutting thick plate by chip forming and non-chip forming methods
   a cropping and shearing machines
   b guillotines
      i mechanical
      ii hydraulic
   c cold sawing
      i circular saws
      ii band saws
         A vertical
         B horizontal
      iii reciprocating
      iv friction
   d planning and milling machines
   e drilling machines
      i pillar
      ii radial arm
      iii portable
      iv magnetic limpet drill
   f rotary shears
   g bevelling machines
      i rotary
      ii reciprocating

2. describe principles, applications for use of thermal cutting techniques for cutting thick plate work and sections
   a state the principle of oxy-fuel gas cutting
   b describe the process of oxy-fuel cutting
      i manual cutting of plate and sections
      ii machine cutting of plate
      iii methods of cutting head control
      iv factors influencing quality of cut
      v reason for ‘three-point’ support of plate
      vi control of distortion
      vii accuracy of shape

c   describe the electric arc process of thermal cutting
   i   arc plasma
   ii   air arc
   iii   carbon arc
   iv   laser cutting
   v   nitrogen water-injected plasma

3. state the advantages and limitations of processes named in 1 and 2

4. compare mechanical and thermal methods of cutting thick plate with reference to
   a   cost of equipment
   b   suitability
   c   versatility
   d   accuracy
   e   quality of cut

Outcome 4 Prepare and use equipment to form and shape thick plate

Practical activities

The candidate will be able to
1. select bending and forming equipment for given thick plate applications
2. prepare bending and forming equipment for use
3. use templates for check shape
4. shape components in accordance with specification

Underpinning knowledge

The candidate will be able to
1. describe principles, applications for bending and forming of thick plate
   - a folding machines
     - i horizontal
     - ii vertical
     - iii double arm folder
     - iv press brake
     - v mechanical press
   - b bending rolls
     - i pyramid
     - ii pinch 3 and 4 roll
     - iii section rolls

2. describe specialised equipment, tooling and techniques for machines named in 1
   - a methods of spring back control for bending and folding
   - b tooling design for air bending techniques
   - c specialised tooling for press brake
   - d use of polyurethane block for use with double arm folder
   - e methods of pre-setting plate edges for rolling
   - f methods of forming cylinders
   - g methods of conical and helical rolling
   - h methods of rolling sectional material
   - i stops, guides fitted to aid production

3. state that the severity of cold bending and folds depends upon
   - a radius of bend
   - b thickness of material
   - c condition of material

4. state the advantages and limitations of processes named in 1 and 2

5. compare bending and forming methods used for thick plate with reference to
   - a cost of equipment
   - b suitability

c versatility
d accuracy
e quality of finish

6. describe the use of specialised guarding used on machines name in 1
   a interlocking devices
   b fail safe circuits
   c light guards
   d gates

Outcome 5 Apply assembly, joining and inspection techniques to thick plate fabrications

Practical activities

The candidate will be able to
1. set up a level surface
2. use a range of techniques for the assembly of thick plate fabrications
3. use a range of techniques for the assemble of circular fabrications
4. use a range of thermal joining techniques for assembly of thick plate fabrications
5. interpret weld symbols and apply to assembly of thick plate fabrications
6. use a range of mechanical joining techniques for the assembly of thick plate fabrications
7. use jigs and fixtures for assembly of thick plate fabrications
8. use a range of inspection techniques to check thick plate fabrications against a specification

Underpinning knowledge

The candidate will be able to
1. briefly describe assembly techniques applied to thick plate fabrications.
    - a state the reason for assembling thick plate fabrication on a level surface
    - b describe methods used to produce level surface
        - i spirit levels
        - ii optical level
        - iii laker level
    - c state the reason for part assemblies and trial erections
    - d describe methods of setting up plate work fabrications, cylindrical fabrications and frames with reference to
        - i logical sequence of assembly
        - ii methods used for alignment
            - A strong backs and wedges
            - B draw cleats/lugs
            - C draw bolts
        - iii methods of avoiding twist
        - iv methods of controlling distortion
        - v use of stays to maintain shape
        - vi use of jigs and fixtures and clamping devices
        - vii use of tack bolts and tack welds
        - viii care and use of lifting tackle
        - ix importance of close contact surfaces
        - x removal of all temporary tack weld and the reinstatement of a good surface

2. briefly describe thermal joining techniques
    - a describe the common welding process used in thick plate fabrication
        - i MMA
        - ii MAG
        - iii TAG
    - b select appropriate welding process for specific applications
    - c state procedures, settings and consumables to produce sound and effective tacking

d interpret weld symbols to BS EN 22553

3. briefly describe the range of joint configuration used in thick plate work
   a ‘open’ square corner joints
   b lap
   c ‘T’ fillets
   d ‘V’, ‘U’ and ‘J’ bevel joints (single and double)
   e flanged
   f cruciform joint

4. briefly describe welding techniques
   a single and multi-run
   b weaving

5. state the requirements of joint design and welding sequence in terms of
   a weld strength
   b distortion control
   c weld economics

6. state the reason for the use of
   a jigs and fixtures to aid assembly
   b manipulators, positioners, rotators to facilitate welding

7. explain the benefits of jigs fixtures and positioners
   a position component parts
   b joint alignment
   c mass production, repetitive work
   d distortion control/dimensional accuracy
   e economy of operation

8. briefly describe mechanical methods of joining
   a the use of bolts
      i black bolts
      ii HSFG bolts
      iii close tolerance bolts
      iv fitted bolts
   b the importance of
      i cleanliness of contact surfaces
      ii correct tensioning
      iii hole clearance
      iv tolerances
      v alignment of holes

9. state the purpose and describe techniques for inspection of thick plate fabrications
   a the function of a datum line or surface
   b measuring equipment to check dimensional accuracy
   c specific tolerances
   d methods of checking accuracy of
      i dimensions
      ii alignment
      iii form
      iv squareness
      v freedom from twist and distortion

e non-destructive testing methods to thick plate fabrications
   i dye penetrant
   ii magnetic particle inspection

f appreciate the importance of good workmanship and finish to suit customer specification and requirements

10. briefly describe finishing processes prior to coating/cladding required for thick plate fabrications
    a de-burring
    b de-slagging
    c abrasive blasting
    d wire brushing

Unit 020 Sheet metalwork fabrication

Rationale
This unit is concerned with the underlying process technology associated with the fabrication of thin plate associated with developed thin plate components, ducting, double curvature work and light sheet metal fabrication. It covers the health and safety aspects of fabrication work, cutting and forming of sheet metal and the production of fabrications using sheet metalwork techniques, including joining by soldering (soft and hard) and resistance welding (spot, seam and projection).

Outcomes
There are five outcomes to this unit. The candidate will be able to
1 identify the health and safety aspects of fabrication
2 prepare and use equipment and tools for sheet metal cutting
3 prepare the equipment and tools for sheet metal forming
4 produce fabrications using sheet metalwork techniques
5 join fabrications using sheet metalwork techniques.

Connection with other awards
It relates to the NVQ Level 3 Fabrication and Welding (1681) units 022-025, 027-030, 032, 035 & 039
It also relates to the *OSCEng ECS* 3.03, 3.04, 3.06 and 3.12.

Assessment
The outcomes from this unit will be assessed using evidence from an assignment which will cover both practical activities and underpinning knowledge.

Outcome 1 Identify the health and safety aspects of fabrication

Practical Activities

The candidate will be able to
1 investigate hazards and risks in a fabrication environment
2 refer to the health and safety regulations that apply to fabrication
3 recommend safety precautions, procedures and PPE to overcome hazards
4 observe safe working practices

Underpinning knowledge

The candidate will be able to
1 identify the implications of health and safety legislation in relation to welding process
   a Health & Safety at Work Act (HSaW) (1974)
   b Control of Substances Hazardous to Health (COSHH) (1988)
      i risk assessment
      ii consumable data sheets
      iii training and awareness
      iv safe working procedures
      v hierarchy of control
   c Provision and Use of Work Equipment (PUWER) (1988
      i scope within the fabrication environment
      ii Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) (1995)
      iii application to fabrication process
         A major injuries
         B over three day injuries
         C diseases
         D dangerous occurrences
   d Management of Health and Safety at Work Regulations (MHSWR) (1999)
      i risk assessment
      ii five steps to risk assessment
      iii training and awareness
      iv safe working procedures

e Personal Protective Equipment at Work Regulations (PPE) (1992)
  i application to welding process
  ii employers' duties
  iii employees' duties
  iv protection against hazards
    A fumes
    B noise
    C airborne particles
    D arc radiation
    E hot metal
    F sparks
    G falling objects

f factors render PPE provided as protection against the above ineffective or unsafe

g Noise at Work Regulations (1989)
  i noise levels – action to be taken at
    A first level 85dB(A)
    B second level 90 dB(A)
    C third level 140 dB(A)

2 state the fire hazards associated with hot working
  a sources of combustion
  b identification of hazards
  c methods of reducing risks
  d identification of suitable extinguishers

3. explain the hazards from arc radiation
  a visible light
  b infra-red
  c ultra-violet
  d effects of a – c
  e methods of protection from effects in d.
    i PPE
    ii screening
    iii warnings
      A verbal
      B notices

4. state hazards from hot metal or slag
  a thermal cutting process
  b arc cutting process
  c welding processes
  d grinding

5. describe safe start-up and shut down processes
  a thermal cutting
  b welding

Outcome 2 Prepare and use equipment and tools for sheet metal cutting

Practical Activities

The candidate will be able to
1 select the fabrication equipment for a given cutting application
2 prepare the fabrication equipment for a given cutting application

Underpinning knowledge

The candidate will be able to
1 describe principles, applications and procedures for use of sheet metalwork cutting equipment
 a drills
  i twist drill nomenclature
  ii drilling machines
   A pedestal
   B bench
   C portable
   D hand
   E electric power
   F pneumatic
 b trepanning
 c tank cutters
 d hole saws
 e rotary shears
  i portable shears
  ii nibblers
   A shear type
   B punch type
   C combination shears
 f guillotines
  i treadle
  ii mechanical
  iii pneumatic
  iv CNC control
  v back stops
  vi front stops
  vii guides
 g universal shearing machine
 h fly press
 i power punch (including CNC control)
 j metal spinning
 k portable angle grinders/sanders

2 describe principles, applications and procedures for use of sheet metalwork fabrication cutting tools

a hand shears
  i straight
  ii left hand
  iii right hand
  iv universal
b bench shears
  i hand-lever
  ii throatless
  iii corrugated
c tinman’s hand-level punch
d rivet removal

Outcome 3 Prepare the equipment and tools for sheet metal forming

Practical Activities

The candidate will be able to
1 select the fabrication equipment for a given forming application
2 prepare the fabrication equipment for a given forming application

Underpinning knowledge

The candidate will be able to
1 describe principles, applications and procedures for use of sheet metalwork fabrication forming tools
   a hammers
   b planishing hammers
   c stretching hammers
   d blocking hammers
   e hollowing hammers
   f mallets
   g wedge shaped mallets
   h wooden blocks
   i sand bags
   j range of bench stakes

2 briefly describe principles, applications and procedures for use of sheet metalwork fabrication forming equipment
   a jennys
      i tooling
   b rolling machines
      i pyramid type
      ii pinch type
      ii slip rolls
      iv hand-operated
      v mechanical
      vi cone rolls
      vii angle-ring bending
   c folding machines
      i box and pan
      ii universal swing-beam
      iii angle bending
      iv simple bench mounted bending
   d press brake
      i tooling
         A dies
         B forming tools
      ii mechanical
      iii electro-hydraulic
      iv up-stroking
      v down-stroking
      vi CNC control

- e fly press
  - i tooling
    - A dies
    - B forming tools
- f stretch forming/shrinking machines
- g vibratory forming machines

Outcome 4 Produce fabrications using sheet metalwork techniques

Practical Activities

The candidate will be able to
1 select the fabrication techniques for a given application
2 use fabrication techniques for a given application
3 use fabrication techniques to produce square, rectangular, cylindrical, conical forms (including offsets)
4 use fabrication techniques to produce transition pieces

Underpinning knowledge
The candidate will be able to
1 briefly describe the transfer of patterns to metal/plastics

2 briefly describe stiffening techniques
  a swaging
  b beading
  c wired edges (including false)
  d folds
  e flanging

3 briefly describe the techniques used to produce forms
  a square
  b rectangular
  c cylindrical
  d conical
  e offsets of a.-d.
  f helical
  g boxed
  h curved panels
  i double curvatures

4 state the techniques used to produce transition pieces
  a square to round
  b round to square
  c breeches

5 briefly describe stretching and shrinking techniques
  a hand forming
  b machine forming

6 briefly describe hand forming techniques
  a hollowing
  b raising
  c planishing
  d flanging
  e double curvature
  f ‘split and weld’ methods

7 describe wheeling techniques

8 describe metal spinning techniques

Outcome 5 Join fabrications using sheet metalwork techniques

Practical Activities

The candidate will be able to
1 assemble fabrications for joining
2 select the use self-secured joints to join sheet metalwork fabrications
3 select the use soft soldering techniques to join sheet metalwork fabrications use fabrication
4 select the use hard soldering/brazing techniques to join sheet metalwork fabrications use fabrication
5 select the use resistance welding processes to join sheet metalwork fabrications use fabrication.

Underpinning knowledge

The candidate will be able to
1 describe methods of fabrication assembly
   a holding methods
   b clamping
   c distortion control methods

2 describe the use of joints (including self-secured)
   a lap
   b grooved seam
   c lock-formed
   d Pittsburgh lock
   e panned down
   f knocked-up
   g jointing allowances
   h junctions that require notched corners

3. briefly describe soft soldering techniques
   a principles of soldering
   b benefits and limitations
   c joint design
   d preparing the joint
   e cleaning the joint
   f types of soft solder
      i melting points
      ii applications
   g types of fluxes

h heat sources
    i copper bit
    ii flame
    iii hot plate
    iv furnace
    v induction
    vii resistance
    viii dip
i cleaning the soldered joint

4. describe hard soldering/brazing techniques
    a principles of brazing
    b benefits and limitations
    c joint design
    d preparing the joint
    e cleaning the joint
    f types of hard solder
        i brazing alloys
        ii silver solders
        iii melting points
        iv applications
    g types of fluxes
    h heat sources
        i flame
        ii gas mixtures
        iii types of torches
        iv furnace
        v induction
        vi resistance
        vii dip
    i cleaning the brazed joint
    j braze welding
    k aluminium brazing

5. briefly describe resistance welding processes
    a spot
    b seam
    c projection
    d principles of resistance welding

e generation of heat by electrical resistance
- i welding current
- ii welding time
- iii resistance at joint interface
- iv $Q = I^2Rt$
  - A electrical resistance within the metals being welded
  - B electrical resistance of the electrodes
  - C contact resistance between the workpieces
  - D the contact resistance of the electrodes and the workpieces
  - E the heat lost to the workpieces
  - F the heat lost from the workpieces
  - G shunt effect

f power sources available
- i transformers
  - A function of step-down transformer for spot welding
  - B current control by primary tappings
  - C welding voltage
- ii contactor
  - A hand activated
  - B foot activated

g state the electrodes available for welding
- i electrode functions
  - A gripping
  - B exertion of force
  - C passage of high current
- ii electrode properties
  - A high electrical conductivity
  - B high thermal conductivity
  - C erosion resistance
  - D resistance to deformation
- iii electrode materials
  - A high conductivity electrolytic copper
  - B copper-alloy bar
- iv electrode tip geometry
  - A domed end
  - B truncated cone
  - C special shapes to obtain access to more complex joints
- v electrode sizes
  - A $d = 5\sqrt{t}$
  - B $d = 2.5 + 2t$
- vi methods of cooling
- vii electrode arms
  - A mechanically sprung – rocker-arm
  - B hydraulic
  - C pneumatic
  - D hand operated lever

Unit 021 Structural steelwork fabrication and erection

Rationale
This unit is concerned with the underlying technology and working practices associated with the fabrication and erection of structural steelwork. The unit is broadly divided into structural materials, fixtures and fastenings, structural fabrication, sitework and safe working practices during fabrication and on site.

Outcomes
There are four outcomes to this unit. The candidate will be able to
1. identify health and safety aspects associated with structural steelwork fabrication and erection
2. identify and select common materials, fixtures and fastenings used in structural steelwork
3. prepare equipment and fabricate structural steelwork
4. erect structural steelwork on site.

Connection with other awards
It follows on from City & Guilds 6983 Level 2 AEP unit 009: Installing and dismantling ancillary steelwork.
It also relates to units 022, 028, 033, 034, 037-042 & 045 of the City & Guilds NVQ in Fabrication & welding (1681)
It also relates to the ECS 2.04, 2.06, 2.09, 2.14 -2.17, 3.03, 3.04, 3.09, 3.12, 3.13, 3.16, 4.08, 6.01, 6.02, 6.06, 7.04, 8.01 and 8.02.

Assessment
The outcomes from this unit will be assessed using evidence from a centre devised assignment which will cover both practical activities and underpinning knowledge.

Outcome 1 Identify health and safety aspects associated with structural steelwork fabrication and erection

Practical activities

The candidate will be able to
1. refer to the health and safety regulations applied to structural steelwork fabrication and erection
2. recommend safety precautions, procedures and PPE to meet specific requirements
3. promote a safe and efficient preparation
4. investigate hazards and risks in a structural steelwork fabrication and erection environment
5. observe safe working practices

Underpinning knowledge

The candidate will be able to
1. describe the implications of the health and safety legislation relating to structural steelwork fabrication and erection
    - a Health and safety at work act (1974HaSW)
    - b Control of substances hazardous to health (1988(COSHH)
        - i risk assessment
        - ii consumable data sheets
        - iii safe working practices
        - iv training and awareness
    - c Provision and use of work equipment (1988(PUWER)
        - i scope within a structural steelwork fabrication and erection environment
    - d Reporting injuries, diseases and dangerous occurrences regulations (1995)(RIDDOR)
        - i application to composite fabrication processes
            - A major injuries
            - B over three day injuries
            - C diseases
            - D dangerous occurrences
    - e Management of health and safety at work regulations (1999(MHSWER
        - i risk assessment
        - ii five steps to risk assessment
        - iii training and awareness
        - iv safe working procedures

f Personal protective equipment at work regulations (1992)
  i application to welding processes
  ii protection against hazards
    A fumes
    B noise
    C airborne particles
    D arc radiation
    E hot metal
    F sparks
    G lifting, handling of material
    H falling objects
  iii factors that render PPE provided as protection against the above ineffective or unsafe
g Noise at work regulations (1989)
  i noise levels – action to be taken at
    A first level 85dB(A)
    B second level 90 dB(A)
    C third level 140 dB(A)
  ii vibration

2. explain the fire hazards associated with structural steelwork fabrication and erection
  a sources of combustion
  b identification of hazards
  c methods of reducing risks
  d identification of suitable extinguishers

3. explain the hazards from arc radiation
  a visible light
  b infra-red
  c ultra-violet
  d effects of a – c
  e methods of protection from effects in d.
    i PPE
    ii screening
    iii warnings
      A verbal
      B notices

4. state hazards from hot metal or slag
  a thermal cutting process
  b arc cutting process
  c welding processes
  d grinding

5. describe safe start-up and shut down processes
  a thermal cutting
  b welding

6. state the safety regulations and accident prevention measures associated with
   a. hand, electrical and compressed air power tools
   b. mechanical and thermal cutting processes
   c. welding processes
   d. lifting equipment

7. describe systems used on site to restrict access by unauthorised personnel

8. state how the lifting capacity of two legged slings varies according to angle between them

9. state the range of personal protective equipment (PPE) required for
   a. mechanical and thermal cutting
   b. forming operations
   c. welding operations
   d. sitework operations

10. explain the relevance of a Permit to Work certificate

Outcome 2 Identify and select common materials, structural steelwork, fixtures and fastenings used in structural steelwork

Practical Activities

The candidate will be able to
1. produce full size section profiles of universal beams (UB) to show variations between serial/nominal size and actual size, including rolling tolerance.

Underpinning Knowledge

The candidate will be able to
1. describe the range of materials used in structural steelwork fabrication
   a low carbon steel
   b low alloy steels
   c high yield alloy steels
   d weather resistant steels (WR 55 grades)

2. identify the range of commercial forms of supply
   a sections
      i rolled steel angle (RSA)
         A equal leg
         B unequal leg
      ii universal beam (UB)
      iii universal column (UC)
      iv rolled steel channel (RSC)
      v rolled steel joist (RSJ)
      vi tee bar
   b hollow sections
      i circular hollow section (CHS)
      ii rectangular hollow section (RHS)
   c plates
      i plain
      ii non-slip (durbar and chequer)
      iii expanded, pierced and punched
   d flat bars

3. identify pre-fabricated sections
   a plate birders
   b box girders
   c lattice girders
   d castellated beams
   e cambered beams
   f laced stanchions
   g battened stanchions
   h portal frames

4. select materials and compare them in terms of
    - a application
    - b limitations of use
    - c load bearing capabilities
        - i beams
            - A simply supported
            - B cantilevered
        - ii columns
            - A concentric
            - B off-centre
    - d ease of fabrication
        - i marking out
        - ii cutting
        - iii jointing
    - e density
    - f fireproof protection requirements
    - g in service maintenance
        - i corrosion prevention treatments
        - ii damage repairs and/or modifications

5. identify fixtures used in structural steelwork
    - a cleats
        - i beam to beam connections
        - ii beam to column connections
    - b columns
        - i base plates
        - ii end plates
        - iii splice plates
    - c gusset plates

6. identify types of fastenings and their applications
    - a bolts
        - i black
        - ii high tensile
        - iii high strength friction grip (HSFG)
        - iv load indicating
        - v close tolerance
        - vi torshear
    - b washers
        - i plain
        - ii hardened steel
        - iii load indicating
        - iv taper
        - v tab
        - vi anti-vibration
    - c shear connectors

Outcome 3 Prepare equipment and fabricate structural steelwork

Practical Activities

The candidate will be able to
1. fabricate a welded beam to beam connection
2. tension bolts to the recommended torque
3. set out a roof truss

Underpinning knowledge

The candidate will be able to
1. describe how to mark out structural material to specification
   a directly onto steelwork
   b using templates

2. identify symbols and abbreviations used on structural drawings and templates for marking out operations
   a SBM
   b C.C
   c S.O.P.
   d ϕ

3. describe how to mark out structural material using as reference
   a datum lines
   b centre lines
   c set out points

4. explain the use of triangulation for checking squareness
   a 3: 4: 5
   b 5: 12: 13

5. describe how to avoid cumulative error in marking out by the avoidance of string dimensions

6. determine the lengths of sections prior to rolling
   a ladder hoops
   b angle rings

7. describe how to mark out non-slip plate (chequer avoiding ‘wrong hand’ or ‘mirror image’ errors

8. describe a method of setting out a camber

9. derive the shapes of bolted gusset plates from standard hole pitch and edge distance

10. describe the types of templates used for marking out
    a plate
    b sections
    c cleats

11. describe the use of
    a box templates
    b battened templates
    c part templates

12. describe notching requirements for joints between structural sections using standard data

13. state the mechanical cutting processes used in the fabrication of structural steelwork
    a shearing
    b cropping
    c notching
    d punching
    e drilling
    f reaming
    g power sawing
        i reciprocating
        ii band
        iii circular
    h end milling/rotary ending

14. state applications for each of the mechanical cutting processes in 13

15. describe thermal cutting processes used in the fabrication of structural steelwork
    a oxy-fuel gas
    b arc-plasma

16. state applications for each of the thermal cutting processes in 15

17. state the forming processes used in the fabrication of structural steelwork
    a plate rolls
        i pinch
        ii pyramid
    b section rolls
    c beam bender

18. state applications for each of the forming processes in 17

19. describe factors which contribute to the quality of bolted connections
    a cleanliness of surfaces in contact
    b alignment of holes
    c correct tensioning

20. explain the reasons for reaming punched holes

21. describe methods of bolt tensioning
    a torque wrench
    b impact wrench

22. state welding processes used in the fabrication of structural steelwork
    a manual metal arc (MMA)
    b metal inert gas (MIG)
    c flux cored

d submerged-arc

23. state applications for each of the welding processes in 22

24. identify visually defects in welded joints
    a undercut
    b surface cracks
    c insufficient reinforcement
    d unequal leg length
    e excessive convexity/concavity

25. describe methods of controlling distortion in welded structures
    a restraint
    b welding sequence
    c pre-setting

26. describe acceptable methods of rectifying excessive distortion in welded structures
    a mechanical force
    b heat

27. state the reasons for assembling steel structures on a level surface

28. describe how a level assembly surface may be prepared
    a water level
    b optical instruments
    c lasers

29. describe the method of assembly of frames and structures with reference to
    a logical sequence
    b stresses in components
    c temporary stays or supports to
        i maintain shape
        ii eliminate distortion
        iii strengthen individual members/components
    d avoidance of twist
    e use of jigs or fixtures
    f avoidance of damage to mating surfaces

30. state the reason for
    a part assemblies
    b trial erections

31. explain what is meant by steelwork being ready for delivery to site in the form of
    a piece small
    b sub-assemblies

Outcome 4 Erect structural steelwork on site

Practical Activities

The candidate will be able to
1. check the level of column bases or assembly surfaces using an optical instrument
2. check the alignment of columns using an optical instrument
3. determine which members in a roof truss are struts and which are ties

Underpinning knowledge

The candidate will be able to
1. describe sitework techniques for
    a levelling steelwork and steelwork bases
    b plumbing columns
    c checking alignment

2. describe the methods of handling, moving and lifting structural steelwork on site
    a use of turn-over dogs
    b packing between stacked sections
    c types of slings
        i chains
        ii ropes
        iii straps
    d use of temporary lifting lugs
    e slinging techniques
    f load balancing when making lifts
    g use of guide ropes to avoid swinging loads

3. visually inspect slings and chains for defects

4. state the types of crane used on site
    a mobile
    b mobile with fly jib
    c tower

5. state the applications and limitation of the cranes in 3

6. state the use of ancillary equipment used on site to lift, move or adjust the position of steelwork
    a pulleys
    b block and tackle
    c pull lifts (sylvesters)
    d hydraulic jacks
    e podger spanners
    f drifts
    g wedges

7. state the function of ancillary steelwork
   a access
      i platforms, decking and walkways
      ii stairways and hooped ladders
      iii handrailing
   b support
      i saddles, brackets and cleats
      ii frameworks
      iii bracings and ties

8. recognise members in a structure that are load bearing

9. determine which members in a framework are
   a struts
   b ties

10. explain the need for supporting steelwork during erection
    a temporary props and bracings
    b falsework

11. explain acceptable modification techniques to steelwork on site
    a misaligned holes
    b incorrect sized members
    c maximum thickness of packings
    d fouling existing steelwork or services

12. explain the consequences of cutting holes in beams to facilitate service piping or ducting

Unit 022 Pipe and tube fabrication

Rationale
This unit is concerned with the underlying process technology associated with pipe and tube fabrication from low carbon steel, stainless steel, cast iron, copper and its alloys, aluminium and its alloys, nickel and its alloys and polymers.
It includes the principles of pipe and tube fabrication together with pipe joining techniques. It also covers health and safety aspects of pipe and tube fabrication, necessary planning template development layout, marking out, cutting, bending, assembly, joining and finishing.

Outcomes
There are five outcomes to this unit. The candidate will be able to
1 identify health and safety aspects associated with thick plate fabrication
2 prepare and plan for effective pipe and tube fabrication
3 prepare and use equipment for cutting pipe and tube
4 prepare and use equipment to bend pipe and tube
5 apply assembly, joining and inspection techniques to pipe and tube fabrication.

Connection with other awards
This unit extends the knowledge contained in
Unit 007 Assembling pipe work systems Applying Engineering Principles Level 2
It relates to units 027-029, 031, 033, 034, 039, 044-046 of the City & Guilds NVQ in Fabrication & welding (1681)
It also relates to the *OSCEng ECS* 1.12, 1.13, 1.17, 1.18, 1.20, 2.01-2.04, 2.06, 2.07, 2.09, 2.10, 2.14-2.17, 3.03, 3.04, 3.09, 3.12, 3.13, 3.16, 4.08, 6.01, 6.06, 7.04, 8.01 and 8.02.

Assessment
The outcomes from this unit will be assessed using evidence from a centre devised assignment with will cover both practical activities and underpinning knowledge

Outcome 1 Identify health and safety aspects associated with pipe and tube fabrication

Practical activities

The candidate will be able to
1 refer to the health and safety regulations applied to pipe and tube fabrication
2 recommend safety precautions, procedures and PPE to meet specific requirements
3 promote a safe and efficient preparation
4 investigate hazards and risks in a fabrication environment
5 observe safe working practices

Underpinning knowledge

The candidate will be able to
1. describe the implications of the health and safety legislation relating to pipe and tube fabrication
    - a Health and Safety At Work Act (1974 (HSaW)
    - b Control of Substances Hazardous To Health (COSHH) (1988)
        - i risk assessment
        - ii consumable data sheets
        - iii safe working practices
        - iv training and awareness
    - c Provision and Use Of Work Equipment (PUWER) (1988)
        - i scope within a pipe and tube fabrication environment
    - d Reporting Injuries, Diseases And Dangerous Occurrences Regulations (RIDDOR) (1995)
        - i application to pipe and tube fabrication processes
            - A major injuries
            - B over three day injuries
            - C diseases
            - D dangerous occurrences
    - e Management Of Health And Safety At Work Regulations (MHSWER) (1999)
        - i risk assessment
        - ii five steps to risk assessment
        - iii training and awareness
        - iv safe working procedures
    - f Personal Protective Equipment At Work Regulations (PPE) (1992)
        - i application to thermal joining processes
        - ii application to use of machines
        - iii application with hot bending of pipe and tube
        - iv employees' duties
        - v employers' duties
        - vi protection against hazards
            - A fumes
            - B noise
            - C airborne particles
            - D arc radiation
            - E hot metal
            - F sparks
            - G lifting, handling of material

H falling objects
viii factors that render PPE provided as protection against the above ineffective or unsafe
g Noise at Work Regulations (1989)
i noise levels – action to be taken at
A first level 85dB(A)
B second level 90 dB(A)
C third level 140 dB(A)
ii vibration
h Lifting Operations, Lifting Equipment Regulations (LOLER) (1998)
i condition, suitability, inspection and identification of lifting chains, ropes and equipment
ii conditions relating to SWL of lifting equipment
iii faults that render wire ropes unserviceable

2. explain the fire hazards associated with pipe and tube fabrication
a sources of combustion
b identification of hazards
c methods of reducing risks
d identification of suitable extinguishers

3. explain the hazards from arc radiation
a visible light
b infra-red
c ultra-violet
d effects of a – c
e methods of protection from effects in d.
i PPE
ii screening
iii warnings
A verbal
B notices

4. state hazards from hot metal or slag
a thermal cutting process
b arc cutting process
c welding processes
d hot bending of pipe and tube
e grinding

5. describe safe start-up and shut down processes
a thermal cutting
b welding

6. describe safe shut-down procedures for pipe work systems
a safety requirements and procedures when shutting down in service pipe lines
i permission to work
ii certification of clearance for work on hazardous pipe lines
A chemical
B flammable liquids
iii arrangements for stand-by operation during shut down
b safety precautions when dismantling a pipe line which is isolated but still under pressure
i safe shut-off isolating valves

ii controlled release of pressure
iii cooling down allowance
iv pressure checking prior to dismantling
v blanking off as appropriate

7. state safety precautions to be taken when carrying out hydrostatic pressure tests

Outcome 2 Prepare and plan for effective production of pipe and tube fabrication

Practical activities

The candidate will be able to
1. interpret instructions and plan a logical sequence of operations for a given task
2 prepare templates for developed shapes, marking out pipe and tube, cutting out shapes and checking formed pipe and tube
3 calculate cutting sizes using standard formula
4. extract information from working drawings and produce component parts/materials cutting lists
5. extract information from working drawing and produce's layouts of a pipe work systems
6. mark out pipe/tube in readiness for cutting, and bending
7. prepare flow charts

Underpinning knowledge

The candidate will be able to
1. describe the selection of pipe work materials for specific applications
    - a state the pipe and tube materials in common use
        - i metals
            - A cast iron
            - B low-carbon steel, low alloy steel and stainless
            - C copper and its alloys
            - D nickel and its alloys
            - E aluminium and its alloys
        - ii non-metals
            - A PVC
            - B polythene
            - C polypropylene
            - D rubber
    - b state methods used to protect pipe work
        - i externally
            - A dipping
            - B spraying
            - C painting
            - D bitumous coating
            - E impregnated tapes
        - ii internally
            - A rubber
            - B cement
            - C resin
            - D synthetic linings
            - E metal linings

c compare the benefits and limitations of a and b for use with
   - i air
   - ii steam
   - iii hydraulic fluid
     - A water
     - B mineral and synthetic oil
   - iv oil
   - v refrigerants
   - vi corrosive fluids

3. select from a range of fitting used in pipe and tube fabrication, reference to malleable iron BSEN 10242, flanges BS 10, valves cast iron BS 3464
   - a elbows
   - b bends
   - c reducers
   - d flanges
   - e couplings
   - f unions
   - g isolation and control valves

4. describe a logical sequence of operations required to manufacture a pipe and tube fabrication, in terms of
   - a economy of materials and labour
   - b simplicity of construction
   - c quantity required
   - d use of production aids
   - e dimensional accuracy
   - f standard of finish

5. determine for the range of materials the optimum methods of
   - a cutting
   - b forming
   - c joining

6. select machines and equipment required for 5

7. produce a flow chart for production to minimise handling

8 extract information from a working drawing and produce component/material cutting lists

9. describe the layout of work
   - a state the function of templates
   - b state the function of a datum surface / line
   - c list and state the function of marking out equipment
   - d determine cutting dimensions by
     - i extracting information from the working drawing
     - ii calculation – use of standard formula
     - iii applies the concept of the neutral line/operations
   - e produce templates for pipe-work fabrication
     - i branches
     - ii tees
     - iii mitred bends

10. describe methods of marking out pipe and tube fabrications with reference to
    - a locations of bend lines
    - b calculation and marking out angle of cut
    - c calculation of allowances for
        - i cutting
        - ii bending
        - iii joining
    - d marking off pipe lengths
    - e marking out templates
    - f adequate cutting and forming instructions to avoid 'wrong hand' error
    - g explains the function of setting out points (sop)

11. describe the trial setting-out of pipe and tube fabrications
    - a full size setting out of pipes and bends, use of
        - i set wires
        - ii bevel bars
        - iii checking fixtures
    - b measurement of angular positions and bend relative to a datum
    - c setting out for set on perpendicular and inclined branches
        - i equal diameter
        - ii un-equal diameter

Outcome 3 Prepare and use equipment for cutting pipe and tube

Practical activities

The candidate will be able to
1. select cutting equipment for given pipe and tube applications
2. prepare cutting equipment for use
3. using templates, guidance systems for cutting pipe and tube
4. produce pipe and tube to correct to shape and size

Underpinning knowledge

The candidate will be able to
1. describe principles, applications for cutting pipe and tube by chip forming and non-chip forming methods
    a pipe and tube cutters
    b cold sawing
        i circular saws
        ii band saws
            A vertical
            B horizontal
        iii reciprocating hack saws – mechanical and hand
        iv abrasive saws
        v hand grinding machines
        vi bevelling machines – reciprocating

2. describe principles, applications for use of thermal cutting techniques for pipe
    a state the principle of oxy-fuel gas cutting
    b describes the process of oxy-fuel cutting
        i manual cutting
        ii machine cutting
        iii methods of cutting head control
        iv factors influencing quality of cut
        v reason for ‘three-point’ support of plate
        vi control of distortion
        vii accuracy of shape
    c describe the electric arc plasma thermal cutting process

3. compare the benefits and limitations of processes named in 1 and 2 with regard to
    a cutting pipe and tube to length
    b preparing the end of pipe and tube for welding
    c preparing pipes for branch attachments

Outcome 4 Prepare and use equipment to bend pipe and tube

Practical activities

The candidate will be able to
1. select bending and forming equipment for given pipe/tube-bending applications
2. prepare bending and forming equipment for use
3. using templates for check shape
4. shape components in accordance with specification using cold bending techniques and hot bending techniques

Underpinning knowledge

The candidate will be able to
1. describe principles, applications of pipe and tube bending
    a state factors to be considered in selecting appropriate hot or cold bending methods
        i pipe dimensions
        ii pipe material
        iii mode of pipe manufacture
        iv degree of accuracy required
        v equipment available

2. describe cold bending techniques
    a describe the principles of operation of the following bending machine types
        i compression
        ii draw
        iii ram press
        iv roll (coils)
    b describe methods of setting up a bending machine to undertake accurate bending of
        i bends in the same plane
        ii bends in two or more different planes
        iii offsets in the same plane
        iv rolled offsets
    c describe free bending techniques
    d compare principles of operation, power sources, bending capacity, bending capability and applications of the bending machine types named in a
    e state the cause of the faults which may occur during cold bending operations
        i flattening
        ii ovality
        iii wrinkling or buckling
        iv changes in wall thickness
    f compare methods of avoiding faults name in e by use of
        i mandrels
        ii springs
        iii low melting alloys
    g state the safety precautions to be observed when using low melting alloys
        i melting, filling and cooling before bending

 empty after bending

3. describe hot bending techniques for pipe
    a state the requirement for
        i sand loaded pipes
        ii no internal support
    b state the equipment required when
        i hand bending
        ii power bending – use of winches
            A heat sources
                I torch
                II furnaces
            B aids for accurate bending
                I templates (wire)
                II localised cooling
    c describe the position of heat lengths to facilitate
        i bends in the same plane
        ii bends in two or more different planes
        iii offsets in the same plane
        vi rolled offsets
    d state the cause of the faults listed which may occur during cold bending operations
        i flattening
        ii burning
        iii wrinkling
        iv changes in wall thickness
        v scaling
    e state methods of avoiding faults listed in d
        i correct machine setting
        ii correct packing of pipe
        iii bend radius is not too small (3 – 5 diameters)
        iv control heat applications

4. state factors to be considered prior to undertaking cold and hot bending
    a correct bend allowance
    b angle of bend
    c true length of bend
    d dimensions of pipe
        i diameter to wall thickness
    e spring back allowance
    f requirement of internal support
    g method of bending

Outcome 5 Apply assembly, joining and inspection techniques to pipe and tube fabrications

Practical activities

The candidate will be able to

1. use a range of techniques for the assembly of pipe and tube fabrications to include: threaded, sleeved, flanged, welded, adhesive bonded, hot air welded
2. use a range of thermal joining techniques for assembly of pipe and tube fabrications
3. interpret weld symbols and applies to assembly of pipe fabrications
4. use a range of mechanical/compression joining techniques for the assembly of pipe and tube fabrications
5. use of pipe supports for a given application
6. use a range of inspection techniques to check pipe and tube fabrications against a specification including visual inspection of joints and pressure testing and thread insertion checks following testing
7. lagging of pipe work systems

Underpinning knowledge

The candidate will be able to

1. describe assembly and joining techniques applied to pipe and tube fabrications
    - a state the in-service conditions to be consider when selecting a pipe joining technique
        - i physical and chemical properties of pipe content
        - ii thermal/pressure cycle
        - iii vibration
    - b describe methods joints used in pipe and tube joining
        - i threaded
        - ii sleeved
        - iii flanged
            - A integral flanges
            - B welded flanges
    - c select types of fitting appropriate to method of joining
        - i threaded fittings to BS 21 or appropriate
        - ii manipulative and non-manipulative fittings for compression joints
        - iii fittings for pipe joints in plastics using
            - A adhesives
            - B hot air gun
            - C hot plate welding techniques
        - iv plain end fittings – for fusion welding
    - d select gasket and joining compounds for a given application with reference to
        - i in-service and environment conditions listed in a
        - ii type of housing
        - iii flange face finish
        - iv range of gasket material and their compatibility with d i
            - A rubber and rubber compounds
            - B plastics
            - C compressed asbestos free gaskets BS 7531
            - D metallic and semi metallic
            - E tapes and cords

v range of jointing compounds and their compatibility with d i

2. describe thermal joining techniques
   a describe the common welding process used in pipe and tube fabrication
      i MMA
      ii MIG/MAG
      iii TIG
   b select appropriate welding process for specific applications
   c state procedures, settings and consumables to produce sound and effective tacking
   d interpret weld symbols to BS EN 22553
   e describe the range of joint configuration used in pipe
      i ‘open’ square corner joints
      ii square butt
      iii fillet
      iv ‘V’, bevel joints (single)
      v flanged

3. identify and state the cause of faults caused by production defects
   a pitting
   b laminations
   c split seams
   d ovality
   e variation in wall thickness
   f variation in diameter

4. describe methods of testing pipe and tube fabrications
   a state the equipment required for hydrostatic testing
   b states the procedure for carrying out tests named in a
   c states safety precautions to be observed when carrying out tests

5. describe the insulation of pipe systems
   a the reasons for insulation
      i avoidance of heat loss
      ii prevention of surface condensation
      iii fire proofing
      iv sound proofing
   b factors to be considered before lagging pipes
      i operation temperature
      ii clearance between pipes
      iii accommodating pipe supports and brackets
      iv clearance between adjacent walls and equipment
   c common insulating materials and their forms of supply
      i materials
         A rock wool
         B fibreglass
         C polystyrene
         D preformed section
         E aluminium cladding
      ii forms of supply
         A preformed (rigid
         B paste
         C sheet, strip or mattress
         D loose fill (in casing or jacket

   Note refer to manufacturers’ catalogues

- d state methods of protecting lagging
  - i environment
  - ii accidental damage
  - iii regular maintenance
- e state hazards inherent in handling and removal of lagging

6. describe pipe supports and their use.
   Note standard symbols for pipe supports are given in BS 1553 (Part 1)
   - a state factors to be considered in installing pipe supports
     - i permissible degree of movement, calculation of expansion movement arising from temperature change
     - ii loading of pipe work
       - A gross weigh of the system
       - B thermal/pressure cycling
       - C hydrostatic testing
     - iii the ability to build a structure to withstand the applied load
     - iv position of supports relative to plant and equipment
     - v vibration
   - b describe methods of accommodating the factors listed in a
     - i use of natural changes in direction of pipe
     - ii expansion loops
     - iii expansion fittings
       - A bellows
       - B sliding type
     - iv constant load adjustable spring hangers
     - v use of shock absorbers and shock absorbing materials
   - c describe types of pipe support in common use and their use
     - i single and multi-pipe hangers from flat bar
     - ii anchor brackets
     - iii pipe bridges and support trestles
     - iv cleats and clamping devices
     - v support rods and locking devices
     - vi intermediate pipe supports
     - vii guides
     - viii flanged
     - ix location and fixing of wind bracing and space supports

Unit 023 Composite fabrication

Rationale
This unit is concerned with the underlying process technology associated with wet lay ups involving dry cloths and resin together with pre-impregnated materials as used in composite fabrication.

It covers health and safety aspects, management of raw materials, construction and use of vacuum bagging, curing techniques appropriate to the application, position and size of the component, together with various lay-up techniques used in complex composite fabrication and repair.

Outcomes
There are four outcomes to this unit. The candidate will be able to
1 identify health and safety aspects of composite fabrication
2 prepare for efficient and effective production of composite fabrications
3 produce components using a range of techniques using resins, dry cloth and pre- impregnated reinforcement materials
4 monitor and check work conforms to specification.

Connection with other awards
This unit extends the knowledge contained in
Unit 23 Making components from composite materials Applying Engineering Principles Level 2
It relate to units 027-029, 033, 034, 037, 047-055 of the City & Guilds NVQ in Fabrication & welding (1681)
It also relates to the *OSCEng ECS* 1.12, 1.13, 1.17-1.20, 2.01, 2.04, 2.10, 2.12, 2.13, 2.15, 2.16, 3.02, 3.05, 3.11, 3.13, 5.07, 6.01-6.03, 6.06, 7.04, 8.01 and 8.02.

Assessment
The outcomes from this unit will be assessed using evidence from a centre devised assignment with will cover both practical activities and underpinning knowledge.

Outcome 1 Identify health and safety aspects of composite fabrication

Practical activities

The candidate will be able to
1 refer to the health and safety regulations applying to composite fabrication
2 recommend safety precautions, procedures and PPE to meet specific requirements
3 promote a safe and efficient preparation
4 investigate hazards and risks in a composite fabrication environment

Underpinning knowledge

The candidate will be able to
1. describe the implications of the health and safety legislation relating to composite fabrication
   - a Health and Safety at Work Act (HSaW) (1974)
   - b Control of Substances Hazardous to health (COSHH) (1988)
     - i risk assessment
     - ii consumable data sheets
     - iii safe working practices
     - iv training and awareness
   - c Provision and Use of Work Equipment (PUWER) (1988)
     - i scope within a composite fabrication environment
   - d Reporting Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) (1995)
     - i application to composite fabrication processes
       - A major injuries
       - B over three day injuries
       - C diseases
       - D dangerous occurrences
   - e Personal Protective Equipment at Work Regulations (PPE) (1992)
     - i application to composite fabrication processes
     - ii employers' duties
     - iii employers duties
     - iv protection against hazards
       - A resin and curing agents
       - B resin vapours
       - C solvents
       - D CFC dust
       - E airborne particles
       - F broken fibre
       - G disposal of CFC and waste resin
       - H noise
       - I contaminated materials
     - v factors that render PPE provided as protection against the above ineffective or unsafe
   - f Management of Health and Safety at Work Regulations (MHSWER) (1999)
     - i risk assessment
     - ii five steps to risk assessment
     - iii training and awareness

iv safe working procedures

g Highly Flammable Liquid and Liquefied Petroleum Gas Regulations (HFLLPG (1972) safe storage requirements of materials used in composite fabrication
    i Resins
    ii Catalysts
    iii Accelerators
    iv Solvents
    v Release agents
    A maximum storage limits (50 litres)
    B 1100% containment requirements against spillage

2. explain the fire hazards associated with composite fabrication
    a sources of combustion
    b identification of hazards
    c methods of avoiding risks
    d identification of suitable extinguishers
    e exothermic reaction – mixing of resins

3. safety precautions relating to FRP working environment
    a segregate from other working areas
    b correct number and type of fire appliances
    c eye washing facilities (10 min duration)
    d washing facilities
    e mixing area with dedicated ventilation
    f well ventilated working area
    g ample dedicated clearly marked waste bins
    h electrical sockets and equipment must meet approved safety standards (flash proof)
    i dedicated lockers (working clothes)
    j Pol lockers to be used for storage of flammable materials
    k CFC waste disposed of regularly
    l no sources of ignition
    m benches should have impervious coverings

Outcome 2 Prepare for efficient and effective production of composite fabrications

Practical activities

The candidate will be able to
1. identify a range of consumables/ancillaries required for a given process
2. select and justifies materials for a given application
3. identify material and resin requirements from a given specification
4. prepare an ordered schedule of activities for quality production of composite fabrications and composite repairs
5. apply calculation to determine the surface area of a component part and gel coat and resin quantities
6. prepare templates to determine the surface area of a component part and gel coat and resin quantities
7. select ancillary equipment required for composite fabrication and repair

Underpinning knowledge

The candidate will be able to
1. state construction techniques for composite fabrication/repair
    a contact moulding
        i hand lay-up
        ii spray
    b resin transfer moulding
    c sandwich construction

2. state factors influencing the selection of techniques named in 1
    a skill requirements
    b initial cost
    c versatility
    d running costs

3. state the limitations of the techniques named in 1
    a material type
        i dry cloth and resins
        ii pre-impregnated cloth
    b size of component
    c location of component

4. identify and select types of material/fibre for specific applications
    a glass
    b carbon fibre
    c aramid
    d peel ply
    e film adhesive

5. select and justify types of cloth weave patterns for reinforcement materials
   a plain weave
   b twill weave
   c satin weave
   d unidirectional weave
   e chopped strand mat
   f needleloom or needled mat
   g woven rovings

6. state reasons for the use of weave patterns and orientation named in 5

7. select and justify matrix systems
   a polyester
   b vinylester
   c epoxy

8. select techniques/methods available to ensure dry reinforcing materials are completely wetted
   a brushes
   b rollers
   c spray equipment

9. describe the storage and management for the use of
   a resin/adhesive and associated hardeners and accelerators
   b dry reinforcing materials
   c sized reinforcing materials
   d pre-impregnated reinforcing materials
   e film adhesives
   f peel ply

10. complete documentation required for the storage and use of materials named in 9

11. select the main components required for vacuum bagging
   a porous release film
   b absorption/bleeder cloth
   c non-porous release cloth
   d air breather
   e vacuum bag film
   f vacuum bag tape
   g various types of connections

12. interpret fibre resin ratios recommended by specifications and manufacturers data sheets (Volume Fraction VR(

13. use formula to calculate surface area
   a surface area of plane figures
   b irregular figures – use of Mid-ordinate or Simpson’s rule

14. use geometrical constructions to determine
   a sections and true shape of solids
   b cutting planes

15. use methods of surface development to determine shape of cloth size and resin quantity for
    - a mitre lines
    - b shaped components
    - c spherical corners

16. describe how to produce templates for
    - a reinforcement cloth and add information for effective use
    - b checking shape, size position of holes, apertures

17. describe how to select template material
    - a card
    - b metal
    - c melinex

18. describe how to use full size layouts to determine shape and size of cloth

19. describe how to complete planning sheets to estimate the quantities of
    - a reinforcing materials
    - b resins
    - c hardeners
    - d catalysts
    - e accelerators
    - f pigments

20. state the purpose of additives
    - a fillers
    - b colour pigments
    - c thixotropic agents

21. describe how to select materials for the sandwich construction
    - a foam
    - b wood
    - c metal
    - d aramid paper

22. state reasons for the use of ancillary equipment
    - a mould supports
    - b temporary moulds/formers where only one side is accessible
    - c platforms
    - d heater blankets
    - e heater lamps
    - f autoclave units
    - g hot bond controllers

23. state procedures required for moulds and formers prior to use to ensure quality production
    - a repair any damaged area
    - b clean mould face
    - c waxing
    - d buffing
    - e application of release agents
    - f correct alignment of split moulds
    - g joint lines filled

24. describe how to plan a procedure for carrying out composite repair
    a replacement of defective honeycomb/sandwich construction
    b defective panels fibre to fibre and fibre to metal using
        i dry reinforcing materials
        ii pre-impregnated
    c scarfed joints
    d lay up design for patch repairs
        i externally stepped run out
        ii internally stepped run out
        iii externally stepped run out with largest ply laid last

25. describe how to select tools and equipment to implement repairs listed in 24

Outcome 3 Produce components using various techniques using resin and dry cloth together with pre-impregnated materials

Practical activities

The candidate will be able to
1. prepare and use moulds, formers and templates
2. select and weigh resins
3. use templates for marking out reinforcement materials
3. prepare/cuts dry cloth and pre-impregnated reinforcement materials in readiness for manufacture
4. prepare a vacuum bag for a component part
5. lay up reinforcement materials in accordance with a specification
6. green trim component parts to meet specifications
7. apply curing techniques in accordance with specifications
8. prepare and set up curing equipment

Underpinning knowledge

The candidate will be able to
1. explain the related technology of mould and former design

2. describe procedures in mould and former preparation prior to use
   a repair any damaged area
   b clean mould face
   c waxing
   d buffing
   e application of release agents
   f assembly of complex moulds
   g correct alignment of split moulds
   h joint lines filled

3. extract information from working drawings and produce templates for marking out reinforcement material

4. apply the related technology in the mixing of resin systems
   a polyester
   b vinylester
   c epoxy

5. describe how to select resins in accordance with specifications and manufacturers' data sheets

6. state important factors for the preparation and use of resins
   a weigh quantities
   b mix quantities
   c cleanliness
   d shelf life
   e pot life

7. describe methods and procedures used for laying up of reinforcing materials
    a wet lay-ups by
        i hand
        ii spray
    b pre-impregnated materials

8. describe methods and procedures used for sandwich construction using
    a foam
    b wood
    c metal
    d aramid paper

9. describe methods of incorporating stiffening and load bearing areas into
    a laminates
    b honeycomb structures

10. describe methods and procedures used for composite repair
    a replacement of defective honeycomb/sandwich construction
    b defective panels fibre to fibre and fibre to metal using
        i dry reinforcing materials
        ii pre-impregnated
    c scarfed joints
    d lay up design for patch repairs
        i externally stepped run out
        ii internally stepped run out
        iii externally stepped run out with largest ply laid last

11. describe the construction of a vacuum bag
    a porous release film
    b absorption/bleeder cloth
    c non-porous release cloth
    d air breather
    e vacuum bag film
    f vacuum bag tape
    g connections required for vacuum pump

12. explain how to use and set up heating equipment for curing cycles

13. explain the requirements for the
    a assembly complex moulds and formers (split moulds
    b disassembly of complex moulds and formers

14. describe finishing requirements
    a when to green trim
    b removal of flash, apertures, flanges from mouldings
    c safe disposal of waste material
    d personal dust protective clothing worn

15. describe the cleaning requirements for tools and equipment following use

16. explain the hazards associated with composite fabrication and repair
    a resins and curing agents
        i damage to eyes
        ii skin disease
        iii be toxic
    b resin vapours
        i cause severe irritation to eyes, nose and throat
        ii irritation is more severe at elevated temperatures
    c solvents cause irritation/permanent damage to eyes and respiratory system
    d CFC dust causes irritation to eyes and respiratory system
    e broken fibres cause skin irritation

17. describe the safe disposal of waste material in accordance with current regulations
    a disposal of carbon fibre waste
        i through registered agents
        ii double seal bags
        iii use of dedicated waste bins
        iv use of impervious bags
        v segregated from domestic waste
            A labelled
            B do not burn
            C land fill only
            D toxic waste

Outcome 4 Monitor and check work conforms to specification

Practical activities

The candidate will be able to
1. inspect composite fabrications/repairs against drawing/specification
2. select methods tools and equipment to check composite fabrications
3. conduct cure hardness tests
4. conduct tests to determine volume fraction ratio (VR)
5. complete report forms

Underpinning knowledge

The candidate will be able to
1. interpret the specification/manufacturer's data sheets

2. select and use measuring equipment to check
   a linear dimensions
   b hole size, position
   c angular dimensions
   d squareness
   e close tolerance dimensions

3. describe how to establish datum surface/reference line

4. describe how to produce a level surface

5. identify defects that may occur in composite fabrication and knows procedures used to deal with them
   a variation in thickness
   b resin rich areas
   c shrinkage
   d crazing
   e delamination/gapping at edges
   f dry areas, poor consolidation
   g porosity/voids
   h over consolidation
   i spalling
   j disband

6. state tests used for inspection
   a visual
   b tap testing for delamination
   c ultrasonic inspection
   d cure tests

7. describe the methods used for testing in 6

8. state the type of failure that may result from specific defects

9. state the criteria for the selection of NDT and DT testing methods

10. state the reason for cure hardness testing
11. describe the procedure for conducting a cure hardness test
    a Barcol hardness test

12. describe how fibre resin ratio (VR) may be checked
    a comparison by calculated mass against actual mass
    b use of ash test on coupon test plates

13. describe how to complete inspection report forms

14. describe how to assess inspection results and make recommendations

Unit 024 Pattern development

Rationale
This unit is concerned with the process of obtaining flat layouts of 3D forms that can be used for producing templates to mark out the material for fabrication to the required form.
This unit combines and extends the knowledge and understanding contained in units: 019 Thick platework, 020 Sheet metalwork and 022 Pipe and tube fabrication.

Outcomes
There are five outcomes to this unit. The candidate will be able to
1 determine lines of intersection
2 develop patterns using parallel line techniques
3 develop patterns using radial line techniques
4 develop patterns using triangulation
5 use templates.

Connection with other awards
This unit relates to units 011-016 of the City & Guilds NVQ in Engineering woodworking and patternmaking (1685). It also relates to units 022-024 on the NVQ in Fabrication & welding (1681)
It also relates to the *OSCEng ECS* 1.02 and 1.14.

Assessment
The outcomes from this unit will be assessed using evidence from a centre devised assignment which will cover both practical activities and underpinning knowledge.

Outcome 1 Determine lines of intersection

Practical Activities

The candidate will be able to
1 determine lines of intersection using projection
2 determine lines of intersection using the principle of the common central sphere
3 determine lines of intersection using the method of cutting planes

Underpinning knowledge

The candidate will be able to
1 identify the use of projection to determine lines of intersection

2 identify the use of common central sphere to determine lines of intersection

3 identify the use of cutting planes to determine lines of intersection

4 explain how to determine of joint lines of ducts
   a where the centre lines lie on centre and in the same plane
   b a right angled tee piece of equal cross-section
   c a right angled tee piece of unequal cross-section
   d an oblique angled tee piece of equal cross-section
   e an oblique angled tee piece of unequal cross-section
   f junctions of three cylinders

5. identify how to use the principle of the common central sphere applied to multiple junction pieces involving right cylinders and right cones
   a use the principle of cutting planes to determine the lines of intersection of
      i right cylindrical branches onto transformer pieces
      ii oblique cones to right cones
      iii oblique cones to oblique cones
      iv inclined right cylinder branches on right cones on and off centre
      v cylindrical and rectangular branch intersections onto rectangular hoppers
      vi cylindrical and rectangular branches on spherical, doomed or dished ends

Outcome 2 Develop patterns using parallel line techniques

Practical Activities

The candidate will be able to

1. apply the parallel line method of pattern development to the forms identified in the underpinning knowledge

Underpinning knowledge

The candidate will be able to

1 identify the use of use parallel line techniques for the development of
   - a segmental bends (right cylindrical and oblique
   - b square or rectangular ducts cut obliquely
   - c right cylinders cut obliquely
   - d oblique cylinders cut obliquely

2. identify the use of parallel line techniques for the development of more complex forms
   - a branch pipes on to boiler, shells, dished ends and domed ends
   - b cylindrical branches onto right and cylindrical segmental bends to include interpenetration of the branch pipe
   - c square and rectangle branches onto right and oblique cones
   - d swan neck transition pieces, rectangle to rectangle in angular planes
   - e transition pieces of apparently twisted sides with openings at right angles and different levels

3. describe how to determine modified set-outs to accommodate plate thickness

4. identify the use of instructions added to templates and patterns produced by parallel line method enabling them to be used effectively.

Outcome 3 Develop patterns using radial line techniques

Practical Activities

The candidate will be able to

1. apply the radial line method of pattern development to the forms identified in the underpinning knowledge component of the unit

Underpinning knowledge

The candidate will be able to

1. describe the use of radial line techniques for the development of
   a. right cones and frusta
   b. oblique cones and frusta
   c. oblique cones cut by a flat surface
   d. oblique cones cut by a curved surface
   e. two way breeches piece made from right cones
   f. two-way breeches piece made from oblique cones

2. describe the use of radial line techniques for the development of more complex shapes
   a. right cones in multiple connections of right cylinders and right cones
   b. breeches pieces involving oblique cones
   c. tapered segmental bends (‘lobster back bends’

3. describe how to determine modified set-outs to accommodate plate thickness

4. describe the use of instructions added to templates and patterns produced by the radial line method enabling them to be used effectively

Outcome 4 Develop patterns using triangulation

Practical Activities

The candidate will be able to

1 apply the triangulation method of pattern development to the forms identified in the underpinning knowledge component of the unit

Underpinning knowledge

The candidate will be able to

1. describe the use of triangulation techniques for the development of
   a hoppers based on square or rectangular based pyramids
   b square or rectangle to round transformers
   c round to square or rectangle transformers
   d transformers and hoppers on and off centre, between parallel planes
   e transformers and hoppers between parallel and non-parallel planes

2. describe the use of triangulation techniques for the development of more complex shapes
   a rectangular to round off-set transformers on a roof apex
   b breeches pieces branching from cylindrical main to equal and unequal diameter ducts
   c rectangular kinked sided hoppers
      i kinked to produce maximum volume
      ii kinked to produce minimum volume
   d spiral blade segments by triangulation
   e application to
      i right cylinders
      ii oblique cylinders
      iii right cones
      iv oblique cones

3 describe how to determine modified set-outs to accommodate plate thickness

4 identify the use of instructions added to templates and patterns produced by the triangulation method enabling them to be used effectively

Outcome 5 Use templates

Practical Activities

The candidate will be able to
1 prepare templates for the marking out of a fabrication using pattern development techniques
2 use calculations to produce dimensions for checking templates
3 modify layouts to accommodated material thickness

Underpinning knowledge

The candidate will be able to
1 explain the reasons for templates
  a avoid repetitive measurement
  b avoid unnecessary material wastage
  c act as a guide to cutting process(es
  d means of checking
    i lengths
    ii angles
    iii shapes
    iv forms
  e precise method of marking hole positions
  f reliable means of assuring repeatability

2 state the applications for templates

3 state types of template
  a pattern development
  b internal
  c external
  d roof truss
  e gusset
  f back-marks
  g hole
  h bushed
  i box

4 describe the impact of new technology on templates and pattern development
  a use of CAD packages
    i standard CAD (eg AutoCAD)
    ii specialist packages (pattern development software)

5 describe template production techniques
  a template shop/loft
  b setting out floor

6 describe the tools used to produce templates
- a saws
- b planes
- c drills
- d marking gauge
- e steel rule
- f compasses
- g dividers
- h trammels
- i protractor
- j engineers square
- k flat square
- l straight edge
- m hammers
- n centre/nipple punches
- o chalk line and soft chalk
- p French chalk
- q coloured and indelible pencils/crayons

7 state materials used to produce templates
- a template paper
- b hardboard
- c timber
- d sheet metal
- e steel plate

8 describe the information contained on templates
- a job/contract number
- b size/thickness of material
- c steel section and length
- d quantity required
- e bending/folding instructions
- f orientation (eg 'this side up', 'left side', 'right hand', etc)
- g drilling requirements
- h cutting instructions
- i assembly reference mark
- j datum(s)

9 describe methods of checking templates by use of calculations
- a circumference of cylinder (πd)
- b cylinder template size (πdl)
- c angle at the apex of a developed cone pattern/half pattern
- d use of triangles
- e use of trigonometry

10 describe methods of marking out from templates, including
- a external forms
- b internal forms
- c holes
- d back marks
- e pitch
- f use of datums

Unit 025 Extrusion

Rationale
This unit is concerned with the technology and practices involved in the forming of components using extrusion processes. Although the unit covers the common extrusion techniques using metals and plastics materials it is demanding in terms of the technological content and the process variable candidates are expected to cover. The unit broadly covers health and safety, extrusion equipment and consumables (ie steels, non-ferrous alloys and polymers and the practicalities of producing a quality, extruded component to a profile and size of given specification.

Outcomes
There are four outcomes to this unit. The candidate will be able to
1 identify the factors that influence the design of extrusion equipment and ancillaries
2 specify the equipment and materials for carrying out the production of extruded sections
3 produce extruded components that conform to specification
4 monitor and control safe extrusion operations to provide a finished component to specification.

Connection with other awards
It relates to the *OSCEng ECS*
1.18-1.20, 2.05, 2.06, 2.10-2.13, 2.17, 3.02, 3.06, 3.13, 3.14, 3.15, 3.16, 6.01- 6.03, 6.05, 6.06 and 6.08.

Assessment
The outcomes from this unit will be assessed using evidence from a centre devised assignment which will cover both practical activities and underpinning knowledge.

Outcome 1 Identify the factors that influence the design of extrusion equipment and ancillaries

Practical Activities

The candidate will be able to

1 identify the design parameters for efficient extrusion productions
2 use component design specification to determine the extrusion process
3 use a range of extrusion parameters and relevant data to determine suitable techniques

Underpinning knowledge

The candidate will be able to

1 list the sources of data on alloys that can be extruded to aid the design process

2 state that the suitability of a material for extrusion depends on
   a the temperature range over which it takes place
   b stiffness of the material
   c inherent abrasive action of the material on the extrusion equipment (friction coefficient)

3 describe the influence of specific alloying elements on the grain structure, properties and behaviour of alloys used for extruded sections
   a aluminium
      i silicon
      ii magnesium
      iii copper
   b steel
      i carbon
      ii low alloy
      iii stainless
   c copper
   d copper alloys
      i brass (zinc)
      ii bronzes (tin, zinc, aluminium)
      iii nickel (cupro-nickels)

4 state the range of fillers for polymers (plastics materials

5 explain the plastic behaviour and deformation of materials during extrusion
   a direct
   b indirect

6 explain the purpose of metal treatments to achieve specific properties
   a grain refinement
   b modification
   c coatings
   d fillers

7 describe hot and cold extrusion processes

8 identify the range of common extrusion techniques
   a axially-symmetrical
   b impact
      i reverse
      ii Hooker
   c asymmetrical (irregular and multi exit)
   d bridge dies

9. state the types of die materials used for different processes

10. explain process limitations
   a material type
   b constant section
   c production rate
   d physical size

11. explain the principles of chamber design to ensure
   a maximum uniform force
   b uniform mandrel movement
   c uniform mandrel ram
   d uniform main ram
   e pressure pad
   f die support
   g efficient heating system
      i heat input and control
      ii insulation
   h ensure acceptable metal flow

12. explain the principles of extruded component design to
   a enable the formation of a complex, uniform section component
      i alloy composition
      ii minimum residual stress/distortion
      iii allow for adequate lubrication
   b aid end user assembly
      i replacing fabricated and cast sections by one single extrusion

13. describe the use and benefits of model making as an aid to the design process

14. explain the influence of die design on
   a material grain flow patterns
   b lubrication requirements
   c reduction ratios
      i 20:1
      ii 60:1
      iii 100:1
   d production rate
   e extrusion pressure
   f extrusion temperature

15. state the applications for extrusion processes
   a benefits
   b limitations

16. explain the purpose of additives used in the extrusion of polymers

17. describe heat treatment processes
    a. annealing
    b. solution treatment
    c. age hardening
    d. stress relief

18. state the volume, density and mass relationship for common extruded alloys
    a. steels
        i. plain carbon
        ii. low alloy
        iii. stainless
    b. copper
        i. pure
        ii. alloys
    c. aluminium
        i. pure
        ii. aluminium alloy
    d. polymers
        i. filled
        ii. unfilled

Outcome 2 Specify the equipment and materials for carrying out the production of extruded sections

Practical Activities

The candidate will be able to
1 identify the extrusion process for a given application
2 assess the suitability of extrusion processes for given applications
3 select and prepare equipment and materials for a given application

Underpinning knowledge

The candidate will be able to
1 explain the difference between direct and indirect (inverted processes)

2 state the factors influencing the selection of extrusion processes
   a unit section
      i lamellar (sheathed cable etc)
      ii tube
      iii solid
      iv irregular
   b unit size/shape
   c unit quantity
   d material type

3. describe the range of processes to for production
   a jobbing non-mechanised
   b mechanised (mechanised)
   c fully automated (computerised)

4 describe the equipment for extrusion processes
   a vertical impact press
   b horizontal impact press

5 describe the range of working parts of extrusion presses for metals
   a billet container
   b container liner
   c pressure pad
   d die
   e mandrel
   f mandrel arm
   g work ram
   h ram arm
   i main ram piston
   j heating element
   k telescopic guide arms
   l chamber housing
   m discharge conveyer systems

6 describe the range of die designs
- a square shoulder
- b taper
- c bell shape
- d taper and mandrel
- e porthole (tubes)

7 describe the range of working parts of extrusion presses for polymers
- a granule hopper
- b heating chamber and element
- c die
- d liner and collar
- e screw ram
- f hydraulic ram

Outcome 3 Produce extruded components that conform to specification

Practical Activities

The candidate will be able to
1. apply appropriate health and safety regulations to production techniques
2. produce an ordered schedule of activities that will ensure the production of quality extrusions
3. produce extrusions using a range of materials and techniques
4. prepare and implement a safe extrusion operation using the correct sequence for a given application

Underpinning knowledge

The candidate will be able to
1 state the current healthy and safety regulations in regard to handling raw materials and lubricants
   a Health and Safety at Work Act (HSaW 1974)
   b Control of Substances Hazardous to Heath (COSHH 1988)

2. state the environmental considerations for processes using organic
   a compounds
   b operator exposure
   c extraction requirements
   d disposal of waste material

3. list the correct tools, equipment and machinery to produce safely extruded components in metals and polymers

4. describe the correct sequence of operations to produce good quality extruded component components
   a set up process equipment
   b select and secure die
   c select and attach ram tool assembly
   d set extrusion pressure
   e set extrusion temperature
   f charge billet chamber/granule hopper
   g attach discharge conveyer system
   h apply finishing technique

5. state the temperature range settings for different materials lies between the minimum limit (work hardening) and the maximum limit ('hot-short')

6. state the temperature range settings for different materials
   a aluminium and aluminium alloys (450 º - 520 º C)
   b copper and brasses – (650 º - 720 º C)
   c low carbon and low alloy steels – (1050 º - 1250 º C)
   d stainless steels and cupro-nickels (1650 º - 1800 º C)
   e thermo-polymers (130 º -180 º C)

7. state that extrusion ram pressure ranges relate to
   a type of material
   b speed
   c temperature
   d die design
   e lubrication

8. state the range of ram pressures between 2000 and 25000MN

9. describe the principle of pneumatic accumulation to achieve high extrusion pressures

Outcome 4 Monitor and control safe extrusion operations to provide a finished component to specification

Practical Activities

The candidate will be able to
1. prepare and use a correct extrusion sequence safely for a given application
2. monitor a safe extrusion and finishing operation
3. perform tests on extrusions and use data to ensure conformity to specification

Underpinning knowledge

The candidate will be able to
1. state the factors that affect extrusion quality
   a use of correct process parameters at all stages of production

2. state the acceptable heating and applied pressure conditions to achieve quality extrusions avoiding imperfections and defects
   a steels
   b aluminium
   c copper
   d polymers

3. state the range of typical extrusion defects
   a 'extrusion defect' (piping)
   b transverse cracking
   c inclusions
   d impurities

4. describe how to remove post extrusion imperfections by 'end separation'

5. describe the importance of controlled lubrication to minimise defects and excessive wear on equipment

6. interpret the results of destructive examinations
   a micro
   b macroscopic
   c spectrographic

7. describe the destructive tests used to assess the quality and serviceability of extruded components
   a tensile strength
   b yield strength
   c fatigue strength
   d proof stress
   e ductility (impact)

8. describe the non-destructive tests used to assess the quality and serviceability of an extruded component
   a ultra sonic
   b radiography

9. use test data to perform calculations the results of which can be used to gauge the integrity of an extruded component

10. describe the common finishing and treatment processes
    a fettling
    b heat treatment
    c straightening
    d coating
    e surface treatments

11. describe the use of conveyor systems to control and manoeuvre extruded sections

Unit 026 Forging

Rationale
This unit is concerned with the technology and practices involved in the forming of components using forging processes. Although the unit covers the common forging techniques using ferrous and non-ferrous metals it is demanding in terms of the technological content and the process variable candidates are expected to cover. The unit broadly covers health and safety, forging equipment and consumables (ie alloy steels and non-ferrous alloys) and the practicalities of producing a quality, forged component to a profile and size of given specification.

Outcomes
There are four outcomes to this unit. The candidate will be able to
1 identify the factors that influence the design of forging equipment and ancillaries
2 specify the equipment and materials for carrying out the production of forged sections
3 produce forged components that conform to specification
4 monitor and control safe forging operations to provide a finished component to specification.

Connection with other awards
This unit relates to units 026 & 039 of the City & Guilds NVQ in Fabrication & welding (1681)
It relates to the *OSCEng ECS* 1.18-1.20, 2.05, 2.06, 2.10-2.13, 2.17, 3.02, 3.06, 3.13-3.16, 6.01-6.03, 6.05, 6.06 and 6.08.

Assessment
The outcomes from this unit will be assessed using evidence from a centre devised assignment which will cover both practical activities and underpinning knowledge.

Outcome 1 Identify the factors that influence the design of forging equipment and ancillaries

Practical Activities

The candidate will be able to
1 identify the design parameters for efficient forging productions
2 use component design specification to determine the forging process
3 use a range of forging parameters and relevant data to determine suitable techniques

Underpinning knowledge

The candidate will be able to
1 list the sources of data on alloys that can be forged to aid the design process

2 describe the influence of specific alloying elements on the grain structure, properties and behaviour of alloys used for forged sections
 a aluminium alloys
  i silicon
  ii magnesium
  iii copper
 b steels
  i carbon
  ii low alloy
  iii stainless
 c copper alloys
  i brass (zinc)
  ii bronzes (tin, zinc, aluminium)
  iii nickel (cupro-nickels)

3 explain the plastic behaviour and deformation of materials

4 explain the principle of recrystallisation of metals

5 state the importance of grain structure on the design strength of a forged component
 a distorted
 b coarse (grain growth)
 c fine

6 explain the purpose of metal treatments to achieve specific properties
 a grain refinement
 b heat treatment

7 describe hot and cold forging processes
 a temperatures
 b techniques

8 identify the range of common forging techniques
 a blooming down
 b smith forging
 c closed die forging

d machine forging (upset)

9. state the types of die, die block and materials used for different processes

10. explain process limitations
    a material type
    b constant section
    c production rate
    d physical size

11. explain the principles of die design to ensure
    a maximum uniform force
    b high tolerance mating faces
    c die cavity capacity (excess metal/flash gutter)
    d material grain flow patterns
    e optimum production rate
    f pressure resistance

12. explain the importance of maintaining
    a uniform ram movement
    b uniform die support (anvil)
    c efficient heating system
        i heat input and control

13 explain the principles of forged component design to
    a enable the formation of a complex, uniform section component
        i alloy composition
        ii minimum residual stress/distortion
        iii high strength
    b aid end user assembly
        i replacing fabricated sections by one single forging

14. describe the use and benefits of model making as an aid to the design process

15. state the applications for forging processes
    a benefits
    b limitations

16 describe heat treatment processes
    a annealing
    b solution treatment
    c age hardening
    d stress relief

17 state the volume, density and mass relationship for common forged alloys
    a steels
        i plain carbon
        ii low alloy
        iii stainless
    b copper alloys
    c aluminium alloys

Outcome 2 Specify the equipment and materials for carrying out the production of forged sections

Practical Activities

The candidate will be able to
1 identify the forging process for a given application
2 assess the suitability of forging processes for given applications
3 select and prepare equipment and materials for a given application

Underpinning knowledge

The candidate will be able to
1 state the factors influencing the selection of forging processes
   a unit size/shape
   b component finish
   c unit quantity
   d material type

2 describe the range of processes for production
   a smith forging
   b closed die forging
   c machine forging (upset)

3 describe the equipment for forging processes
   a vertical hydraulic press
   b double acting hammer press
   c board drop hammer
   d forging rolls
   e manual implements

4 describe the range of working parts of forging presses for metals
   a control valves
   b ram system
   c piston assembly
   d anvil arrangements
   e die (upper and lower)
   f heating systems
   g telescopic guide arms
   h buffer stations (holding unit
   i discharge conveyer systems

5 describe the die design arrangements for different processes to eliminate
   a abrupt changes in contour (stress raisers
   b rough surface profile
   c accurate billet to component volume ratio

6 state the length/diameter relationships

- a to avoid buckling of unsupported material
  - i L < 2.5D (L = protrusion from gripping die > 3D) where D = diameter of billet section
  - ii single stroke upset forging (L1 =/> Lo – 2.5D) where Lo = original billet length and L1 = length of forged component

7 describe the stages of forming (multiple operations) to produce a component

- a drop
- b hand (mechanically assisted)
- c roller

Outcome 3 Produce forged components that conform to specification

Practical Activities

The candidate will be able to
1 apply appropriate health and safety regulations to production techniques
2 produce an ordered schedule of activities that will ensure the production of quality forgings
3 produce forgings using a range of techniques
4 prepare and implement a safe forging operation using the correct sequence for
a given application.

Underpinning knowledge

The candidate will be able to
1. state the current healthy and safety regulations in regard to handling hot metals
   a Health surveillance in the foundry industry
   b Health and Safety at Work Act (HSaW) 1974
   c Control of Substances Hazardous to Heath (COSHH) 1988

2. state the environmental considerations for processes using organic compounds
   a operator exposure
   b extraction requirements
   c disposal of waste material

3. list the correct tools, equipment and machinery to produce safely forged components in metal alloys

4. describe the correct sequence of operations to produce good quality forged components
   a set up process equipment
   b select and secure upper and lower dies
   c set up ram tool assembly
   d set ram pressure

5 describe how to check the mathematical relationships
   a billet/component volume
   b material support length/billet diameter

6 describe how to set heating unit for billet working temperature

7 describe how to check alignment prior to operation

8 describe how to attach discharge conveyer system

9 describe how to apply finishing technique

10 state the approximate forging temperature ranges for common forged alloys
   a aluminium (320 - 480º C)
   b copper (450 - 1350º C)
   c carbon steels (760 - 1300º C)
   d low alloy steels (840 - 1200º C)

e stainless steels (850 - 1200º C)

11 state that forging ram pressure ranges relate to

- a type of material
- b speed
- c temperature
- d die design
- e lubrication

12 state the range of ram pressures between 1000 and 2000MN

13 describe the stages in forming a component

- a multiple hammer smith forging
- b blooming down
- c groove forming/multiple rollers
- d upset forging (double acting press)
- e cold heading

14 describe suitable applications for

- a multiple hammer smith forging
- b blooming down
- c groove forming/multiple rollers
- d upset forging (double acting press)

Outcome 4 Monitor and control safe forging operations to provide a finished component to specification

Practical Activities

The candidate will be able to
1 prepare and use a correct forging sequence safely for a given application
2 monitor a safe forging and finishing operation
3 perform tests on forgings and use data to ensure conformity to specification

Underpinning knowledge

The candidate will be able to
1 state the factors that affect forging quality
   a use of correct process parameters at all stages of production

2 state the acceptable heating and applied pressure conditions to achieve quality forgings avoiding imperfections and defects in metal alloys
   a steels (low alloy)
   b steels (stainless)
   c aluminium
   d copper

3. state the range of typical forging defects
   a billet kinking
   b flash line cracking
   c inclusions (overheated or burnt metal)
   d cold shuts
   e coarse grain
   f discontinuity in the fibre flow
   g poor impressions

4 describe how to remove post surface imperfections in forged components

5 describe how to remove grain structure imperfections in forged components

6. interpret the results of destructive examinations
   a micro
   b macroscopic
   c spectrographic

7. describe the destructive tests used to assess the quality and serviceability of forged components
   a tensile strength
   b yield strength
   c fatigue strength
   d proof stress
   e ductility (impact)

8. describe the non-destructive tests used to assess the quality and serviceability of a forged component
   a ultra sonic
   b radiography
   c dye-penetrant

9. describe how to use test data to perform calculations the results of which can be used to gauge the integrity of a forged component

10. describe the common finishing and treatment processes
   a fettling
   b heat treatment
   c coating
   d surface treatments

11 describe the use of conveyor systems to control and manoeuvre forged sections

Unit 027 Vacuum forming and moulding

Rationale

This unit is concerned with the technology and practices involved in the forming of components using vacuum forming and blow moulding processes. Although the unit covers the common process techniques using plastics materials it is demanding in terms of the technological content and the process variable candidates are expected to cover. The unit broadly covers health and safety, vacuum forming and blow moulding equipment and consumables (ie polymers- thermoplastic and thermosetting) and the practicalities of producing a quality, formed and moulded component to a profile and size of given specification.

Outcomes

There are four outcomes to this unit. The candidate will be able to

1. identify the factors that influence the design of forming and moulding equipment and ancillaries
2. specify the equipment and materials for carrying out the production of formed and moulded sections
3. produce formed and moulded components that conform to specification
4. monitor and control safe forming and moulding operations to provide a finished component to specification.

Connection with other awards

This unit relates to Units 039, 052 & 053 of the City & Guilds NVQ in Fabrication & welding (1681)
It relates to the *OSCENG ECS* 1.18, 1.19, 1.20, 2.05, 2.06, 2.10-2.13, 2.17, 3.02, 3.06, 3.13-3.16, 6.01-6.03, 6.05, 6.06 and 6.08.

Assessment

The outcomes from this unit will be assessed using evidence from a centre devised assignment, which will cover both practical activities and underpinning knowledge.

Outcome 1 Identify the factors that influence the design of forming and moulding equipment and ancillaries

Practical Activities

The candidate will be able to
1 identify the design parameters for efficient forming and moulding production
2 use component design specification to determine the forming/moulding process
3 use a range of extrusion parameters and relevant data to determine suitable techniques

Underpinning knowledge

The candidate will be able to
1 list the sources of data on polymers that can be moulded and formed to aid the design process

2 state that the suitability of a material for moulding and forming depends on the
  a temperature range over which it take place
  b type of polymer
  c forming or moulding technique
  d applied pressure

3 describe the influence of specific fillers on the molecular structure, properties and behaviour of polymers used for formed and moulded sections
  a stiffening (form stability)
  b resistance to environmental conditions
  c workability

4 state the range of fillers for polymers (plastics materials)
  a pigments
  b resins
    i plasticizing
    ii drying
    iii hardening
  c acidic solutions
  d alkali solutions
  e silicon

5 explain the behaviour of polymers under forming and moulding conditions (rheological properties)
  a thermoplastics
    i flow and workability
    ii softening temperature
  b thermosetting
    i controlled cross-linking
    ii permanence

6 explain the purpose of controlled heat and pressure to produce plastic flow

7 identify the range of common forming and moulding processes
- a vacuum forming
- b blow moulding
- c rotation moulding
- d compression moulding
- e transfer moulding
- f calendering
- g blown film

8 state the types of mould materials used for different processes

9 explain process limitations
- a material type
- b shape and section
- c production rate
- d physical size

10 explain the principles of equipment design to ensure
- a maximum uniform force (vacuum
- b smooth transfer of plastics material
- c controlled feed rates
- d die material and finish
- e efficient, controlled heating system
  - i heat input and control
  - ii insulation

11. explain the principles of vacuum formed and moulded component design to
- a enable the formation of a complex and/or uniform symmetrical section components
- b aid end user assembly by replacing multiple part components with one single component
- c produce large volume light containers
- d produce long continuous thin film sections

12 explain the influence of die design on
- a polymer flow patterns
- b surface finish and texture
- c production rate
- d forming/moulding pressure
- e process temperature

13 state the applications for forming and moulding processes
- a benefits
- b limitations

Outcome 2 Specify the equipment and materials for carrying out the production formed and moulded sections

Practical Activities

The candidate will be able to
1 identify the forming and moulding process for a given application
2 assess the suitability of vacuum forming and plastics materials moulding processes for given applications
3 select and prepare equipment and materials for a given application

Underpinning knowledge

The candidate will be able to

1 explain the difference between direct and indirect moulding/forming processes
   a pressure/vacuum assisted
   b direct contact shaping/working
   c combination of pressure and direct contact

2 state the factors influencing the selection of forming/moulding processes
   a unit section
      i film/lamellar/composite
      ii tube/container
      iii solid
      iv irregular
      v symmetrical
   b unit size/shape
   c unit quantity
   d polymer type

3 describe the range of processes for production
   a jobbing
   b mechanised (mechanised)
   c fully automated (computerised)

4 describe the working equipment for vacuum forming/blow moulding processes
   a mould chamber
   b heating coils/system
   c pattern/die tool
   d pressure/vacuum pump
   e clamping frames
   f releasing jets

5 describe the working equipment for compression and transfer moulding
   a heating and cooling platens
   b form dies/moulds
   c mould cavity
   d mould plunger
   e guide pins
   f hydraulic ram/piston
   g release jets

6 describe the working equipment for calendaring
   a extruded plastics material dough feed system
   b guide chute
   c compound rolls assembly
   d thermostatically controlled roll heating unit
   e post process conditioning unit
   f host coiling drum/reel
   g cooling chamber

7 describe the range of working parts of injection moulding equipment for polymers
   a granule hopper
   b heating chamber and element
   c die
   d liner and collar
   e screw ram
   f hydraulic ram

Outcome 3 Produce formed and moulded components that conform to specification

Practical Activities

The candidate will be able to

1. apply appropriate health and safety regulations to production techniques
2. produce an ordered schedule of activities that will ensure the production of quality formed and moulded components
3. produce formed and moulded components using a range of materials and techniques
4. prepare and implement a safe forming and moulding operation using the correct sequence for a given application

Underpinning knowledge

The candidate will be able to

1. state the current healthy and safety regulations in regard to handling raw materials and chemicals
   a. Health and Safety at Work Act (HSaW) 1974
   b. Control of Substances Hazardous to Heath (COSHH) 1988

2. state the environmental considerations for processes using organic compounds
   a. operator exposure
   b. extraction requirements
   c. disposal of waste material
   d. ambient working conditions

3. list the correct tools, equipment and machinery to produce safely components polymers
   a. thermoplastics materials
   b. thermosetting materials

4. describe the correct sequence of operations to produce good quality formed and moulded components
   a. set up process equipment
   b. select and secure die/mould/roll assembly
   c. select and attach appropriate ram tool assembly (where applicable
   d. set pressure/vacuum
   e. set temperature
   f. charge material feed system
   g. attach discharge conveyer system
   h. apply finishing technique as required

5. state the working parameters for thermosetting materials
   a. temperature range (150 º - 715 º C)
   b. applied pressure (10 - 40 MNm?^{2})

6. state the working parameters for different thermoplastics materials
   a. temperature range (200 º -300 º C)
   b. applied pressure (2 - 3 MNm?^{2}))

7. state the range of ram pressures between 2000 and 25000MN

8. describe the principles of using plastics materials for surface coatings

9. state that the use of plasticizers improves the flow and workability characteristics of polymers by lowering the glass transition temperature of the material

10. state that plasticizers must be compatible and result in structural permanence

Outcome 4 Monitor and control safe forming and moulding operations to provide a finished component to specification

Practical Activities

The candidate will be able to
1 prepare and use a correct forming/moulding sequence safely for a given application
2 monitor a safe forming/moulding and finishing operation
3 perform tests on finished component and use data to ensure conformity to specification

Underpinning knowledge

The candidate will be able to
1 state the factors that affect forming and moulding quality
 a use of correct process parameters at all stages of production

2 state the acceptable heating and applied pressure conditions to achieve quality products in thermoplastics materials
 a vacuum formed
 b blow moulded
 c calendered
 d blown film

3 state the acceptable heating and applied pressure conditions to achieve quality products in thermosetting plastics materials
 a compression moulded
 b transfer moulded
 c cast

4 state the range of typical formed and moulded defects
 a porosity
 b holes
 c inconsistent wall thickness/section
 d impurities
 e deformation

5 describe how to remove post forming/mouldings by recycling

6 describe the importance of controlled processing conditions to minimise defects and excessive wear on equipment

7 interpret the results of examinations
 a macroscopic
 b density

8. describe the destructive tests used to assess the quality and serviceability of extruded components
 a yield strength
 b fatigue strength

9. describe the ultra-violet light and polaroid scope used to assess the quality and serviceability of formed and moulded component

10. use test data to perform calculations the results of which can be used to gauge the integrity of formed and moulded components

11. describe the common finishing and treatment processes
    - a fettling/knifing
    - b sterilising

12. describe the use of conveyor systems to control and manoeuvre finished components

Unit 028 Mould and core production and casting

Rationale

This unit is concerned with the technology and practices involved in the moulding and core-making process and the production of castings. Although the unit covers the common mould and core production techniques and casting using sand as the base material it is demanding in terms of the technological content and the process variable candidates are expected to cover. The unit broadly covers health and safety, mould, core and casting equipment and consumables (ie metals, sands, binders/additives) and the practicalities of producing a quality, cast component from a pattern of given specification.

Outcomes

There are four outcomes to this unit. The candidate will be able to

1 identify the factors that influence the design moulds, cores and castings
2 specify the equipment and materials for carrying out the production of moulds and cores
3 produce moulds, cores and castings that conform to specification
4 monitor and control safe casting operations to provide a finished component to specification

Connection with other awards

This unit relates to units 004-013 of the City & Guilds NVQ in Materials processing & finishing (1683)
It also relates to the *OSCEng ECS* 1.18-1.20, 2.05, 2.06, 2.10-2.13, 2.17, 3.02, 3.06, 3.13-3.16, 6.01-6.03, 6.05, 6.06 and 6.08.

Assessment

The outcomes from this unit will be assessed using evidence from a centre devised assignment, which will cover both practical activities and underpinning knowledge.

Outcome 1 Identify the factors that influence the design moulds, cores and castings

Practical Activities

The candidate will be able to
1 identify the design parameters for efficient for efficient casting productions
2 use casting design data to determine the casting process
3 use a range of mould-making and core-making parameters to determine suitable techniques

Underpinning knowledge

The candidate will be able to
1 list the sources of casting alloys data to aid the design process

2 describe the influence of specific alloying elements on the grain structure, properties and behaviour of casting alloys
- a aluminium
  - i silicon
  - ii magnesium
  - iii copper
- b cast iron (basic)
  - i carbon
  - ii silicon
  - iii phosphorous
  - iv sulphur
  - v manganese
- c cast iron (alloy)
  - i magnesium
  - ii nickel
  - iii chromium
- d brass
- e bronze
- f magnesium
- g steel (carbon and stainless)
- h zinc

3 explain the purpose of metal treatments to achieve specific properties
- a grain refinement
- b modification
- c spheroidising
- d inoculation

4 state the range of common casting processes
- a clay-bonded sand
- b diecasting
- c shell
- d investment
- e silicate-bonded sand
- f no-bond sand systems
- g centrifugal techniques

5. state the types of pattern/die materials used for different processes

6. explain process limitations
   - a casting
     - i profile (shape
     - ii alloy type)
   - b alloy type
   - c jobbing
   - d mechanised
   - e automated (robotics)

7. explain the principles of casting design to ensure minimum stresses to
   - a avoid cracking and distortion
     - i design profile/shape
     - ii restraint
       - A mould/core
       - B die/core
     - iii alloy composition and conductivity
     - iv heat input and distribution
     - vi mould/core restraint
     - viii casting sequence
   - b ensure directional solidification
     - i good temperature gradient to avoid hot spots
   - c ensure acceptable metal flow
     - i small cast products
     - ii thin sections
     - iii alloy composition
       - A phosphorous in cast iron

8 explain the principles of cast-weld design to
   - a enable the thermal joining of several castings to form a single component
     - i alloy composition
     - ii minimum residual stress/distortion
   - b aid end user assembly
     - i replacing multiple assembled castings by one single casting

9 describe the use and benefits of model making as an aid to the design process

10 state the range of processes available for mould and core production

11 explain the influence of mould/die design on solidification rates and properties of casting

12 state the application for mould and core production processes
   - a benefits
   - b limitations

13 explain the purpose of binders and additives used in mould and core production

14 state the need to test core and mould making materials prior to use to avoid casting defects

15. state the range of mixtures used to produce casting in ferrous and non-ferrous alloys
    a clay bonded
    b silicate
    c resin mix

16. briefly describe the preparation of pattern and core box equipment and constituent parts to ensure correct casting production

17 state the necessary pattern-making allowances for ferrous and non-ferrous casting alloys to allow for
    a contractions
    b camber
    c residual stress

18 describe heat treatment processes
    a annealing
    b solution treatment
    c age hardening
    d stress relief

19. state the volume, density and mass relationship for common casting alloys
    a cast iron
    b aluminium/aluminium alloy

Outcome 2 Specify the equipment and materials for carrying out the production of moulds and cores

Practical Activities

The candidate will be able to
1 identify the sand process for a given application
2 select and prepare the equipment and materials for a given application
3 use standard tests to verify the suitability and quality of foundry sands
4 specify any treatments necessary to ensure casting quality

Underpinning knowledge

The candidate will be able to
1 state the factors influencing the selection of mould-making and core-making processes
   a unit size/shape
   b unit quantity
   c casting alloy

2 describe the range of mould and core processes to for production
   a jobbing (hand
   b mechanised (machine assisted
   c fully automated (machine controlled

3 state the range and types of sand and mixtures for mould-making and coremaking
   a natural
   b synthetic
   c silica
   d zircon
   e chromite

4 describe the difference between natural and other sand bonding systems available to
   a improve surface finish
   b improve breakdown properties
   c minimise mould/metal reactions
   d reduce casting defects

5 state the classification of binders into organic and non-organic
   a polymerisation
   b gels

6 state the range and types of binder and additives used with sands and clay(s)
   a oils
   b silicates
   c resins
   d coal dust (including substitutes
   e cereals
   f chemical inhibitors

7 describe the types of sand mould process and preparation methods compatible with production requirements
   a green sand
   b sodium silicate/CO2
   c air set sodium silicate
   d air set resins
   e full mould

8 describe the types of sand core-making process and preparation methods compatible with production requirements
   a gas cured resins
   b heat cured resins
   c sodium silicate/CO2
   d air set sodium silicate
   e air set resins

9 list pattern and corebox materials used to ensure casting quality
   a wood
   b metal
   c resin
   d polystyrene

10 describe the types of mould and core-making machines suitable for production requirements

11 the tools and equipment requirements for each stage of the mould and core-making operations

12 describe the equipment and features for checking sand quality
   a storage facility
   b weighing devices
   c standard rammer
   d air ovens
   e compression tester

13 state the factors considered in the testing of sands to meet production requirements
   a calculation of
      i moisture content
      ii shatter index
   b compression strength
      i green
      ii dry
   c permeability
   d sieve analysis
   e compactability

14 describe coring and closing procedures for maintaining absolute cleanliness of mould cavity

15. describe molten metal treatments that produce pouring quality liquid metal
   a degassing
   b inoculation
   c modification

16. state the SI units of measurement for tested variables

Outcome 3 Produce moulds, cores and castings that conform to specification

Practical Activities

The candidate will be able to
1 apply appropriate health and safety regulations to production techniques
2 produce an ordered schedule of activities that will ensure the production of quality moulds, cores and castings
3 produce moulds and cores using a range of techniques
4 prepare and implement a safe casting operation using the correct sequence for
a given application

Underpinning knowledge

The candidate will be able to
1 state the current healthy and safety regulations in regard to handling mould, core- making materials and liquid metals
   a Health surveillance in the foundry industry
   b Health and Safety at Work Act 1974 (HSaW)
   c Control of Substances Hazardous to Health (1988 (COSHH)

2 state the environmental considerations for processes using organic compounds
   a operator exposure
   b extraction requirements
   c disposal of spent sand

3 list the correct tools, equipment and machinery to produce safely moulds, cores and cast components

4 describe the correct sequence of operations to produce good quality cast components
   a moulding
   b core-making
   c coring
   d closing
   e casting
   f knocking out
   g finishing

5 describe the techniques used to aid compaction during mould and core-making
   a vibration
   b diaphragms
   c adjustable heads

6 state the correct and safe procedure for
   a operating sand mixers and mills
   b sequence of additions and timings for sand mixers
   c calibrating continuous mixer requirements (checking sand and binder throughput)
   d charging and discharging sand preparation equipment

7 explain the operation for producing sand moulds
  a two-part
  b multi part

8 describe the range of mould-making techniques
  a odd sides
  b parting down
  c mould reinforcement
  d stop off pieces
  e drawbacks
  f cover cores
  g loose pieces

9 describe the use of sand systems
  a using mould boxes
  b not using mould boxes

10 describe the melting characteristics of common ferrous and non-ferrous alloys

11 describe the pouring requirements for liquid alloys
  a temperature
  b mould entry speed

12 describe the position of feeders and gating systems to produce quality castings

Outcome 4 Monitor and control safe casting operations to provide a finished component to specification

Practical Activities

The candidate will be able to
1 prepare and use a correct casting sequence safely for a given application
2 monitor a safe casting and finishing operation
3 perform tests on castings and use data to ensure conformity to specification

Underpinning knowledge

The candidate will be able to

1. state the factors that affect casting quality
   a use of correct process parameters at all stages of production

2. state the acceptable melting and casting conditions to achieve quality cast alloys avoiding dross/slag/gas/explosions
   a iron
   b magnesium
   c aluminium
   d steel

3. describe how to remove runners and feeders effectively

4. describe the knock out requirements and procedure to maintain casting quality

5. describe the reclamation processes for different sand processes
   a attrition
   b thermal

6. interpret the results of destructive examinations
   a micro
   b macroscopic
   c spectrographic

7. describe the destructive tests used to assess the quality and serviceability of a finished casting
   a hardness
   b tensile strength
   c proof stress
   d ductility (impact

8. describe the non-destructive tests used to assess the quality and serviceability of a finished casting
   a ultra sonic
   b radiography

9. use test data to perform calculations the results of which can be used to gauge the integrity of a finished casting

10. describe the common defects associated with poor
    a melting and casting practice
    b mould-making
    c core-making
    d coring and closing practices

11. describe the common finishing and treatment processes
    a machining
    b grinding
    c welding
    d heat treatment
    e straightening
    f impregnation

12. describe the use of jigs and fixtures to manipulate castings to enable assessment against specification

Unit 029 Specialised casting processes

Rationale
This unit is concerned with the technology and practices involved in process and the production of castings using specialised processes. Although the unit covers the common production techniques using die casting, centrifugal and investment processes it is demanding in terms of the technological content and the process variable candidates are expected to cover. The unit broadly covers health and safety, die, mould, core and casting equipment and consumables (ie metals, refractories, lubricants etc.) and the practicalities of producing a quality, cast component from a mould or die of given specification.

Outcomes
There are four outcomes to this unit. The candidate will be able to
1 identify the factors that influence the design of moulds, cores and dies for castings
2 specify the equipment and materials for carrying out the production of moulds, cores and dies
3 produce moulds, cores, dies and castings that conform to specification
4 monitor and control safe casting operations to provide a finished component to specification.

Connection with other awards
This unit relates to units 004-013, 022-025 of the City & Guilds NVQ in Materials processing & finishing (1683)

It also relates to the *OSCEng ECS* 1.18-1.20, 2.05, 2.06, 2.10, 2.11-2.13, 2.17, 3.02, 3.06, 3.13-3.16, 6.01-6.03, 6.05, 6.06 and 6.08.

Assessment
The outcomes from this unit will be assessed using evidence from a centre devised assignment which will cover both practical activities and underpinning knowledge.

Outcome 1 Identify the factors that influence the design of moulds, cores and dies for castings

Practical Activities

The candidate will be able to

1 identify the design parameters for efficient for efficient casting productions
2 use casting design data to determine the casting process
3 use a range of mould, core and die making parameters to determine suitable process and techniques

Underpinning knowledge

The candidate will be able to

1 list the sources of casting alloys data to aid the design process

2 describe the melting characteristics of common alloys
   a ferrous
   b non-ferrous

3. explain the purpose of metal treatments to achieve specific properties
   a grain refinement
   b modification
   c spheroidising
   d inoculation
   e fluxing

4. identify the range of die casting processes
   a gravity
   b low pressure
   c high pressure

5. identify the range of specialised casting processes
   a shell
   b block
   c investment
   d centrifugal
      i true
      ii semi

6. state the range of materials used for die-cast components
   a zinc/zinc based alloys
   b aluminium/aluminium based alloys
   c magnesium/magnesium based alloys

7. state the range of materials used for shell/investment/ centrifugal cast components
   a steel
   b copper/copper alloys
   c cast iron

8. state the materials used for cores in die-casting
   a sand

b metal

9. list the range of diecoatings
   - a lubricating
   - b insulating

10. describe the types of core/die/pattern materials used for different processes
   - a dies
     - i cast iron
     - ii alloy steels
     - iii refractories and binders
   - b moulds and cores
     - i sands/shell
     - ii resins (cold set)
   - c patterns
     - i waxes

11. explain process limitations
   - a casting
     - i size
     - ii profile (shape)
     - iii alloy type
   - b alloy type
   - c jobbing
   - d mechanised
   - e automated (robotics)

12 explain the principles of casting design to ensure minimum stresses to
   - a avoid cracking and distortion
     - i design profile/shape
     - ii restraint
       - A mould/core
       - B die/core
     - iii alloy composition and conductivity
     - iv heat input and distribution
     - v mould/core restraint
     - vi casting sequence
     - vii ensure directional solidification
     - viii good temperature gradient to avoid hot spots
   - b ensure acceptable metal flow
     - i small cast products
     - ii thin sections
     - iii alloy composition
       - A phosphorous in cast iron

13 describe the use and benefits of model making as an aid to the design process

14 state the range of processes available for die, mould and core production

15 explain the influence of mould/die/refractories design on solidification rates, structure and properties of casting
   - a strength
   - b surface finish
   - c homogeneity (freedom form defects)

16 state the application for mould and core production processes
   a benefits
   b limitations

17 explain the purpose of binders and additives used in mould and core production

18 state the need to test core and mould making materials prior to use to avoid casting defects

19 describe heat treatment processes
   a annealing
   b solution treatment
   c age hardening
   d stress relief

20 state the volume, density and mass relationship for common casting alloys
   a cast iron
   b aluminium/aluminium alloys
   c zinc/magnesium based alloys

21 state the SI units of measurement for tested variables

Outcome 2 Specify the equipment and materials for carrying out the production of moulds, cores and dies

Practical Activities

The candidate will be able to
1 identify the process and technique for a given application
2 select and prepare the equipment and materials for a given application
3 use standard tests to verify the suitability and quality of casting materials
4 specify any treatments necessary to ensure casting quality

Underpinning knowledge

The candidate will be able to
1. state the factors influencing the selection of casting processes
   a cost
   b technical considerations
   c manual/automated/mechanised
   d component specification

2. state the range of applications the diecasting processes
   a benefits
   b limitations

3. describe the equipment for diecasting
   a gravity (manual and machine
   b cold chamber
   c hot chamber

4. describe the types of diecasting machines compatible with production requirements
   a manual
   b automation
   c robotics

5. state the factors influencing the selection of mould-making and core-making processes
   a unit size/shape
   b unit quantity
   c casting alloy

6. describe the range of mould and core processes to for production
   a jobbing (hand
   b mechanised (machine assisted
   c fully automated (machine controlled

7 state the range and types of sand and mixtures for mould-making and core-making
   a natural (silica
   b synthetic
   c grain size

d location

8 explain how grain size distribution and binder additions influence the properties of sands
   a strength
   b permeability
   c loss on ignition

9 describe the difference between natural and other sand bonding systems available to
   a improve surface finish
   b improve breakdown properties
   c minimise mould/metal reactions
   d reduce casting defects

10 state the classification of binders into organic and non-organic
   a polymerisation
   b gels

11. describe the types of mould and core-making machines suitable for production requirements

12. the tools and equipment requirements for each stage of the mould core and die making operations

13. describe the equipment and features for checking sand quality
   a storage facility
   b weighing devices
   c standard rammer
   d air ovens
   e compression tester

14. state the factors considered in the testing of sands to meet production requirements
   a calculation of
      i moisture content
      ii shatter index
      iii compression strength
      iv green
      v dry
   b permeability
   c sieve analysis
   d compactability

15. describe coring and closing procedures for maintaining absolute cleanliness of mould/die cavity

16. describe molten metal treatments that produce pouring quality liquid metal
   a degassing
   b inoculation
   c modification
   d fluxing

Outcome 3 Produce moulds, cores, dies and castings that conform to specification

Practical Activities

The candidate will be able to
1 apply appropriate health and safety regulations to production techniques
2 produce an ordered schedule of activities that will ensure the production of quality moulds, cores/ dies and castings
3 produce moulds, cores and dies using a range of techniques
4 prepare and implement a safe casting operation using the correct sequence for
a given application

Underpinning knowledge

The candidate will be able to
1. state the current healthy and safety regulations in regard to handling mould, core and die –making materials and liquid metals
   a Health surveillance in the foundry industry (HSC) 1998
   b Health and Safety at Work Act (HSaW) 1994
   c Control of Substances Hazardous to Health (COSHH) 1998

2. state the environmental considerations for processes using organic compounds
   a operator exposure
   b extraction requirements
   c disposal of spent sand

3. list the correct tools, equipment and machinery to produce safely, moulds, cores, dies and cast components

4. describe the correct sequence of operations to produce good quality cast components
   a investment
      i pattern construction
      ii mould-making (shell, block)
      iii de-waxing
      iv positioning for pouring
      v knocking out
      vi finishing
   b centrifugal
      i preparing die surface
      ii setting machine
      iii setting conditions for pouring
      iv facilitating die rotation
      v ejecting casting
      vi dressing

5. describe the techniques used to aid compaction during mould and core-making
   a vibration
   b diaphragms
   c adjustable heads

6. state the correct and safe procedure for
   - a operating sand mixers and mills
   - b sequence of additions and timings for sand mixers
   - c calibrating continuous mixer requirements (checking sand and binder throughput)
   - d charging and discharging sand preparation equipment

7. describe the correct sequence of operations to produce good quality die cast components
   - a preparing die surface
   - b coring
   - c assembling die
   - d closing
   - e locking
   - f injecting
   - g setting dwell allowance
   - h ejecting casting
   - i finishing

8. describe the operation of centrifugal casting machinery
   - a horizontal
   - b semi-centrifuge
   - c centrifuge (multiple mould)

9. describe the operation of moulding processes
   - a shell
     - i dump box
     - ii sand and binder arrangement
     - iii pattern plate
     - iv pattern
     - v ejector mechanism
   - b investment
     - i master pattern
     - ii wax insert/component pattern
     - iii support plate
     - iv investment material
     - v heating source
     - vi pressure chamber (indirect arc process

10. describe the range of die casting machinery using metal dies
   - a direct air
   - b cold chamber
   - c Polak
   - d Gooseneck

11. describe the operation of die casting machinery using metal dies
    a gravity fed
        i setting die temperature
        ii fixing die assembly
        iii determining pouring speed
        iv determining coating requirements
        v setting locking mechanism
        vi ejecting casting
        vii finishing
    b pressurised
        i fixing machine framework
        ii setting power systems
        iii setting die temperatures
        iv determining pouring speeds
        v determining coating requirements
        vi setting metal transfer system
            A manual
            B automatic
        vii setting locking system
        viii setting injection system
            A hot chamber
            B cold chamber
        ix setting ejection and core pull systems
        x controlling power
        xi finishing

12. describe the application of different mould-making techniques

13. describe the use of sand systems
    a using mould boxes
    b not using mould boxes

14. describe the pouring requirements for liquid alloys
    a temperature
    b mould/cavity entry speed

15. describe the position of feeders and gating systems to produce quality castings

16. describe the use of job cards for ensuring consistent quality on high production processes

Outcome 4 Monitor and control safe casting operations to provide a finished component to specification

Practical Activities

The candidate will be able to

1. prepare and use a correct casting sequence safely for a given application
2. monitor a safe casting and finishing operation
3. perform tests on castings and use data to ensure conformity to specification

Underpinning knowledge

The candidate will be able to

1 state the factors that affect casting quality
- a use of correct process parameters at all stages of production

2 state the acceptable melting and casting conditions to achieve quality cast alloys avoiding dross/slag/gas/explosions
- a magnesium
- b aluminium
- c cast iron

3 describe how to remove runners and feeders effectively

4 describe the knock out requirements and procedure to maintain casting quality

5. describe the correct ejection techniques to prevent
- a cracking
- b distortion

6. describe common defects associated with specialised processes
- a die casting
  - i misrun
  - ii porosity
  - iii voids
  - iv shrinkage
  - v cracking
- b centrifugal and investment
  - i cracking
  - ii porosity
  - iii inclusions
  - iv casting fins

7. describe the reclamation processes for different core sand processes
- a attrition
- b thermal

8. interpret the results of destructive examinations
   a micro
   b macroscopic
   c spectrographic

9. describe the destructive tests used to assess the quality and serviceability of a finished casting
   a hardness
   b tensile strength
   c proof stress
   d ductility (impact

10. describe the non-destructive tests used to assess the quality and serviceability of a finished casting
    a ultra sonic
    b radiography
    c dye-penetrant

11. use test data to perform calculations the results of which can be used to gauge the integrity of a finished casting

12. describe the common finishing and treatment processes
    a machining
    b grinding/fettling
    c welding
    d heat treatment
    e straightening
    f impregnation

13. describe the use of jigs and fixtures to manipulate castings to enable assessment against specification

Unit 030 Pattern and model-making

Rationale
This unit is concerned with the technology and practices involved in the pattern and engineering model-making process. Although the unit covers pattern and model-making techniques using conventional hand and machine operations it is demanding in terms of the technological content and the process variable that candidates are expected to cover. The unit broadly covers health and safety, pattern and model-making equipment and consumables (ie metals, woods, plasters, clays, rubbers, resins and plastics materials) and the practicalities of producing a quality pattern to a given specification.

Outcomes
There are four outcomes to this unit. The candidate will be able to
1 identify the factors that influence the design and production of patterns and engineering models
2 specify the equipment and materials for carrying out the production of patterns and engineering models
3 produce patterns and engineering models that conform to specification
4 monitor and control safe pattern and model-making operations to provide a finished component to specification.

Connection with other awards
This unit relates to units 011-020 of the City & Guilds NVQ in Engineering woodworking, pattern & model making (1685)
It also relates to the *OSCEng ECS* 1.18-1.20, 2.05, 2.06, 2.10, 2.11-2.13, 2.17, 3.02, 3.06, 3.13-3.16, 6.01-6.03, 6.05, 6.06 and 6.08.

Assessment
The outcomes from this unit will be assessed using evidence from a centre devised assignment which will cover both practical activities and underpinning knowledge.

Outcome 1 Identify the factors that influence the design and production of patterns and engineering models

Practical Activities

The candidate will be able to

1 identify the design parameters for efficient pattern and model-making production
2 use design specifications and data to determine the process requirements
3 use a range of pattern and model-making parameters to determine suitable processes and techniques

Underpinning knowledge

The candidate will be able to

1 list the British and International standards and relate the terminology to pattern and model-making production

2 state the factors influencing the design and selection of the method of constructing patterns
- a strength
- b rigidity
- c density
- d shape
- e doweling requirements
- f rapping
- g lifting and handling facilities
- h cost

3 explain the influence of pattern design in preventing casting defects
- a material
- b changes in section
- c contour and angles
- d riser position
- e surface texture

4 describe the solutions for minimising casting defects through pattern design using
- a camber
- b padding
- c tee bars
- d cracking webs

5 describe the purpose of using full size pattern-makers' layouts marked on wood for determining complex models, pattern and corebox construction

6 explain the difference between an engineering drawing and a pattern layout

7 state the key information gained from pattern layouts
  a optimum construction method
  b joint positions
  c methods of fixing
  d core prints
  e cutting lists

8 describe the methods for determining
  a taper allowances
  b machining allowances
  c contraction allowances
  d coreprint type
  e cutting lists

9 explain how to interpret drawings to prepare specifications for
  a patterns
  b engineering models
  c moulds
  d cores
  e castings
    i machine parts
    ii vessels/containers
    iii engineering assemblies

10 explain how to transfer grid lines from a design brief to set out the production parameters for a clay model using
  a tabulation from X,Y and Z planes
  b datum points
  c line and tape drawing techniques

11 explain the precedence for one-off engineering components
  a time saving
  b safety imperative
  c operational requirements
  d shape complexity
  e dimensional accuracy

Outcome 2 Specify the equipment and materials for carrying out the production of patterns and engineering models

Practical Activities

The candidate will be able to
identify the pattern/model-making process for a given application
access the suitability of pattern/model-making processes for given applications
select and prepare equipment and materials for a given application

Underpinning knowledge

The candidate will be able to

1 state the types of pattern equipment
   a one-piece
   b flat back
   c shell
   d split
   e skeleton
   f strickles
   g sweeps
   h plated

2 describe the methods of pattern construction
   a box
   b segment
   c solid
   d split
   e open joint
   f lag
   g stave

3 state the factors limiting process applications
   a production costs
   b production rate
   c material specification
   d pattern/model size and shape

4 state the methods used in pattern construction to reduce warping and shrinkage

5 describe the techniques used to produce patterns for open, multi-part and core assembly moulds
   a jointing
   b use of dowels
   c fillets
   d fillers
   e carving
   f surface finishing

6 describe the methods used to produce pattern plates

7 explain the application of moulding aids
- a oddsides
- b loose pieces
- c stopping-off pieces
- d cover cores
- e drawbacks

8 state the range of materials used in pattern and model-making
- a clay(s
- b timbers
  - i natural
  - ii synthetic
  - iii laminate
- c metals
  - i pure
  - ii alloys
- d plastics materials (including additives)
  - i thermosetting
  - ii thermoplastics
- e resins
- f plasters
- g waxes
  - i soluble
  - ii insoluble
- h rubbers
  - i natural
  - ii synthetic
- i ceramics
- j carbon

9 state the range of styling and modelling operations used with clays
- a jointing methods for buck building
- b working and fixing
- c layering of clays
- d use of templates
- e section templates

10 state the factors influencing the selection of clay styling and modelling operations
- a composition and workability
- b strength
- c handling and storage
- d surface finish
- e type of coatings

11 state the features/properties that influence the selection of pattern and model-making materials
- a timber
  - i seasoning and grading
  - ii resistance to warping and shrinkage
  - iii resistance to common defects
  - iv storage requirements
  - v handling and workability

b metals and alloys
  i ductility
  ii wear resistance
  iii corrosion resistance
  iv strength
  v machinability
  vi thermal stability and behaviour

12 state the factors influencing the choice of material for pattern and model-making
  a properties
    i mechanical
    ii thermal
  b surface finish/texture
  c density
  d casting
    i production quantity
    ii production method
  e cost

13 state the range of finishing materials used in pattern and model-making
  a solvents and thinners
  b primers
  c paints
  d varnishes
  e abrasive papers and compounds

14 state the jointing devices used for pattern and model-making
  a adhesives
  b screws
  c nails
  d dogs
  e clamps
  f jigs and fixtures

15 state the jointing devices used in buck construction of clay models
  a adhesives
  b woodscrews
  c pins
  d rawl-plugs

16 describe the range and safe operation of equipment used in pattern and model-making operations
- a hand tools
  - i files
  - ii rasps
  - iii planes
  - iv chisels
  - v hammers and mallets
  - vi radii formers
  - vii sleekers
  - viii clamps and fixing devices
  - ix stapler
  - x screwdrivers
  - xi drilling jigs
  - xii centring devices
  - xiii machine vices
  - xiv angle plates
  - xv parallel and ‘V’ blocks
  - xvi scrapers
    - A flat
    - B curved
- b hand power tools (mains and battery)
  - i drilling machines
  - ii screwdrivers
  - iii saws
    - A circular
    - B jig
  - iv routers
  - v planes
  - vi sanders
    - A disc
    - B belt
    - C orbital
  - vii rotating tables
- c power tools
  - i bench drilling machines
  - ii pedestal drilling machines
  - iii lathes
  - iv sanding and bobbing machines
  - v bandsaw
  - vi circularsaw
  - vii planing machines
  - viii planning/thicknessing machines

17 explain the applications of machine tools for
- a finish planning (facing)
- b thicknessing
- c finish sanding
- d profile sanding
- e edging
- f rebating
- g bevelling
- h chamfering

Outcome 3 Produce patterns and engineering models that conform to specification

Practical Activities

The candidate will be able to
1 apply appropriate health and safety regulations to production techniques
2 produce an ordered schedule of activities that will ensure the production of quality patterns and engineering models
3 prepare and implement safe pattern and model-makings operation using the correct sequence for a given application
4 produce patterns and engineering models using a range of techniques

Underpinning knowledge

The candidate will be able to
1 state the current healthy and safety regulations in regard to handling mould, core- making materials and liquid metals
   a Health surveillance in the foundry industry
   b PUWER
      i Abrasive wheels
      ii Electricity at work
   c HSaW
   d COSHH

2. list the correct tools, equipment and machinery to produce safely
   a patterns
   b engineering models
   c clay models

3. describe the correct sequence of operations to produce good quality patterns and engineering models to include
   a marking out and laying out
   b template preparation
   c marking out
   d positioning and workholding
   e cutting and shaping (hand and machine operations
   f drilling, tapping chain linked holes
   g countersinking
   h counterboring
   i trepanning
   j spot facing and boring

4 describe the procedures for producing, in a range of materials
   a datums
   b flat surfaces
   c curves
   d holes/bores
   e fillets
   f radii
   g edge profiles
   h locating holes and collars
   i locating pins and dowels

5 describe the procedures for producing dimensions, in clay
   a flat surfaces
   b surfaces (square to each other or to base board)
   c surfaces parallel to opposing face or base board
   d smooth surface
   e true radii and contour blended

6 describe the handing and assembly of component parts to form a complete pattern or engineering model

7 explain mirror imaging for symmetrical shaped multi part patterns and engineering models

8 describe the range and application of finishing techniques used to protect and display a finished pattern or engineering model
   a painting
      i brush
      ii spray
   b varnishing

Outcome 4 Monitor and control safe pattern and model-making operations to provide a finished component to specification

Practical Activities

The candidate will be able to

1. prepare and use a correct pattern/model-making sequence safely for a given application
2. monitor a safe pattern/model-making and finishing operation
3. inspect patterns/models and use data to ensure conformity to specification

Underpinning knowledge

The candidate will be able to

1. state the factors that affect pattern and engineering model-making quality
   a. use of correct process parameters at all stages of production

2. state the actions necessary to rectify deviations from efficient process operation
   a. alter working parameters
   b. use alternative process/technique
   c. use alternative materials

3. state the tolerance levels that should be achieved and how they vary across different processes

4. describe safe and efficient methods of removing excess material

5. state the key dimensional properties to be measured
   a. length
   b. flatness
   c. parallelism
   d. surface roughness
   e. angles
   f. profiles
   g. relative position
   h. roundness and concentricity
   i. accuracy of form

6. define the terminology of measurement in relation to specification
   a. indicated size
   b. reading
   c. mean size
   d. reading value
   e. measuring range
   f. tool accuracy

7 state the tools and equipment used for measuring and checking relative position
   a surface plates and tables
   b vee-blocks
   c spirit levels
   d straight edges
   e feeler gauges
   f cylindrical gauges
   g taper pin gauges
   h electronic and digital measuring devices

8 state the general rules of accuracy in relation to
   a acceptable tolerances
   b standard temperature 20°C

9 state the procedure for pattern/corebox inspection and testing

10 state the factors controlling the accuracy of machines
   a suitability of machine for operation
   b condition of machine
   c suitability and condition of tools
   d workholding devices
   e feed rates
   f operator competence

11 state the checking procedure for clay ovens
   a correct temperature
   b unit correctly sealed/closed
   c clean trays
   d reclaimed clay free from contamination
   e extraction systems operational
   f operator PPE/RPE

12 describe the treatments required to finish clay modelling

13 describe the safety precautions to be taken when finishing patterns and engineering models using
   a paints
   b varnishes
   c solvents

Unit 031 Manufacturing machinery and ancillary systems

Rationale

This unit is concerned with the routine maintenance, repair and modifications to all types of manufacturing machinery.

This consists of machine tools (drills, lathes, millers, grinders (precision and off hand), power saws and boring machines). It includes the mechanical and fluid power features of NC and CNC machines and robots, but NOT the control systems.
It also covers rolling mills, extrusion equipment and presses, filling, bottling and packaging plant and conveying and transfer equipment (but not as fork lift trucks and cranes or other mobile devices).

Candidates will not usually be expected to know the constructional features of the components of hydraulic, pneumatic or refrigeration systems, or other specialist equipment, only the function of each. However they should be able to apply general engineering principles to identify the causes of a fault and safely carry out any replacements needed to bring the equipment back on line.

Outcomes

There are four outcomes to this unit. The candidate will be able to

1 identify the components and features of utilities
2 plan and prepare for the maintenance or installation operation
3 carry out inspections, maintenance or installation tasks
4 commission or re-commission the system, restore the work area and store resources correctly.

Connection with other awards

This unit relates to units 006-009, 021, 022. 024, 026-029 of the City & Guilds NVQ in Engineering maintenance (1688)

It also relates to *OSCEng ECS* 2.10-2.16, 4.01-4.05, 4.07, 4.08, 5.01-5.17, 6.01-6.08 and 7.01-7.03.

Assessment

The outcome from this unit will be assessed using evidence from a centre devised assignment which will cover both practical activities and under pinning knowledge.

Outcome 1 Identify components and ancillary equipment used with manufacturing machinery, their principles and operation

Practical Activities

The candidate will be able to
1. identify machinery /ancillary equipment by visual examination in conjunction with system drawings.
2. specify the function of each piece of machinery and its application in relation to other equipment.
3. select components to meet specified functions as required for maintenance using manufacturers' data and information.

Underpinning knowledge

The candidate will be able to
1. describe the general principles of construction of machinery to obtain
   a strength
   b rigidity
   c stiffness

2. state the principles of friction related to applied loads and surface finish

3. state the different types of slideways and methods of adjustment
   a vee
   b flat
   c dovetail
   d circular

4. describe the general construction of clutches (friction and dog) and braking systems

5. describe coolant supply methods to cutting tools (soluble and straight oils)
   a pump types
   b filtration and cooling requirements

6. state the fitting and adjustment methods for types of bearings
   a plain and taper roller
   b self aligning bearings
   c recirculatory ball types

7. describe the types and uses of belt and chain drives
   a alignment of pulleys and chain wheels
   b refitting single vee belts and matched sets
   c correctly tensioning belts and chains

8. describe the different gear forms and their applications
   a spur
   b helical
   c bevel
   d rack and pinion

e worm and wormwheel

9. state the meaning of gear terminology
   a addendum, dedendum and clearance
   b diametral pitch, circular pitch and module

10. state the materials used for gear construction
   a cast iron
   b alloy steels (including surface hardened)
   c non ferrous alloys (brass and bronze derivations)
   d plastics

11. state how to calculate gear ratios for the types listed in ‘8’ (including simple and compound trains)

12. state the relationship between torque and power transmitted and the loads on gear teeth

13. explain why end thrust may result from some gear forms and how it is overcome

14. describe common gear defects and state the likely causes
   a pitting
   b scoring and scuffing
   c flaking

15. describe gear box layouts and means of selecting different output speeds

16. state the common thread forms used on machine drives and their applications
   a vee
   b square (including multi-start)
   c Acme

17. describe the relationship between the lead of a screw and the motion transmitted

18. describe the methods of engaging screw drives
   a fixed nuts
   b split nuts

19. state the principles of cams in terms of lift, dwell and types of motion produced

20. state the principles of fluid power systems as applied to manufacturing machinery

21. state the function of basic hydraulic components and how they are used in a simple system
   a reservoirs
   b pumps
   c actuators (rotary and linear)
   d valves and the methods of operation (mechanical and pilot)
      i directional control
      ii flow control
      iii pressure control
      iv uni-directional

22. describe the methods of providing clean, dry air to a machine tool from the air mains

23. describe the function of basic pneumatic components and their applications in a simple system
    a actuators
    b valves and the methods of operation (mechanical, pilot and electrical solenoid)
        i directional control
        ii flow control
        iii pressure control
        iv uni-directional
    c pneumatic/hydraulic pressure intensifiers
    d silencers

25. describe the methods for testing machinery, equipment and auxiliary components for
    a dimensional accuracy
    b flatness and wind
    c roundness
    d surface finish

26. describe the methods of testing machinery and equipment for movements and alignment
    a parallel
    b squareness
    c concentricity
    d alignment of shafts to BS 3170

27. describe the setting of guards, stops and automatic safety cut-outs

Outcome 2 Plan and prepare for the maintenance or installation operation

Practical activities

The candidate will be able to
1. identify the type and extent of work to be carried out
2. relate current legislation and codes of practice to the given tasks
3. carry out a risk assessment by listing the procedures and requirements for setting up safe working conditions
4. collect manufacturers' information, related work records, circuit diagrams and other necessary data
5. check availability of materials, tools and equipment and prepare requisitions or works orders as required
6. assemble all tools, materials and other equipment that will be needed

Underpinning knowledge

The candidate will be able to
1. describe the layout, function of components and operational features of the manufacturing machinery and system to be installed or maintained
   a special considerations as prescribed by the manufacturer
   b the methods of lifting, supporting, or otherwise making system components safe
   c how the work to be undertaken may interact with or affect other systems or production facilities

2. state the specific implications of Statutory Regulations, Codes of Practice related to installing or maintaining steam generation systems
   a disposal of toxic waste and other such substances as defined by COSHH and Environmental Protection Acts
   b pressure systems and portable gas containers
   c working at heights and in confined spaces

3. identify the methods of isolating the equipment or system
   a isolating switches
   b removal of fuses
   c closing and 'locking off' of valves
   d removal of valves and blanking of pipes

4. state procedures for de-pressurising systems and testing them to be in a safe condition

5. describe the procedure for draining oil or other such substances and their safe and legitimate disposal

6. state the need for providing equipment to deal with
   a spillage and contamination (including any special PPE such as breathing apparatus
   b fire
   c personal injury

7. state the emergency shut down and evacuation procedures for the work area

Outcome 3 Carry out inspections and general maintenance tasks

Practical Activities

The candidate will be able to

1. carry out a maintenance OR pre-installation inspection on manufacturing machinery, equipment or systems
2. diagnose and repair a faulty system and/or components OR install a system

Underpinning knowledge

The candidate will be able to

1. describe the methods used to avoid distortion and damage to, or leakage from, pipework
   a disconnecting
   b aligning
   c connecting

2. list the procedure needed to safely and effectively dismantle components
   a make identification (witness marks) on components so that they can be correctly reassembled or re- aligned
   b label and safely store parts that have been removed

3. state the precautions needed to avoid danger from, or damage to, components whilst installing, dismantling and assembling from
   a misalignment
   b use of wrong tools or excessive force
   c uncontrolled release of springs
   d scoring of surfaces.

4. state how to protect dismantled components from contamination
   a blanking off open ports
   b use of correct cleaning agents and lint free cloths

5. identify the essential points to be checked when inspecting manufacturing machinery and components
   a bearing surfaces
   b erosion and pitting
   c split or worn seals
   d signs of overheating (colour changes
   e condition of filters for signs of metallic or other particles, indications of emulsions or oil deterioration

6. state the procedures for re-assembling components to avoid damage using the approved sequence for tightening bolts and applying specified torque and the application of lubrication to seals

7. state the need for correctly labelling re-built components for replacement in a system or returning to stores

8. describe routine tests for
   a checking oil for signs of oxidation and acidity
   b bench testing re-assembled components.
   c pressure testing pipework and pressure vessels

9. list the precautions to be taken when refilling systems with specified oils

10. describe methods of safely bleeding systems to eliminate air locks and avoid spillage

11. state the different ways of presenting information that can be used to appraise the outcome of a maintenance or installation activity

Outcome 4 De-isolate, commission or re-commission the system, restore the work area and resources

Practical Activities

The candidate will be able to
1. bring the system on line and adjust as required until the working parameters have been fully met
2. restore work areas to a clean and safe condition on completion of maintenance or installation
3. identify hazardous substances that may have been used or discovered during the work and give the approved method of disposal for each such substance.
4. specify any work needed for the restoration of work areas.
5. hand over the system to the authorised persons
6. complete a report on the actions taken.

Underpinning knowledge

The candidate will be able to
1. state the precautions to be taken when
   a refilling or recharging systems
   b opening up the system to the sources of pressure

2. describe methods of safely draining, bleeding and purging systems to avoid undue leakage or contamination

3. state how to set up and test interlocks, sensors and limit switches

4. list the sequence of bringing systems back to the specified working conditions by
   a removal of protective covers and blanks
   b opening appropriate valves or switches
   c operating the system under gradually increasing pressures or loads

5. identify any materials used that are classified as hazardous and those that can be recycled

6. state the methods of securing pipework and safety fittings (guards, handrails)

7. state the necessity for, and methods of, reporting any damage caused by the maintenance or installation activity where additional restoration work may be needed
   a brickwork
   b grouting
   c plastering
   d decorating

8. describe methods of replacing insulation, lagging and other protective coverings

9. state methods of applying identification markings to different parts of a system
    a. colour identification of pipework to BS1710
    b. using appropriate and approved codings for electrical connections and components

10. state the need to let all interested parties know of any changes that may affect the operation of the system, or of any new conditions that could exist in the work area.

11. state the procedure for terminating any ‘Permits to Work’ that have been implemented

12. explain how any work termination documents or reports that may be required are completed and passed on to an authorised person

Unit 032   Utilities systems

Rationale
This unit is concerned with identifying the maintenance and/or installation requirements of utilities systems needed for industrial purposes. These include compressed air, electricity and steam (but not boilers.)

The unit will cover system layouts and their main components, the selection and use of appropriate tools and equipment, the procedures and techniques involved with safely installing and isolating systems, removing or replacing components, commissioning, or restoring, a system to a fully operative condition

Outcomes
There are four outcomes to this unit. The candidate will be able to
1 identify the components and features of utilities
2 plan and prepare for the maintenance or installation operation
3 carry out monitoring, inspection and maintenance or installation work.
4 commission or re-commission the system, restore the work area and resources.

Connection with other awards
This unit relates to units 010-019, 022, 023, 025, 026, 029, 030, 033, 034, 038 & 043 of the City & Guilds NVQ in Engineering maintenance (1688)

It also relates to the *OSCEng ECS* 2.10 –2.16, 4.01-4.05, 4.07-4.08, 5.01-5.07, 6.01-6.08 and 7.01-7.03.

Assessment
The outcomes from this unit will be assessed using evidence from a centre devised assignment which will cover both practical activities and underpinning knowledge.

Outcome 1 Identify the components and features of utilities

Practical Activities

The candidate will be able to
1. identify components from circuit or plant diagrams using current standards.
2. trace utilities systems and make labelled circuit diagrams to show the positions of main or designated components within the systems
3. use manufacturers' data to determine the suitability of components and equipment for specified purposes

Underpinning knowledge

The candidate will be able to
1. describe the nature and behaviour of air
   a dangers of compressed air
   b relationships between force, area and pressure and how to use them for calculations
   c relationships between volume, temperature and pressure and how to use them for calculations
   d relative humidity and its relationship with air pressure and temperature

2. describe different types of air compressor and state their performance capability in terms of pressure and volumetric output of free air delivered (FAD) for
   a piston types – single stage and multi-stage
   b screw
   c centrifugal

3. describe the basic component parts and layout of each type of compressor listed in 2

4. state the purpose of intercoolers and aftercoolers and describe their construction and layout

5. state the need for air receivers
   a their function
   b associated essential equipment fitted to receivers
   c legal requirements for installation, inspection and testing.

6. state the need for air dryers and describe the common types
   a absorption
   b adsorption
   c refrigerant types (super dryers

7. describe the main features of pipework and systems used for supplying compressed air
    a factors affecting pressure drops and flow rates and the relationships between these and pipe sizes.
    b how information can be obtained by the use of nomograms.
    c pipework materials and applications
    d methods of connecting and supporting different forms of pipework with respect to access and vibration
    e mains layouts – methods of isolating, draining (including slope and 'take off' arrangements
    f the costs associated with air leaks
    g service units – filters, pressure regulators and lubricators

8. describe the nature of steam and its properties
    a heat transfer principles and the applications to heat exchangers
    b calculation of heat flows (Temperature difference x Surface area x Heat transfer coefficient)
    c heat content of steam, relationships between pressure and temperature (basic use of steam tables)

9. identify types of steam and their applications
    a saturated
    b dry saturated
    c superheated

10. describe the main features of pipework and systems used for supplying steam
    a materials and applications
    b connecting methods for HP and LP systems
    c flanged joints (screwed and welded)
    d pipe support systems to allow for expansion and vibration
    e jointing materials (fibre based, corrugated metallic and spiral wound
    f lagging and insulation
    g causes and prevention of water hammer
    h drainage methods, manual cocks and steam traps

11. describe the functions and main features of drain coolers, condensers and condensate return systems

12. describe the types and main features of steam valves used for
    a system isolation and safety
    b pressure reduction and control
    c flow control

13. state the uses of LP and exhaust steam for fan heaters, calorifiers and economisers

14. state the meaning of common electrical terms and state their units and relationships as applicable
    a voltage, current and resistance (basic Ohms Law)
    b power, voltage and current (relationship between electrical and mechanical power
    c heating and magnetic effects
    d ac and dc voltages differences and applications

15. describe different electrical supply systems and their applications and limitations
    a supply from grid
    b 3 phase 4 wire
    c single phase
    d 12V and 24V requirements and uses

16. describe the types and uses of transformers (fixed and portable)

17. describe isolating and control methods
    a isolators and circuit breakers
    b switchgear and distribution panels
    c fuses, no-volt release and residual current detectors

18. describe different methods of electrical distribution, their applications and limitations
    a cable forms and selection (size, insulation– including IMS and screened)
    b cable protection methods including conduit and armoured
    c bus bars
    d extension reels (heating effects on coiled cable)

19. describe the use of meters for testing continuity, voltage and resistance

Outcome 2 Plan and prepare for the maintenance or installation operation

Practical activities

The candidate will be able to

1. identify the type and extent of work to be carried out
2. relate current legislation and codes of practice to the given tasks
3. carry out a risk assessment by listing the procedures and requirements for setting up safe working conditions
4. collect manufacturers' information, related work records, circuit diagrams and other necessary data
5. check availability of materials, tools and equipment and prepare requisitions or works orders as required
6. assemble all tools, materials and other equipment that will be needed

Underpinning knowledge

The candidate will be able to

1. describe the layout, function of components and operational features of the utilities system to be installed or maintained
   a special considerations as prescribed by the manufacturer
   b the methods of lifting, supporting, or otherwise making components safe
   c how the work to be undertaken may interact with or affect other systems or production facilities

2. state the specific implications of Statutory Regulations, Codes of Practice related to installing or maintaining utilities
   a disposal of toxic waste and other such substances as defined by COSHH and Environmental Protection Acts
   b pressure systems and portable gas containers
   c working at heights and in confined spaces
   d electrical installations and testing of equipment and appliances according to the IEE and Electricity at Work Regulations

3. identify the methods of isolating the equipment or system
   a isolating switches
   b removal of fuses
   c closing and 'locking off' of valves
   d removal of valves and blanking of pipes

4. state procedures for de-pressurising systems (including air receivers and storage vessels) and testing them to be in a safe condition.

5. describe the procedure for draining oil or other such substances and their safe and legitimate disposal

6. state the need for providing equipment, including any special PPE, to deal with
   a spillage and contamination
   b fire
   c personal injury

7. state the emergency shut down and evacuation procedures for the specific work areas

Outcome 3 Carry out monitoring, inspection and maintenance or installation work

Practical Activities

The candidate will be able to
1. carry out a maintenance OR pre-installation inspection on factory/plant equipment or systems
2. diagnose and repair a faulty system and/or components OR install a system

Underpinning knowledge

The candidate will be able to
1. describe the methods used to avoid distortion and damage to, or leakage from, pipework
   a disconnecting
   b aligning
   c connecting

2. state the precautions needed to avoid danger from, or damage to, components whilst installing, dismantling and assembling from
   a misalignment
   b use of wrong tools or excessive force
   c uncontrolled release of springs
   d scoring of surfaces.

3. state the need for protecting components and systems from contamination by
   a blanking off open ports
   b using correct cleaning agents and lint free cloths.
   c storing parts in appropriate containers

4. state methods of making identification (witness) marks on components so that they can be correctly reassembled or re- aligned

5. list the essential points to be checked when inspecting components or equipment either before or during the maintenance or installation activity
   a bearing or other contact surfaces
   b signs of corrosion and/or erosion (internal and external
   c visible external condition
   d split or worn seals
   e signs of overheating (colour changes
   f condition of filters
      i excessive pressure drops (choking
      ii signs of metallic or other particles
      iii indications of emulsions or oil deterioration

6 describe how to remove, fit and replace
   a bearings
   b seals
   c springs
   d circlips
   e keys
   f brushes

7. describe how to prepare or make new gaskets or joints (including preparation of surfaces and/or housings) and repack glands

8. list the procedures for assembling or re-assembling components to avoid damage using the approved sequence for tightening bolts and applying specified torque and the recommended lubrication methods

9. describe methods of bench testing re-assembled components.

10. describe how to hydraulically pressure test pipework and pressure vessels

11. describe the methods of testing electrical equipment/circuitry for insulation and continuity

12. state the need for correctly labelling unused or re-built components that are to be returned to stores

Outcome 4 De-isolate, commission or re-commission the system, restore the work area and resources

Practical Activities

The candidate will be able to
1 bring the system on line and adjust as required until the working parameters have been fully met
2. restore work areas to a clean and safe condition on completion of maintenance or installation
3. identify hazardous substances that may have been used or discovered during the work and give the approved method of disposal for each such substance.
4. specify any work needed for the restoration of work areas.
5. hand over the system to the authorised persons
6. complete a report on the actions taken.

Underpinning knowledge

The candidate will be able to
1. state the precautions to be taken when
   a refilling or recharging systems
   b opening up the system to the sources of pressure (particular attention to steam)

2. describe methods of safely draining, bleeding and purging systems to avoid undue leakage or contamination

3. state how to set up and test interlocks, sensors and limit switches

4. list the sequence of bringing systems back to the specified working conditions by
   a removal of protective covers and blanks
   b opening appropriate valves or switches
   c operating the system under gradually increasing pressures or loads

5. describe methods of securing pipework, cables and safety fittings (guards, handrails)

6. identify any materials used that are classified as hazardous and those that can be recycled

7. state the necessity for, and methods of, reporting any damage caused by the maintenance or installation activity where additional restoration work may be needed
   a brickwork
   b grouting
   c plastering
   d decorating

8. describe methods of replacing insulation, lagging and other protective coverings

9. state methods of applying identification markings to different parts of a system

a colour identification of pipework to BS1710

b using appropriate and approved codings for electrical connections and components

10. state the need to let all interested parties know of any changes that may affect the operation of the system, or of any new conditions that could exist in the work area

11. state the procedure for terminating any ‘Permits to Work’ that have been implemented

12. explain how any work termination documents or reports that may be required are completed and passed on to an authorised person

Unit 033 Factory/plant services

Rationale
This unit is concerned with identifying the maintenance and/or installation requirements of systems commonly used in industrial plant and premises. These include heating and ventilation, fresh water and waste, low water systems, fuel and gas storage and distribution.

The unit will cover system layouts and their main components, the selection and use of appropriate tools and equipment, the procedures and techniques involved with safely isolating systems, removing and replacing components, and restoring a system back to a full working condition.

Outcomes
There are four outcomes to this unit. The candidate will be able to
1 identify the components and features of factory/plant services
2 plan and prepare for the maintenance or installation operation
3 carry out monitoring, inspection and maintenance or installation work.
4 commission or re-commission the system, restore the work area and resources.

Connection with other awards
This unit relates to units 001-004, 009, 010, 029-042 of the City & Guilds NVQ in Engineering maintenance (1688)

It also relates to the *OSCEng ECS* 2.10 –2.16, 4.01-4.05, 4.07-4.08, 5.01-5.07, 6.01-6.08 and 7.01-7.03.

Assessment
The outcome from this unit will be assessed using evidence from a centre devised assignment which will cover both practical activities and under pinning knowledge.

Outcome 1 Identify the components and features of factory plant services

Practical activities

The candidate will be able to
1. identify components from circuit or plant diagrams using current standards. (BS 1553)
2. follow service systems and make labelled circuit diagrams to show positions of main components within the systems
3. use manufacturer's data to determine the suitability of components for specified purposes in terms of applied loads, pressure, flow, capacity and temperature

Underpinning knowledge

The candidate will be able to
1. describe the different cold, hot and process water supply and disposal methods
    - a the nature of water and the treatments required
        - i acidic and alkaline – corrosive effects
        - ii dissolved solids – effects and softening processes
        - iii bacterial content and treatment
        - iv un-dissolved solids – erosion
    - b storage requirements and methods – including cleansing and testing services
    - c types of water pump
        - i positive displacement
        - ii centrifugal
    - d types of valve
        - i isolating (gate and screw down)
        - ii pressure control including relief
        - iii flow control
    - e pipework requirements
        - i materials
        - ii joining methods and fittings by means of flanged and screwed connectors
        - iii the use of elbows and T-connectors.
        - iv identification and protection – lagging and tracing
    - f heat exchangers
        - i single and multi-pass
        - ii calorifiers
    - g water sprinkler systems, detector types and testing
    - h storage and settling tanks
    - i arrangements for the disposal of
        - i clean and contaminated waters
        - ii toxic liquid waste

2. state the properties and requirements of fuel oil systems
    - a basic fuel characteristics and combustion principles
        - i air/fuel mixture
        - ii flammability and explosion
        - iii viscosity and flow characteristics
        - iv light and heavy types and applications

b safety precautions when storing, handling and supplying fuels
  i types of tank and content measuring methods
  ii need for barrier walls and spillage trenches
  iii isolating and emergency procedure
  iv warning and information signs and notices
c types of fuel pump
  i positive displacement
  ii centrifugal
d types of valve
  i isolating (gate and screw down)
  ii pressure control
  iii flow control
e pipework
  i materials
  ii joining methods and fittings (elbows, Y and T connectors)
  iii identification (to BS 1710) and protection – lagging and tracing

3. state the properties and requirements for gases and supply systems
  a types of gas for fuel and processing applications
    i propane
    ii acetylene
    iii oxygen
    iv ammonia
    v nitrogen
    vi argon
  b storage methods and requirements
    i identification of cylinders and lines
    ii ventilation
    iii flame proof switches
    iv securing cylinders
    v security of access
  c safe practices for filling and distribution
  d procedures for evacuating pipework and disposal of contents removed according to current legislation
  e methods of testing for gas presence and leaks.
  f procedures to be followed when detected gas levels are unsafe
  g line purging and pressure testing techniques
  h types of valve used for plant and services equipment
    i isolating (gate and screw down
    ii pressure control
    iii flow control

4. state the principles of heating and ventilating systems
  a the requirements for acceptable habitability in terms of temperatures, humidity, airborne particles, fumes, odours and bacterial content
  b recommended number of air changes for welding shops, general workshops, office blocks, stores and warehouses
  c the relationships between air velocity, ducting area and volume of air delivered using simple calculations or data tables
  d 'U' values of common construction materials - wood, bricks, concrete, insulation
  e factors affecting pressure drops and losses in a system
  f specific heat values for air and water and steam
  g sources of heat into an area
    i external from solar radiation

ii internal from electrical equipment and occupants

h basic heating and ventilating components and their symbols according to current BS and ISO standards

i changeover, bypass and isolating valves and their methods of actuation (manual, mechanical, electrical)

ii circulating pumps

iii heating and cooling units components (including drainage systems)

iv humidifiers

v fans (centrifugal and axial)

vi the effect of fan speed and power needed for different airflow rates

vii filtration units

viii large particle extraction (wood chips and similar particulates)

i the methods of mounting and fixing the items listed in h

j types of pipework and ducting.

i materials for construction and insulation

ii flange connecting methods

iii noise reduction baffles

k the layouts of

i hot water central heating systems

ii single and double duct systems (with heater and cooler elements, etc)

l monitoring and control of systems

i from a central control point

ii local sensors and overrides

iii testing of cooling water sources for bacterial content (Legionella)

iv automatic recorders for the analysis of system operation and efficiency

Outcome 2 Plan and prepare for the maintenance or installation operation

Practical activities

The candidate will be able to
1. identify the type and extent of work to be carried out
2. carry out a risk assessment by listing the procedures and requirements for setting up safe working conditions
3. collect manufacturers' information, related work records, circuit diagrams and other necessary data.
4. check availability of materials, tools and equipment and prepare requisitions or works orders as required
5. assemble all tools, materials and other equipment that will be needed

Underpinning knowledge

The candidate will be able to
1. describe the layout, function of components and operational features of the plant or services system to be installed or maintained
   a special considerations as prescribed by the manufacturer
   b the methods of lifting, supporting, or otherwise making system components safe
   c how the work to be undertaken may interact with or affect other systems or production facilities

2. state the specific implications of Statutory Regulations, Codes of Practice related to installing or maintaining utilities
   a disposal of toxic waste and other such substances as defined by COSHH and Environmental Protection Acts
   b pressure systems and portable gas containers
   c working at heights and in confined spaces
   d electrical installations and testing of equipment and appliances according to the IEE and Electricity at Work Regulations

3. identify the methods of isolating the equipment or system
   a isolating switches
   b removal of fuses
   c closing and 'locking off' of valves
   d removal of valves and blanking of pipes

4. state procedures for de-pressurising systems (including air receivers and storage vessels) and testing them to be in a safe condition.

5. describe the procedure for draining oil or other such substances and their safe and legitimate disposal

6. state the need for providing equipment to deal with
   a spillage and contamination (including any special PPE such as breathing apparatus
   b fire
   c personal injury

7. state the emergency shut down and evacuation procedures

Outcome 3 Carry out the monitoring, inspection and maintenance or installation activity

Practical Activities

The candidate will be able to
1. carry out a maintenance or pre installation inspection
2. repair a faulty system or component or inspect a system

Underpinning knowledge

The candidate will be able to
1. describe the methods used to avoid distortion and damage to, or leakage from, pipework
   a disconnecting
   b aligning
   c connecting

2. state the precautions needed to avoid danger from, or damage to, components whilst installing, dismantling and assembling from
   a misalignment
   b use of wrong tools or excessive force
   c uncontrolled release of springs
   d scoring of surfaces.

3. identify the need for protection of dismantled components or systems from contamination by
   a blanking off open ports
   b using correct cleaning agents and lint free cloths.
   c storing removed parts in appropriate containers

4 state methods of making identification (witness) marks on components so that they can be correctly reassembled or re- aligned

5. list the essential points to be checked when inspecting components or equipment either before or during the maintenance or installation activity
   a bearing or other contact surfaces
   b signs of corrosion and/or erosion (internal and external)
   c visible external condition
   d split or worn seals
   e signs of overheating (colour changes)
   f condition of filters
      i excessive pressure drops (choking)
      ii signs of metallic or other particles
      iii indications of emulsions or oil deterioration

6. describe how to remove, fit and replace
   a bearings
   b seals
   c springs
   d circlips
   e keys

f brushes

7. describe how to prepare or make new gaskets or joints (including preparation of surfaces and/or housings) and repack glands

8. list the procedures for re-assembling components to avoid damage using the approved sequence for tightening bolts and applying specified torque and the application of lubrication to seals.

9. describe methods of bench testing re-assembled components.

10. state the need for correctly labelling re-built components for replacement in a system or returning to stores.

11. describe how to hydraulically pressure test pipework and pressure vessels

12. state what information needs to be supplied when completing a report following a maintenance activity

13. list the different ways of presenting information that can be used to appraise the outcome of a maintenance or installation activity

Outcome 4 Commission or re-commission the system, restore the work area and resources

Practical Activities

The candidate will be able to
1. bring the system on line and adjust as required until the working parameters have been fully met
2. restore work areas to a clean and safe condition on completion of maintenance or installation
3. identify hazardous substances that may have been used or discovered during the work and give the approved method of disposal for each such substance.
4. specify any work needed for the restoration of work areas.
5. hand over the system to the authorised persons
6. complete a report on the actions taken

Underpinning knowledge

The candidate will be able to
1. state the precautions to be taken when
   a refilling or recharging systems
   b opening up the system to the sources of pressure (particular attention to steam

2. describe methods of safely draining, bleeding and purging systems to avoid undue leakage or contamination

3. describe how to set up and test interlocks, sensors and limit switches

4. list the sequence of bringing systems back to the specified working conditions by
   a removal of protective covers and blanks
   b opening appropriate valves or switches
   c operating the system under gradually increasing pressures or loads

5. identify any materials used that are classified as hazardous and those that can be recycled

6. state the methods of securing pipework and safety fittings (guards, handrails)

7. state the necessity for, and methods of, reporting any damage caused by the maintenance or installation activity where additional restoration work may be needed
   a brickwork
   b grouting
   c plastering
   d decorating

8 describe methods of replacing insulation, lagging and other protective coverings

9. state methods of applying identification markings to different parts of a system
   a colour identification of pipework to BS1710
   b using appropriate and approved codings for electrical connections and components

10. state the need to let all interested parties know of any changes that may affect the operation of the system, or of any new conditions that could exist in the work area

11. state the procedure for terminating any ‘Permits to Work’ that have been implemented

12. explain how any work termination documents or reports that may be required are completed and passed on to an authorised person

Unit 034 Hydraulic systems and components

Rationale
This unit is concerned with the principles of hydraulic power transmission, identifying hydraulic components and their symbols and the interpretation of circuit diagrams. It also covers the procedures and techniques involved with isolating systems safely, the ability to install or rebuild circuits from given information, removing and replacing components in a circuit and restoring a system back to a full working condition and causes of common faults in hydraulic systems.

When training rigs are used then a method of safely applying reasonable loads to fully test the operation of a circuit must be provided ie not simply that the specified actuator movements are obtained.

Outcomes
There are four outcomes to this unit. The candidate will be able to
1 identify the components and features of factory/plant services
2. plan and prepare for the maintenance or installation operation
3 carry out monitoring, inspection and maintenance or installation work.
4 commission or re-commission the system, restore the work area and resources.

Connection with other awards
This unit relates to units 001-006, 009, 010, 019-024, 026, 028-030 of the City & Guilds NVQ in Engineering maintenance (1688)
It also relates to *OSCEng ECS* 2.10-2.16, 4.01-4.05, 4.07, 4.08, 5.01-5.07, 6.01-6.08 and 7.01-7.03.

Assessment
The outcomes from this unit will be assessed using evidence from a centre devised assignment which will cover both practical activities and underpinning knowledge.

Outcome 1 Identify hydraulic components and their operation in relation to fluid power principles

Practical Activities

The candidate will be able to
1. identify the hydraulic components in a system as represented on a drawing by current symbols and state the function of each within the given circuit.
2. determine the sequence of events and any interaction between components in a circuit from given circuit diagrams.
3. select components to meet specified functions in terms of action, pressure and flow using manufacturers' catalogues, or other given data

Underpinning knowledge

The candidate will be able to
1. state the relationships between force, pressure and area and carry out simple calculations

2. identify the factors affecting pressure drops and losses in a system

3. state the effect of fluid flow rate on actuator speed and power produced

4. describe the changes in fluid energy that take place throughout a system (head, velocity and pressure – hydraulic hammer)

5. list the characteristics of hydraulic fluids
   a viscosity, density and lubricity (including effects of temperature and aeration)
   b flash point and fire resistant forms

6. state why of oil additives are needed

7. state the causes of deterioration of hydraulic oils
   a chemical changes due to oxidation overheating
   b contamination by suspended solids and moisture
   c wrong storage conditions

8. identify the potential hazards of hydraulic oils
   a toxicity
   b harmful effects on skin

9. state the procedures for storing and handling of hydraulic fluids

10. identify basic pneumatic components and their current standard symbols according to BS2917 and ISO1219-1 for
    a pumps
       i piston types (axial, radial and variable delivery – swash plate)
       ii gear types (internal and external)
       iii vane types (fixed and variable capacity)
    b actuators
       i linear – single acting, double acting, telescopic and differential (ram) type cylinders (uncushioned and cushioned forms)

ii rotary – (hydraulic motors)piston and sliding vane types

c valves and their methods of actuation (manual, mechanical, electrical and pilot)
   i rotary and spool directional control valves – 2/2, 3/2, 4/2, 5/2 and 4/3 (including all neutral position variants of 3 position types)
   ii non-return (plain and pilot operated)
   iii pressure control – pressure regulating and relief (simple and compound)
   iv flow control – simple restrictors, uni-directional and pressure compensated types
   v modular (stacker) and cartridge valve assemblies
   vi identification of valve ports using current systems (PABT and numeric)

d auxiliary components
   i reservoirs
   ii accumulators
   iii pressure intensifiers
   iv filters

11. describe the main constructional features of the items listed in 10 including
   a types of seals and their applications (static and dynamic)
   b seal materials, compatibility and methods of assembly
   c methods of mounting and fixing valves and actuators
   d attachment of connectors and pipework

12. state the methods used for connecting pipework and hoses and how systems are installed to minimise pressure drops and flow restriction

13. state the factors that determine the choice of components for particular purposes

14. identify the relative positions of components in a circuit to achieve
   a counterbalance
   b unloading and offloading
   c meter-in, meter-out and bleed off speed control
   d sequential operation.

15. state the possible causes of common faults in hydraulic systems
   a slow, erratic and intermittent motion of actuators
   b lack of specified system pressure
   c cavitation
   d overheating of oil

Outcome 2 Plan and prepare for the maintenance or installation operation

Practical activities

The candidate will be able to
1. identify the type and extent of work to be carried out
2. relate current legislation and codes of practice to the given tasks
3. carry out a risk assessment by listing the procedures and requirements for setting up safe working conditions
4. collect manufacturers' information, related work records, circuit diagrams and other necessary data.
5. check availability of materials, tools and equipment and prepare requisitions or works orders as required
6. assemble all tools, materials and other equipment that will be needed

Underpinning knowledge

The candidate will be able to
1. describe the layout, function of components and operational features of the hydraulic system to be installed or maintained
    a special considerations as prescribed by the manufacturer
    b the methods of lifting, supporting, or otherwise making system components safe
    c how the work to be undertaken may interact with or affect other systems or production facilities

2. state the specific implications of Statutory Regulations, Codes of Practice related to installing or maintaining hydraulic systems
    a disposal of toxic waste and other such substances as defined by COSHH and Environmental Protection Acts
    b pressure systems and portable gas containers
    c working at heights and in confined spaces
    d electrical installations and testing of equipment and appliances according to the IEE and Electricity at Work Regulations

3. identify the methods of isolating the equipment or system
    a isolating switches
    b removal of fuses
    c closing and 'locking off' of valves
    d removal of valves and blanking of pipes

4. state procedures for de-pressurising systems (including reservoirs and storage vessels and testing them to be in a safe condition.

5. describe the procedure for draining oil or other such substances and their safe and legitimate disposal

6. state the need for providing equipment (including any special PPE to deal with
    a spillage and contamination
    b fire
    c personal injury

7. state the emergency shut down and evacuation procedures for the work area

Outcome 3 Carry out inspections and general maintenance tasks

Practical Activities

The candidate will be able to
1. carry out a maintenance OR pre-installation inspection on factory/plant equipment or systems
2. diagnose and repair a faulty system and/or components OR install a system.

Underpinning knowledge

The candidate will be able to
1. describe the methods used to avoid distortion and damage to, or leakage from, pipework
   a disconnecting
   b aligning
   c connecting

2. list the procedure needed to safely and effectively dismantle components
   a make identification (witness) marks on components so that they can be correctly reassembled or re- aligned
   b label and safely store parts that have been removed

3. state the precautions needed to avoid danger from, or damage to, components whilst installing, dismantling and assembling from
   a misalignment
   b use of wrong tools or excessive force
   c uncontrolled release of springs
   d scoring of surfaces.

4. state how to protect dismantled components from contamination
   a blanking off open ports
   b use of correct cleaning agents and lint free cloths

5. identify the essential points to be checked when inspecting hydraulic components
   a bearing surfaces
   b erosion and pitting (eg of gear teeth or vane edges
   c split or worn seals
   d signs of overheating (colour changes
   e condition of filters for signs of metallic or other particles, indications of emulsions or oil deterioration.

6. state the procedures for re-assembling components to avoid damage using the approved sequence for tightening bolts and applying specified torque and the application of lubrication to seals.

7. state the need for correctly labelling re-built components for replacement in a system or returning to stores

8. describe routine tests for
   a checking oil for signs of oxidation and acidity
   b bench testing re-assembled components.
   c pressure testing pipework and pressure vessels

9. list the precautions to be taken when refilling systems with hydraulic oil

10 describe methods of safely bleeding systems to eliminate air locks and avoid spillage

11. list the procedures for charging gas filled accumulators

12. describe the different ways of presenting information that can be used to appraise the outcome of a maintenance or installation activity

Outcome 4 De-isolate, commission or re-commission the system, restore the work area and resources

Practical Activities

The candidate will be able to
1. bring the system on line and adjust as required until the working parameters have been fully met
2. restore work areas to a clean and safe condition on completion of maintenance or installation
3. identify hazardous substances that may have been used or discovered during the work and give the approved method of disposal for each such substance.
4. specify any work needed for the restoration of work areas
5. hand over the system to the authorised persons
6. complete a report on the actions taken

Underpinning knowledge

The candidate will be able to
1. state the precautions to be taken when
   a refilling or recharging systems
   b opening up the system to the sources of pressure

2 describe methods of safely draining, bleeding and purging systems to avoid undue leakage or contamination

3. state how to set up and test interlocks, sensors and limit switches

4. list the sequence of bringing systems back to the specified working conditions by
   a removal of protective covers and blanks
   b opening appropriate valves or switches
   c operating the system under gradually increasing pressures or loads

5. identify any materials used that are classified as hazardous and those that can be recycled

6. state the methods of securing pipework and safety fittings (guards, handrails)

7. state the necessity for, and methods of, reporting any damage caused by the maintenance or installation activity where additional restoration work may be needed
   a brickwork
   b grouting
   c plastering
   d decorating

8. describe methods of replacing insulation, lagging and other protective coverings

9. state methods of applying identification markings to different parts of a system
   a colour identification of pipework to BS1710
   b using appropriate and approved codings for electrical connections and components

10. state the need to let all interested parties know of any changes that may affect the operation of the system, or of any new conditions that could exist in the work area.

11. state the procedure for terminating any ‘Permits to Work’ that have been implemented

12. explain how any work termination documents or reports that may be required are completed and passed on to an authorised person

Unit 035 Pneumatic systems and components

Rationale
This unit is concerned with the principles of pneumatic power transmission, identifying pneumatic components and their symbols and the interpretation of circuit diagrams, the procedures and techniques involved with isolating systems safely, the ability to construct basic circuits from given information. It also covers removing and replacing components and restoring a system back to a full working condition, causes of common faults in pneumatic systems and the selection of appropriate tools and equipment.

Outcomes
There are four outcomes to this unit. The candidate will be able to
1 identify the components and features of utilities
2 plan and prepare for the maintenance or installation operation
3 carry out inspections, maintenance or installation tasks
4 commission or re-commission the system, restore the work area and store resources correctly

Connection with other awards
This unit relates to units 001-006, 009, 010, 028-030 of the City & Guilds NVQ in Engineering maintenance (1688)
It also relates to the *OSCEng ECS* 2.10 –2.16, 4.01-4.05, 4.07-4.08, 5.01-5.07, 6.01-6.08 and 7.01-7.03.

Assessment

The outcomes from this unit will be assessed using evidence from a centre devised assignment which will cover both practical activities and underpinning knowledge.

Outcome 1 Identify pneumatic components and their operation in relation to fluid power principles

Practical Activities

The candidate will be able to
1. identify the pneumatic components in a system as represented on a drawing by current symbols and state the function of each within the given circuit
2. determine the sequence of events and any interaction between components in a circuit from given circuit diagrams
3. select components to meet specified functions in terms of action, pressure and flow by using manufacturers' catalogues or other given data
4. programme a PLC to carry out a specified sequence

Underpinning knowledge

The candidate will be able to
1. identify and use the relationships between force, pressure and area
2. state the factors affecting pressure drops and losses in a system (use of nomograms for pipe selection)
3. state the effect of air flow rate on actuator speed and power produced
4. identify the changes in energy throughout a system
5. identify basic pneumatic components and their current standard symbols according to BS2917 and ISO1219-1 for:-
   a actuators
      i linear – single acting, double acting, telescopic, and differential cylinders (cushioned and un-cushioned types
      ii rotary – (air motors piston and sliding vane types)
   b valves and their methods of actuation (manual, mechanical, electrical and pilot)
      i directional control – rotary and spool, including all neutral position variants of 5/3 valves, non-return (plain and pilot operated)
      ii pressure control – pressure regulating and relief
      iii flow control – simple restrictors and by-pass forms
      iv two pressure and shuttle valves (OR and AND logic)
      v quick exhaust
      vi impulse generators
      vii identification of valve ports using current systems
   c auxiliary components
      i accumulators
      ii pressure intensifiers
      iii filters
      iv silencers

6. describe the main constructional features of the items listed in 5 including
   a types of seals and their applications (static and dynamic)
   b seal materials, compatibility and methods of fitting
   c methods of mounting and fixing valves and actuators
   d attachment of connectors and pipework to components

7. list the types of pipework and connecting methods (rigid, flexible and push-in)

8. state the factors for efficient and safe routing of pipes to minimise pressure drops and flow restriction

9. identify components needed for particular purposes and their relative positions in a circuit to obtain speed control and sequential operation.

10. list the reasons for held (maintained) signals and methods of overcoming this problem for circuits requiring up to 3 group cascade layouts.

11. state causes of basic faults (slow, erratic and intermittent motion

12 identify the basic needs for circuits with electro pneumatic operation.
    - a types of sensor or contact
        - i induction
        - ii magnetic
        - iii reed switches
    - b relays
    - c rotary switches

13. describe the principles of programmable logic controllers (PLCs) using a ‘black box’ treatment only

14. describe basic the programming methods and the need for requiring feedback signals

Outcome 2 Plan and prepare for the maintenance or Installation operation

Practical activities

The candidate will be able to
1. identify the type and extent of work to be carried out
2. relate current legislation and codes of practice to the given tasks
3. carry out a risk assessment by listing the procedures and requirements for setting up safe working conditions
4. collect manufacturers' information, related work records, circuit diagrams and other necessary data
5. check availability of materials, tools and equipment and prepare requisitions or works orders as required
6. assemble all tools, materials and other equipment that will be needed

Underpinning knowledge

The candidate will be able to
1. describe the layout, function of components and operational features of the pneumatic system to be installed or maintained
   a special considerations as prescribed by the manufacturer
   b the methods of lifting, supporting, or otherwise making system components safe
   c how the work to be undertaken may interact with or affect other systems or production facilities

2. state the specific implications of Statutory Regulations, Codes of Practice related to installing or maintaining pneumatic systems
   a disposal of toxic waste and other such substances as defined by COSHH and Environmental Protection Acts
   b pressure systems and portable gas containers
   c working at heights and in confined spaces

3. identify the methods of isolating the equipment or system
   a isolating switches
   b removal of fuses
   c closing and 'locking off' of valves
   d removal of valves and blanking of pipes

4. state procedures for de-pressurising systems (including air receivers and storage vessels and testing them to be in a safe condition.

5. describe the procedure for draining oil or other such substances and their safe and legitimate disposal

6. state the need for providing equipment to deal with
   a spillage and contamination (including any special PPE such as breathing apparatus)
   b fire
   c personal injury

7. state the emergency shut down and evacuation procedures for the work area

Outcome 3 Carry out inspections and general maintenance tasks

Practical Activities

The candidate will be able to
1. carry out a maintenance OR pre-installation inspection on factory/plant equipment or systems
2. diagnose and repair a faulty system and/or components OR install a system.

Underpinning knowledge

The candidate will to be able to
1. describe the methods used to avoid distortion and damage to, or leakage from, pipework
   a disconnecting
   b aligning
   c connecting

2. list the procedure needed to safely and effectively dismantle components
   a make identification (witness) marks on components so that they can be correctly reassembled or re- aligned
   b label and safely store parts that have been removed

3. state the precautions needed to avoid danger from, or damage to, components whilst installing, dismantling and assembling from
   a misalignment
   b use of wrong tools or excessive force
   c uncontrolled release of springs
   d scoring of surfaces.

4. state how to protect dismantled components from contamination
   a blanking off open ports
   b use of correct cleaning agents and lint free cloths

5. identify the essential points to be checked when inspecting pneumatic components
   a bearing surfaces
   b erosion and pitting
   c split or worn seals
   d signs of overheating (colour changes
   e condition of filters for signs of metallic or other particles, indications of emulsions or oil deterioration.

6. state the procedures for re-assembling components to avoid damage using the approved sequence for tightening bolts and applying specified torque and the application of lubrication to seals.

7. state the need for correctly labelling re-built components for replacement in a system or returning to stores.

8. describe routine tests for
   a checking oil for signs of oxidation and acidity
   b bench testing re-assembled components.
   c pressure testing pipework and pressure vessels

9. list the precautions to be taken when refilling systems with hydraulic oil

10. describe methods of safely bleeding systems to eliminate air locks and avoid spillage

11. list the procedures for charging gas filled accumulators

12. describe the different ways of presenting information that can be used to appraise the outcome of a maintenance or installation activity

Outcome 4 De-isolate, commission or re-commission the system, restore the work area and resources

Practical Activities

The candidate will be able to
1 bring the system on line and adjust as required until the working parameters have been fully met
2. restore work areas to a clean and safe condition on completion of maintenance or installation
3. identify hazardous substances that may have been used or discovered during the work and give the approved method of disposal for each such substance
4. specify any work needed for the restoration of work areas.
5. hand over the system to the authorised persons
6. complete a report on the actions taken

Underpinning knowledge

The candidate will be able to
1. state the precautions to be taken when
   a refilling or recharging systems
   b opening up the system to the sources of pressure

2. describe methods of safely draining, bleeding and purging systems to avoid undue leakage or contamination

3. state how to set up and test interlocks, sensors and limit switches

4. list the sequence of bringing systems back to the specified working conditions by
   a removal of protective covers and blanks
   b opening appropriate valves or switches
   c operating the system under gradually increasing pressures or loads

5. identify any materials used that are classified as hazardous and those that can be recycled

6. state the methods of securing pipework and safety fittings (guards, handrails)

7. state the necessity for, and methods of, reporting any damage caused by the maintenance or installation activity where additional restoration work may be needed
   a brickwork
   b grouting
   c plastering
   d decorating

8. describe methods of replacing insulation, lagging and other protective coverings

9. state methods of applying identification markings to different parts of a system
   a colour identification of pipework to BS1710

b using appropriate and approved codings for electrical connections and components

10. state the need to let all interested parties know of any changes that may affect the operation of the system, or of any new conditions that could exist in the work area

11. state the procedure for terminating any ‘Permits to Work’ that have been implemented

12. explain how any work termination documents or reports that may be required are completed and passed on to an authorised person

Unit 036 Steam generation systems and ancillary equipment

Rationale
This unit is concerned with identifying the basic principles and types of boilers, the components, equipment and sub-systems needed for steam generation and the procedures and techniques involved with safely isolating systems. It also covers removing and replacing components, and restoring a system back to a full working condition and the selection of appropriate tools and equipment for carrying out the required maintenance.

Outcomes
There are four outcomes to this unit. The candidate will be able to

1 identify the components and features of utilities
2 plan and prepare for the maintenance or installation operation
3 carry out inspections, maintenance or installation tasks
4 commission or re-commission the system, restore the work area and store resources correctly.

Connection with other awards
This unit relates to units 001-006, 009, 010, 019-031, 033 & 035 of the City & Guilds NVQ in Engineering maintenance (1688)
It also relates to the *OSCEng ECS* 2.10 –2.16, 4.01-4.05, 4.07-4.08, 5.01-5.07, 6.01-6.08 and 7.01-7.03.

Assessment
The outcomes from this unit will be assessed using evidence from a centre devised assignment which will cover both practical activities and under pinning knowledge.

Outcome 1 Identify the principles and operation of components and sub-systems used with steam generation plant

Practical Activities

The candidate will be able to
1. make drawings, using standard symbols where appropriate to identify the components and sub-systems needed for steam generation within a specified system
2. identify the function of the essential components needed in a system or sub-system
3. use steam tables to find the relationships between pressure, temperature and heat content of steam
4. use manufacturers' catalogues, or other given data, to select components or equipment to meet specified functions in terms of required volumes (fuel, air and steam, pressures and temperatures

Underpinning knowledge

The candidate will be able to
1. state the principles and factors affecting heat transfer by conduction, convection and radiation

2. state the uses of steam tables to determine
   a heat values for water and steam
   b relationship between the pressure and boiling points of water

3. state the meaning of the terminology associated with steam generation
   a sensible heat
   b latent heat
   c superheat
   d enthalpy

4. state the basic principles of combustion of hydrocarbon fuels and the products of combustion

5. explain the need for the correct proportions of air and fuel for complete combustion

6. state the methods of supplying air to boilers
   a natural
   b forced draught

7. describe dispersal methods for flue gases in accordance with current regulations and good environmental practice

8. state the materials used for boiler and furnace construction
   a shells
   b tubes
   c furnace linings
   d insulation

9. describe the components and equipment use for steam generation
   a types of boiler
      i fire tube and water tube
      ii single and double pass
      iii superheated
      iv Lancashire and Scotch types
   b valves types, their uses and methods of operation (manual/mechanical, remote)
      i control and isolating
      ii pressure relief (direct, and pilot operated for superheat systems
      iii blow down and drainage valves (including steam traps)
      iv automatic water level control (feed regulators)
   c pumps (circulating, feed and furnace fuel oil
   d condensers, pre-heaters, economisers
   e air supply fans (axial and centrifugal)

10. identify the symbols for boilers, associated plant and pipework from current standard symbols according to BS 1553, BS 1710 (or corresponding ISO standards)

11. describe the main constructional features of the items listed in 10

12. identify the requirements of pipework
   a materials and jointing methods for HP and LP systems
   b pipe support systems to allow for expansion and vibration
   c lagging and identification
   d causes and prevention of water hammer
   e drainage methods, manual cocks and steam traps

13. state the factors affecting the efficiency of steam generation systems

14. describe the methods used to monitor pressure, temperature, levels and flow (including chart recorders)

15. describe the types and uses of control systems and cut outs (manual and automatic)

16. describe the causes of corrosion for steam generation components
   a external
      i wet lagging
      ii soot accumulations
      iii leakages around valves and handhole doors
   b internal
      i acidic feed water
      ii failure of sacrificial anodes

17. describe the processes used for boiler water treatment
   a softening and demineralization plants
   b use of boiler compound to reduce acidity, protect internal surfaces and precipitate out any dissolved solids
   c the need to maximise the use of condensate (including use of ‘flash steam’ for secondary heating purposes)
   d boiler water testing

18. state the requirements for feed water supply systems
    a storage tanks
    b make up feed systems
    c feed heaters

19. state the requirements for fuel supply systems
    a solid
        i safe storage and supply methods (conveyors)
        ii preparation (grading and pulverising)
    b liquid
        i storage – (coffer dams and trenches)
        ii supply – pumping and filtration, trace heating of pipework, fuel heaters, sprayer setting and cleaning methods.
    c gas supply
        i storage - safe positioning, provision for ventilation and leakage
        ii control and reducing valves (when stored in liquid form)

20. describe the procedures for standard operational maintenance routines
    a blowing down
    b soot blowing
    c replacement of sight (water level glasses)
    d testing the operation of safety valves
    e internal cleaning and inspection of drums and tubes
    f testing of pressure vessels for insurance certificates

Outcome 2 Plan and prepare for the maintenance or installation operation

Practical activities

The candidate will be able to
1. identify the type and extent of work to be carried out
2. relate current legislation and codes of practice to the given tasks
3. carry out a risk assessment by listing the procedures and requirements for setting up safe working conditions
4. collect manufacturers' information, related work records, circuit diagrams and other necessary data
5. check availability of materials, tools and equipment and prepare requisitions or works orders as required
6. assemble all tools, materials and other equipment that will be needed

Underpinning knowledge

The candidate will be able to
1. describe the layout, function of components and operational features of the pneumatic system to be installed or maintained
   a special considerations as prescribed by the manufacturer
   b the methods of lifting, supporting, or otherwise making system components safe
   c how the work to be undertaken may interact with or affect other systems or production facilities

2. state the specific implications of Statutory Regulations, Codes of Practice related to installing or maintaining steam generation systems
   a disposal of toxic waste and other such substances as defined by COSHH and Environmental Protection Acts
   b pressure systems and portable gas containers
   c working at heights and in confined spaces

3. identify the methods of isolating the equipment or system
   a isolating switches
   b removal of fuses
   c closing and 'locking off' of valves
   d removal of valves and blanking of pipes

4. state procedures for de-pressurising systems and testing them to be in a safe condition

5. describe the procedure for draining oil or other such substances and their safe and legitimate disposal

6. state the need for providing equipment to deal with
   a spillage and contamination (including any special PPE such as breathing apparatus)
   b fire
   c personal injury

7. state the emergency shut down and evacuation procedures for the work area

Outcome 3 Carry out inspections and general maintenance tasks

Practical Activities

The candidate will be able to
1. carry out a maintenance OR pre-installation inspection on steam generation equipment or systems
2. diagnose and repair a faulty system and/or components OR install a system

Underpinning knowledge

The candidate will be able to
1. describe the methods used to avoid distortion and damage to, or leakage from, pipework
   a disconnecting
   b aligning
   c connecting

2. list the procedure needed to safely and effectively dismantle components
   a make identification (witness) marks on components so that they can be correctly reassembled or re- aligned
   b label and safely store parts that have been removed

3. state the precautions needed to avoid danger from, or damage to, components whilst installing, dismantling and assembling from
   a misalignment
   b use of wrong tools or excessive force
   c uncontrolled release of springs
   d scoring of surfaces.

4. state how to protect dismantled components from contamination
   a blanking off open ports
   b use of correct cleaning agents and lint free cloths

5. identify the essential points to be checked when inspecting pneumatic components
   a bearing surfaces
   b erosion and pitting
   c split or worn seals
   d signs of overheating (colour changes
   e condition of filters for signs of metallic or other particles, indications of emulsions or oil deterioration

6. state the procedures for re-assembling components to avoid damage using the approved sequence for tightening bolts and applying specified torque and the application of lubrication to seals

7. state the need for correctly labelling re-built components for replacement in a system or returning to stores

8. describe routine tests for
    a checking oil for signs of oxidation and acidity
    b bench testing re-assembled components.
    c pressure testing pipework and pressure vessels

9. list the precautions to be taken when refilling systems with hydraulic oil

10. describe methods of safely bleeding systems to eliminate air locks and avoid spillage

11. list the procedures for charging gas filled accumulators

12. description the different ways of presenting information that can be used to appraise the outcome of a maintenance or installation activity

Outcome 4 De-isolate, commission or re-commission the system, restore the work area and resources

Practical Activities

The candidate will be able to
1. bring the system on line and adjust as required until the working parameters have been fully met
2. restore work areas to a clean and safe condition on completion of maintenance or installation
3. identify hazardous substances that may have been used or discovered during the work and give the approved method of disposal for each such substance
4. specify any work needed for the restoration of work areas
5. hand over the system to the authorised persons
6. complete a report on the actions taken

Underpinning knowledge

The candidate will be able to
1. state the precautions to be taken when
   a refilling or recharging systems
   b opening up the system to the sources of pressure

2. describe methods of safely draining, bleeding and purging systems to avoid undue leakage or contamination

3. state how to set up and test interlocks, sensors and limit switches

4. list the sequence of bringing systems back to the specified working conditions by
   a removal of protective covers and blanks
   b opening appropriate valves or switches
   c operating the system under gradually increasing pressures or loads

5. identify any materials used that are classified as hazardous and those that can be recycled

6. state the methods of securing pipework and safety fittings (guards, handrails)

7 state the necessity for, and methods of, reporting any damage caused by the maintenance or installation activity where additional restoration work may be needed
   a brickwork
   b grouting
   c plastering
   d decorating

8. describe methods of replacing insulation, lagging and other protective coverings

9. state methods of applying identification markings to different parts of a system
   a colour identification of pipework to BS1710

b using appropriate and approved codings for electrical connections and components

10. state the need to let all interested parties know of any changes that may affect the operation of the system, or of any new conditions that could exist in the work area

11. state the procedure for terminating any ‘Permits to Work’ that have been implemented

12. explain how any work termination documents or reports that may be required are completed and passed on to an authorised person

Unit 037 Power generation systems and ancillary equipment

Rationale
This unit is concerned with identifying the basic principles of internal combustion (IC) engines (petrol, diesel and gas turbine)used in static or portable situations, but not within vehicles.

It will necessitate an understanding of the principles of steam and internal combustion powered units (reciprocating and turbine), a study of the components parts of these units and the associated sub-systems and fault identification. It will also cover the procedures and techniques involved with safely isolating systems, removing and replacing components, restoring a system back to a full working condition and the selection of appropriate tools and equipment for carrying out the required maintenance.

Outcomes
There are four outcomes to this unit. The candidate will be able to
1 identify the components and features of utilities
2 plan and prepare for the maintenance or installation operation
3. carry out inspections, maintenance or installation tasks
4 commission or re-commission the system, restore the work area and store resources correctly.

Connection with other awards
This unit relates to units 001-006, 009, 010, 023-030, 033-034 of the City & Guilds NVQ in Engineering maintenance (1688)
It also relates to the *OSCEng ECS* 2.10 –2.16, 4.01-4.05, 4.07-4.08, 5.01-5.07, 6.01-6.08 and 7.01-7.03.

Assessment
The outcome from this unit will be assessed using evidence from a centre devised assignment which will cover both practical activities and under pinning knowledge.

Outcome 1 Identify the principles and operation of components and sub-systems used with auxiliary power generation plant

Practical Activities

The candidate will be able to
1. identify the components and sub-systems needed for power generation units from drawings that use standard symbols
2. identify the function of the essential components needed for power generation plant or sub-systems
3. select components or equipment to meet specified functions in terms of required volumes (fuel, air and steam), pressures and temperatures using manufacturers' catalogues or other data

Underpinning knowledge

The candidate will be able to
1. state the basic principles of combustion of hydrocarbon fuels and the products of combustion

2. explain the need for the correct proportions of air and fuel for complete combustion

3. list the ways in which energy forms can be achieved
   a chemical to heat
   b heat to mechanical
   c kinetic to mechanical

4. state the principles and factors affecting heat transfer by conduction, convection and radiation

5. describe the basic four stroke and two stroke cycle for spark and compression ignition (CI) systems
   a valve timing diagrams (for all types) defining lead, lag and overlap
   b ignition and combustion requirements
      i obtaining the correct air pressures and temperatures
      ii uniform mixtures of air and fuel in the required proportions
      iii effects of incorrect mixtures
      iv use of pressure/volume and crank angle/pressure diagrams to show the stages in combustion processes

6. identify general layouts of the following types of engine
   a in-line
   b vee
   c engine capacity in terms of bore, stroke and number of cylinders

7. state the meaning of torque and its relationship with engines speed and power produced

8. list the factors affecting the efficiency of power generation systems

9. describe systems for supplying fuels to power units
   a from storage point to engine
   b by carburettors (venturi, throttle control, main and idling jets)
   c injection pumps
   d injectors (types and spray patterns
   e gas flow-regulating valves

10. describe methods of supplying air to IC engines
   a normally aspirated
   b under pressure (supercharged and turbo-charged)
      i construction and positioning of chargers
      ii need for correct operating procedures to avoid damage during start up and shut down
   c air filtration (dry and wet types)

11. describe the main features of electrical systems
   a coil ignition and components – switch, coil, condensers, contact breakers, distributors, spark plug types, suppressors
   b magneto – rotating armature, rotating magnet, contact breakers and mechanisms
   c alternators and generators and including voltage regulators.
   d batteries – checking of condition and recharging

12. describe the component parts of cooling water supply systems
   a closed circulation via heat exchangers (radiators)
   b pump types
   c temperature control methods (thermostats)
   d water treatment for preventing scaling, corrosion and freezing
   e relation between pressure and boiling point and resultant dangers

13. identify the component parts of lubrication systems
   a pressurised
      i pump types
      ii filters
      iii pressure control and warning systems
      iv oil coolers
   b splash methods of lubricating cylinder walls and valve mechanisms

14. list the types of oil and grease (and additives) used specifically for IC engines

15. describe different starting methods for IC engines
   a electric
   b compressed air
   c hydraulic
   d manual
   e starting aids
      i volatile gas injection
      ii heater plugs
      iii excess fuel (choke)
      iv decompression devices

16. describe the general construction details of reciprocating IC engines
    a cylinder blocks and heads (use of wet and dry liners)
    b crankshafts and bearing arrangements
    c cam shafts and valve timing arrangements
    d piston assemblies (gudgeon pins and types of piston ring)
    e bearing types and applications
        i ball and roller
        ii solid bush
        iii split bearings (white-metalled and shell types)

17. state general principles and construction of turbines
    a rotor and stator blade configurations
    b blade shapes - impulse and reaction types – multi-staging
    c methods of attaching blades on to rotor discs
    d need to allow for expansion of gases for steam and gas

18. identify the different stages of a gas turbine engine and the associated components
    a compressor – blade materials, changes in air pressures and temperatures
    b combustion chambers
        i materials
        ii fuel injection and mixing arrangement (primary and secondary)
        iii internal and external combustion zones
    c turbines
        i blade materials
        ii attachment methods (including shrouding)
    d power take off arrangements (reduction gearing)
    e control methods for safe and efficient running
        i acceleration control units
        ii steady speed governors
        iii overspeed and temperature trips
        iv use of exhaust gases to preheat air inlet to combustion zones

19. state the dispersal methods for exhaust gases in accordance with current regulations and good practice

20. identify the different stages of a steam turbines and the associated components
    a control nozzle arrangements
    b speed governing and overspeed trips
    c exhaust steam arrangements and condensers

21. list the materials used for the different components of power units and the reasons for their selection

22. list possible causes of corrosion in IC engines
    a cooling water
    b condensation
    c reactions with combustion products

23. state the requirements and checks needed for standard maintenance and installation routines associated with the components and systems listed

24. list the possible causes of commonly observed symptoms related to IC engines
    a smoke from exhausts
    b overheating
    c knocking or pinking
    d misfiring or loss of power
    e excessive consumption (of fuel and oil)

Outcome 2 Plan and prepare for the maintenance or installation operation

Practical activities

The candidate will be able to

1. identify the type and extent of work to be carried out
2. relate current legislation and codes of practice to the given tasks
3. carry out a risk assessment by listing the procedures and requirements for setting up safe working conditions
4. collect manufacturers' information, related work records, circuit diagrams and other necessary data
5. check availability of materials, tools and equipment and prepare requisitions or works orders as required
6. assemble all tools, materials and other equipment that will be needed

Underpinning knowledge

The candidate will be able to

1. describe the layout, function of components and operational features of the pneumatic system to be installed or maintained
    a special considerations as prescribed by the manufacturer
    b the methods of lifting, supporting, or otherwise making system components safe
    c how the work to be undertaken may interact with or affect other systems or production facilities

2. state the specific implications of Statutory Regulations, Codes of Practice related to installing or maintaining steam generation systems
    a disposal of toxic waste and other such substances as defined by COSHH and Environmental Protection Acts
    b pressure systems and portable gas containers
    c working at heights and in confined spaces

3. identify the methods of isolating the equipment or system
    a isolating switches
    b removal of fuses
    c closing and 'locking off' of valves
    d removal of valves and blanking of pipes

4. state procedures for de-pressurising systems and testing them to be in a safe condition

5. describe the procedure for draining oil or other such substances and their safe and legitimate disposal

6. state the need for providing equipment to deal with
    a spillage and contamination (including any special PPE such as breathing apparatus
    b fire
    c personal injury

7. state the emergency shut down and evacuation procedures for the work area

Outcome 3 Carry out inspections and general maintenance tasks

Practical Activities

The candidate will be able to
1. carry out a maintenance OR pre-installation inspection on power generation equipment or systems
2. diagnose and repair a faulty system and/or components OR install a system

Underpinning knowledge

The candidate will be able to
1. describe the methods used to avoid distortion and damage to, or leakage from, pipework
   a disconnecting
   b aligning
   c connecting

2. list the procedure needed to safely and effectively dismantle components
   a make identification (witness) marks on components so that they can be correctly reassembled or re- aligned
   b label and safely store parts that have been removed

3. state the precautions needed to avoid danger from, or damage to, components whilst installing, dismantling and assembling from
   a misalignment
   b use of wrong tools or excessive force
   c uncontrolled release of springs
   d scoring of surfaces

4. state how to protect dismantled components from contamination
   a blanking off open ports
   b use of correct cleaning agents and lint free cloths

5. identify the essential points to be checked when inspecting pneumatic components
   a bearing surfaces
   b erosion and pitting
   c split or worn seals
   d signs of overheating (colour changes
   e condition of filters for signs of metallic or other particles, indications of emulsions or oil deterioration

6. state the procedures for re-assembling components to avoid damage using the approved sequence for tightening bolts and applying specified torque and the application of lubrication to seals

7. state the need for correctly labelling re-built components for replacement in a system or returning to stores

8. describe routine tests for
   a checking oil for signs of oxidation and acidity
   b bench testing re-assembled components.
   c pressure testing pipework and pressure vessels

9. list the precautions to be taken when refilling systems with hydraulic oil

10. describe methods of safely bleeding systems to eliminate air locks and avoid spillage

11. list the procedures for charging gas filled accumulators

12. describe the different ways of presenting information that can be used to appraise the outcome of a maintenance or installation activity

Outcome 4 De-isolate, commission or re-commission the system, restore the work area and resources

Practical Activities

The candidate will be able to
1. bring the system on line and adjust as required until the working parameters have been fully met
2. restore work areas to a clean and safe condition on completion of maintenance or installation
3. identify hazardous substances that may have been used or discovered during the work and give the approved method of disposal for each such substance
4. specify any work needed for the restoration of work areas
5. hand over the system to the authorised persons
6. complete a report on the actions taken

Underpinning knowledge

The candidate will be able to
1. state the precautions to be taken when
   a refilling or recharging systems
   b opening up the system to the sources of pressure

2. describe methods of safely draining, bleeding and purging systems to avoid undue leakage or contamination

3. state how to set up and test interlocks, sensors and limit switches

4. list the sequence of bringing systems back to the specified working conditions by
   a removal of protective covers and blanks
   b opening appropriate valves or switches
   c operating the system under gradually increasing pressures or loads

5. identify any materials used that are classified as hazardous and those that can be recycled

6. state the methods of securing pipework and safety fittings (guards, handrails

7. state the necessity for, and methods of, reporting any damage caused by the maintenance or installation activity where additional restoration work may be needed
   a brickwork
   b grouting
   c plastering
   d decorating

8. describe methods of replacing insulation, lagging and other protective coverings

9. state methods of applying identification markings to different parts of a system
   a colour identification of pipework to BS1710

b	using appropriate and approved codings for electrical connections and components

10. state the need to let all interested parties know of any changes that may affect the operation of the system, or of any new conditions that could exist in the work area.

11. state the procedure for terminating any ‘Permits to Work’ that have been implemented

12. explain how any work termination documents or reports that may be required are completed and passed on to an authorised person

Unit 038 Refrigeration plant and systems

Rationale
This unit is concerned with identifying the basic principles of refrigeration. It will necessitate an understanding of the layout and components used in common systems and fault identification. It will cover the procedures and techniques involved with safely isolating systems, removing and replacing refrigerant gases and components and restoring a system back to a full working condition.

It will also include the selection of appropriate tools and equipment for carrying out the required installation and maintenance. This unit is relevant to candidates who wish to extend their knowledge of Heating and Ventilating systems for complete air conditioned systems.

Outcomes
There are four outcomes to this unit. The candidate will be able to
1 identify the components and features of utilities
2 plan and prepare for the maintenance or installation operation
3 carry out inspections, maintenance or installation tasks
4 commission or re-commission the system, restore the work area and store resources correctly.

Connection with other awards
This unit relates to units 001-006, 014-018, 023-025, 027-030, 039-043 of the City & Guilds NVQ in Engineering maintenance (1688)
It also relates to the *OSCEng ECS* 2.10 –2.16, 4.01-4.05, 4.07-4.08, 5.01-5.07, 6.01-6.08 and 7.01-7.03.

Assessment
The outcome from this unit will be assessed using evidence from a centre devised assignment which will cover both practical activities and under pinning knowledge.

Outcome 1 Identify components and sub systems used with refrigeration systems their principles and operation

Practical Activities

The candidate should be able to
1. identify refrigeration system components and ancillary equipment by visual examination in conjunction with system drawings.
2. identify the methods used to determine the way in which the system is functioning
3. select components to meet specified functions in terms of required temperatures and refrigeration load using manufacturers' catalogues, or other given data

Underpinning knowledge

The candidate should be able to
1. state the principles and factors affecting heat transfer by conduction, convection and radiation

2. state the relationship between the pressure and boiling points of liquids

3. explain the meaning of the terminology associated with refrigeration
   a sensible heat
   b latent heat
   c superheat
   d enthalpy

4. state the sources of heat values for liquids and vapours

5. describe changes in state and energy throughout a refrigeration system

6. describe the compression and absorption refrigeration cycles

7. state the purpose of refrigeration components
   a compressors
      i open and sealed drive types
      ii reciprocating
      iii rotary
   b expansion valves and their methods of actuation
   c condensers
      i air cooled
      ii water cooled
   d evaporators
   e auxiliary components
      i liquid receivers
      ii filter/dryers
      iii sight glasses
      iv oil traps and separators
      v pressure controls and cut-outs
      vi temperature controls and cut-outs
      vii combination pressure/temperature gauges

8. describe the main constructional features of the items listed in ‘7’ above including
   a types of seals (static and dynamic)
   b methods of mounting and fixing
   c drive belt fitting and tensioning between prime mover and compressor
   d coupling and clutch mechanisms for drives

9. state the requirements for pipework
   a layouts (fall) to avoid oil accumulations
   b connecting methods
      i flared joints
      ii compression fittings

10. state the main refrigerant types, their properties, identifying features and applications
   a ammonia R717
   b chlorofluorocarbons (CFC)and hydrofluorocarbons (HFC) R22 and R134a
   c azeotropic mixtures R500 and R502
   d use of secondary refrigerants for large volume and cryogenic systems

11. describe the electrical equipment, starting and control methods used for refrigeration
   a types of sensor or contact
   b thermostat
   c relays (primary and secondary coil starts)
   d negative temperature coefficient (NTC) devices - thermistors

12 describe the types and operation of refrigerant recovery units used for evacuating and pumping down.

13. describe methods of measuring, storing and disposing of refrigerants removed from a system

14. describe leak testing methods
   a soap bubbles
   b halide torch
   c electronic detectors

15. state the reasons for and methods of defrosting evaporators
   a mechanical
   b reverse gas flow

16. describe the process of recharging refrigeration units
   a nitrogen purging
   b external driers
   c determining quantity of refrigerant

17. describe the symptoms of refrigeration systems that are
   a undercharged
   b overcharged

Outcome 2 Plan and prepare for the maintenance or installation operation

Practical activities

The candidate will be able to

1. identify the type and extent of work to be carried out
2. relate current legislation and codes of practice to the given tasks
3. carry out a risk assessment by listing the procedures and requirements for setting up safe working conditions
4. collect manufacturers' information, related work records, circuit diagrams and other necessary data.
5. check availability of materials, tools and equipment and prepare requisitions or works orders as required
6. assemble all tools, materials and other equipment that will be needed

Underpinning knowledge

The candidate will be able to

1. describe the layout, function of components and operational features of the refrigeration system to be installed or maintained
   a special considerations as prescribed by the manufacturer
   b the methods of lifting, supporting, or otherwise making components safe
   c how the work to be undertaken may interact with or affect other systems or production facilities

2. state the specific implications of Statutory Regulations, Codes of Practice related to installing or maintaining refrigeration systems
   a disposal of toxic waste and other such substances as defined by COSHH andEnvironmental Protection Acts
   b restrictions on the use of CFCs according to the Montreal Protocol, their replacement by other approved refrigerants and the method of disposing of CFCs (and the need to record the quantities disposed)
   c pressure systems and portable gas containers
   d working at heights and in confined spaces

3. identify the methods of isolating the equipment or system
   a isolating switches
   b removal of fuses
   c closing and 'locking off' of valves
   d removal of valves and blanking of pipes

4. state procedures for de-pressurising systems and testing them to be in a safe condition

5. describe the procedure for draining oil or other such substances and their safe and legitimate disposal

6. state the need for providing equipment to deal with
   a spillage and contamination (including any special PPE ie breathing apparatus)
   b fire
   c personal injury

7. state the emergency shut down and evacuation procedures for the work area

Outcome 3 Carry out inspections and general maintenance tasks

Practical Activities

The candidate will be able to
1. carry out a maintenance OR pre-installation inspection on refrigeration equipment or systems
2. diagnose and repair a faulty system and/or components OR install a system

Underpinning knowledge

The candidate will be able to
1. describe the methods used to avoid distortion and damage to, or leakage from, pipework
   a disconnecting
   b aligning
   c connecting

2. list the procedure needed to safely and effectively dismantle components
   a make identification (witness) marks on components so that they can be correctly reassembled or re- aligned
   b label and safely store parts that have been removed

3. state the precautions needed to avoid danger from, or damage to, components whilst installing, dismantling and assembling from
   a misalignment
   b use of wrong tools or excessive force
   c uncontrolled release of springs
   d scoring of surfaces

4. state how to protect dismantled components from contamination
   a blanking off open ports
   b use of correct cleaning agents and lint free cloths

5. identify the essential points to be checked when inspecting refrigeration components
   a bearing surfaces
   b erosion and pitting
   c split or worn seals
   d signs of overheating (colour changes)
   e condition of filters for signs of metallic or other particles, indications of emulsions or oil deterioration.

6. state the procedures for re-assembling components to avoid damage using the approved sequence for tightening bolts and applying specified torque and the application of lubrication to seals

7. state the need for correctly labelling re-built components for replacement in a system or returning to stores

8. describe routine tests for
   a checking oil for signs of oxidation and acidity
   b bench testing re-assembled components.
   c pressure testing pipework and pressure vessels

9. list the precautions to be taken when refilling systems with refrigerant oils

10. describe methods of bleeding systems safely to eliminate air locks and avoid spillage

11. describe the different ways of presenting information that can be used to appraise the outcome of a maintenance or installation activity

Outcome 4 De-isolate, commission or re-commission the system, restore the work area and resources

Practical Activities

The candidate will be able to

1. bring the system on line and adjust as required until the working parameters have been fully met
2. restore work areas to a clean and safe condition on completion of maintenance or installation
3. identify hazardous substances that may have been used or discovered during the work and give the approved method of disposal for each such substance.
4. specify any work needed for the restoration of work areas
5. hand over the system to the authorised persons
6. complete a report on the actions taken

Underpinning knowledge

The candidate will be able to

1. state the precautions to be taken when
   a refilling or recharging systems
   b opening up the system to the sources of pressure

2. describe methods of draining, bleeding and purging systems safely to avoid undue leakage or contamination

3. state how to set up and test interlocks, sensors and limit switches

4. list the sequence of bringing systems back to the specified working conditions by
   a removal of protective covers and blanks
   b opening appropriate valves or switches
   c operating the system under gradually increasing pressures or loads

5. identify any materials used that are classified as hazardous and those that can be recycled

6. state the methods of securing pipework and safety fittings (guards, handrails)

7. state the necessity for, and methods of, reporting any damage caused by the maintenance or installation activity where additional restoration work may be needed
   a brickwork
   b grouting
   c plastering
   d decorating

8. describe methods of replacing insulation, lagging and other protective coverings

9. state methods of applying identification markings to different parts of a system
    a colour identification of pipework to BS1710
    b using appropriate and approved codings for electrical connections and components

10. state the need to let all interested parties know of any changes that may affect the operation of the system, or of any new conditions that could exist in the work area

11. state the procedure for terminating any ‘Permits to Work’ that have been implemented

12. explain how any work termination documents or reports that may be required are completed and passed on to an authorised person

Unit 039 Turning

Rationale
This unit is concerned with the requirements necessary to successfully machine by turning it includes the preparation of the machine, selection and the preparing of the required methods of work holding, the selection and the correct mounting of cutting tools. It also covers the operations required and safe working practices to complete the machining operations.

The workpiece MUST be produced to BS EN 20286-1 with a surface texture of an appropriate standard

Outcomes
There are three outcomes to this unit. The candidate will be able to
1 prepare the machine for machining
2 manufacture the component and monitor the processes
3 reinstate the work area

Connection with other awards
This unit relates to units 001-007, 052-055 of the City & Guilds NVQ in Mechanical manufacturing engineering (1682)

It also relates to the *OSCEng ECS* 2.01, 2.02, 2.03, 2.12, 2.15, 3.04, 3.13.

Assessment
The outcomes from this unit will be assessed using evidence from a centre devised assignment which will cover both practical activities and underpinning knowledge.

Outcome 1 Prepare the machine for the machining

Practical Activities

The candidate will be able to
1. select and set up a suitable lathe to meet component and production specifications
2. inspect lathe (including safety mechanisms)
3. produce a table of, and set speeds and feeds required
4. select, prepare and mount cutting tools
5. produce a chart indicating the approximate times for machining the component, including down times

Underpinning Knowledge

The candidate will be able to
1. explain the range and type of lathes
   - a centre
   - b capstan
   - c turret

2. state the features, parts, applications and reasons for the choice of the lathes
   - a centre lathe
   - b capstan lathe
   - c turret lathe

3. describe the checks required
   - a safety switches
   - b interlock devices
   - c emergency stops
   - d alignment tests
     - i headstock
     - ii tailstock
     - iii centres

4. describe turning operations
   - a sliding and facing
   - b recessing
   - c parting off
   - d profile turning
     - i generating
     - ii forming
   - e knurling
   - f taper turning
     - i off set tailstock
     - ii taper turning attachment
   - g drilling
   - h boring
   - i reaming
   - j threading internal and external
     - i taps and dies
     - ii chasers

iii single point tools

5. define cutting speed as relative speed between tool point and work surface

6. explain the factors affecting choice of cutting speed
   a work material being cut
   b cutting tool material
   c type of cutting operation
   d surface finish required
   e type of cutting fluid required

7. define feed as distance the tool travels per revolution of the work (mm/rev)

8. explain the factors affecting choice of feed
   a finish required
   b rate of material removal
      i type of cutting tool material
      ii power of machine
   c type of cutting operation being carried out

9. calculate cutting speeds and feeds between tool point and work surface

10. calculate
   a actual cutting times
   b total machining times

11. state the types and properties of cutting fluid
   a aqueous
      i oil-type
      ii chemical
   b synthetic
   c gases

12. describe the range, setting, methods of use and characteristics of workholding methods and devices
   a three jaw chuck
      i hard jaws
      ii soft jaws
   b four jaw chuck
      i normal
      ii reverse
      iii regular shapes
      iv irregular shapes
      v balancing
   c collets
      i parallel
      ii expanding
   d face plate
      i hold work directly on plate
      ii hold work via a fixture
      iii balancing
   e magnetic and pneumatic devices
   f catch plates and carriers

g centres and sleeves
  i dead
  ii running
  iii live
h mandrels
  i plain
  ii expanding
i steadies
  i fixed
  ii travelling
j fixtures
k spigots
l bar feed

13. state the purpose of workholding
  a locate workpiece
  b restrain workpiece against cutting forces

14. state the types of defects that can be found on equipment

15. describe the types, identifying features and applications of lathe tools
  a solid bit
  b butt welded
  c brazing insert
  d single point tip
  e disposable/indexible insert tips

16. state the cutting tool materials, their uses and effects on cutting speed, feed and surface finish
  a high speed steel
  b alloyed steel
  c brazed tungsten carbide
  d cemented carbide
  e ceramics
  f diamond

17. state the types of tool bit and their holders
  a material
  b shape and size to current standards

18. explain cutting tool geometry its purpose and effects
  a factors affecting penetration of material by cutting
    i hardness of cutting tool material in relation to material being cut
    ii sharpness of cutting tool
    iii wedge form of cutting tool
    iv chip breakers
  b angle of wedge shape and their function, terminology and sizes
    i rake angle: positive, neutral and negative
    ii wedge angle
    iii approach angle
    iv centre height and its effect

c forces acting at the tool point
  i orthogonal cutting
    A two forces acting: Fc = main cutting force, Ff = feed force
  ii oblique cutting
    A third force Fr = radial force

19. describe the types, identifying feature and applications of other cutting tools used on lathes
  a boring tools and holders
  b drills
    i twist
    ii core
  c purpose of reaming:
    i dimensional accuracy
    ii quality of surface finish
  d dimensional and geometrical accuracy of reamers
    i importance of correct drill size
  e types of machine reamer
    i machine
    ii chucking
    iii expanding
    iv taper
  f nomenclature of reamers
  g accessories used with reamers
    i extension sockets
    ii reduction sleeves
    iii machine tapers
    iv floating reamer

20. describe the method of mounting and holding tools and cutters
  a cutting tools
    i single post
    ii quick change tool post
    iii fourway tool post
    iv capstan/turret toolholders
      A front tool box
      B rear tool box
  b cutters
    i tailstock
    ii chucks
    iii special workholding devices
      A tap and die holders
      B die box
      C roller box
      D floating reamer holder

Outcome 2 Manufacture the component and monitor the processes

Practical Activities

The candidate will be able to
1. produce an operations sheet (for all of them
2 carry out safety checks on machine, tools and equipment and record results
3. mount and secure work piece
4. set tool parameters, produce a component to specifications, using a range of machining methods, single and multiple tool settings (minimum of **three)**, surface texture to be of an appropriate standard; BS EN 20286-1
5. monitor the turning process cutting, measurement, dimensions, geometrical and surface texture
6. change cutting tools, cutters and set up as required
7. maintain and adjust variables to ensure to complete operation

Underpinning Knowledge

The candidate will be able to
1. explain the methods of starting and stopping the lathe, including emergency stop procedure

2. describe the basic care and maintenance of the machine

3. explain the methods to produce: roughing and finishing cuts
    a external
    b internal
    c faces
    d recesses
    e undercuts
    f between centres
    g parting off
    h drilling holes
        i centre drilling
        ii pilot drilling
        iii drilling
            A through holes
            B blind holes
            C flat bottom
    i reaming holes
        i through
        ii blind
    j boring holes
        i through
        ii blind
    k tapers
        i form tool
        ii compound slide
        iii offset tailstock
        iv taper turning attachment
    l forms/profiles
        i tool

        ii   copying attachment
    m   chamfers
    n   threading
        i   external
            A   dies and die boxes
            B   chasers
            C   single point: right hand single start, vee and acme threads and two start square
        ii   internal
            A   taps
            B   chasers
            C   single point: right hand single start, vee and acme threads and two start square
    o   parting off
        i   front tool post
        ii   rear tool post
    p   knurling

4. describe the types of chip produced when turning
    a   continuous
        i   materials that produce type of chip
        ii   methods of prevention
        iii   dangers
    b   discontinuous
        i   materials that produce type of chip

5 describe the relationship between feed rate and depth of cut and the effect on material removal rate

6. explain the possible problems and rectification likely to occur whilst machining the product in terms of
    a   machine
    b   tooling
    c   material
    d   specifications
        i   dimensions
        ii   surface finish
    e   machining times
    f   down times
    g   cutting fluid

7. describe the operational procedures and how they can be varied to improve efficiency

8. determine the workrate that can be achieved

9. explain the factors to be considered for effective production of components
    a   correct sequence of machining operations to maximise production
    b   eliminating unnecessary tool changes
    c   eliminate unnecessary materials handling
    d   eliminate making out and ensure conformity of components using
        i   fixtures
        ii   stops and guides
    e   adjust parameters to improve quality and production efficiency

10. explain production problems encountered and possible remedies
    a oversize/undersize components
        i tool wear
        ii slackness in slides
        iii deflection
    b inconsistency of product shape
        i deflection
        ii clamping
        iii stops
        iv alignment of fixtures
    c vibration
        i condition of machine
        ii tooling
        iii set up
        iv speeds and feeds
    d surface damage of component
        i blunt tools
        ii clamping
    e product schedules not being met

11. explain the need to comply with statutory health and safety legislation to protect the health and safety of self and others within the vicinity of the machining operations
    a safety check on **all** parts of the machine and equipment
    b ensure all guards are in working order, in place and in use
    c wear the correct personal protective equipment (PPE)
    d ensure materials handling is carried out safety at all times
    e obtain COSHH information prior to commencing and adhere to it throughout with regard to
        i lubricants
        ii cutting fluids
        iii cleaning materials

Outcome 3 Reinstate the work area

Practical Activities

The candidate will be able to
1. identify and comply with relevant health and safety legislation
2. produce a plan for reinstatement of the work area
3. restore work area used for machining to specified requirements
4. sign off recognition slips by returning tools, equipment, measuring instruments and materials to appropriate storage units
5. identify, dispose of and record hazardous substances which may have been used
6. identify remedial actions required to solve any problems in restoring work area and record actions taken

Underpinning Knowledge

The candidate will be able to
1. explain health and safety and environmental legislations for waste disposal, and implications of not following legal requirements

2. state the importance of maintaining the safety and cleanliness of machinery, tools, equipment and the work area
   a isolate machines
   b manual cleaning
   c machine assisted cleaning
   d use and correct storing of cleaning agents
   e identify and label products
   f inspection of components, tools and equipment on the completion of work
   g sort items in 'f' into reusable, rework ,waste and return to store
   h clean and store personal protective equipment

3. describe the correct procedures for dealing with waste materials
   a types of waste produced
   b storage and waste removal
   c disposal methods
      i recycle
      ii solid waste
      iii liquid waste

4. describe the potential problems that may occur during restoring the work area and actions to be taken

5 describe the actions to be taken in the event of a spillage
   a barriers and safety signs
   b use of PPE
   c aids to containment and prevention of spillage reaching watercourse
   d aides for cleaning
   e notification of appropriate person

Unit 040 Milling

Rationale
This unit is concerned with the requirements necessary to successfully machine by milling, it includes the preparation of the machine, selection and the preparing of the required methods of work holding, the selection and the correct mounting of cutting tools. It also covers the operations required and safe working practices to complete the machining operations.

The workpiece **must** be produced to BS EN20286-1 with a surface texture of an appropriate standard.

Outcomes
There are three outcomes to this unit. The candidate will be able to:
1 prepare the machine for machining
2 manufacture the component and monitor the processes
3 reinstate the work area.

Connection with other awards
This unit relates to units 001-003, 008-015,-052of the City & Guilds NVQ in Mechanical manufacturing engineering (1682).
It also relates to the *OSCEng ECS* 2.01, 2.02, 2.03, 2.15, 3.04 and 3.13.

Assessment
The outcomes from this unit will be assessed using evidence from a centre devised assignment which will cover both practical activities and underpinning knowledge.

Outcome 1 Prepare the machine for the machining

Practical Activities

The candidate will be able to
1. select and set up a suitable milling machine to meet component and production specifications
2. inspect and commission the milling machine, (including safety mechanisms)
3. carry out relevant alignment checks
4. produce a table of, and set speeds and feeds required
5. select, prepare and mount cutting tools
6. produce a chart indicating the approximate times for machining the component, including lead in and down times

Underpinning Knowledge

The candidate will be able to
1. explain the range and type of milling machines
   a horizontal
   b vertical
   c universal

2. outline the, construction, parts, applications and reasons for the choice of milling machines
   a horizontal
   b vertical
   c universal

3. explain the checks required
   a safety switches
   b interlock devices
   c emergency stops
   d alignment tests
      i table
      ii vertical spindle/quill

4. state equipment operating and care procedures

5. describe horizontal milling operations
   a milling flat surfaces
      i horizontal
      ii vertical
   b production of slots
   c slitting thin plate
   d gang milling
   e straddle milling
   f cutting keyways
   g gear cutting

6. describe vertical milling operations
   a milling flat surfaces
      i horizontal
      ii vertical
   b producing slots
      i tee
      ii dovetail
   c sunk and recessed surfaces
   d keyway cutting: including woodruff

7. define cutting speed as relative speed between tool point and work surface

8. explain the factors affecting choice of cutting speed
   a work material being cut
   b cutting tool material
   c type of cutting operation
   d type of cutter
   e surface finish required
   f type of cutting fluid required

9. define feed
   a cut/tooth
   b table feed rate (mm/min)
   c calculate feed, formula (feed/tooth x number of teeth x rev/min)

10. explain the factors affecting choice of feed
   a finish required
   b rate of material removal
      i type of cutting tool material
      ii power of machine
   c type of cutting operation being carried out
   d type of cutter

11. calculate cutting speeds for milling

12. calculate actual cutting time, approach distance and total machining times

13. state the types and properties of cutting fluid
   a aqueous
      i oil-type
      ii chemical
   b synthetic

14. explain the purpose of cutting fluids
   a provision of lubrication at tool point
   b absorption and removal of heat from the cutting zone
   c maintaining clean cutting zone
   d washing away chips

15. explain the relationship between rotation of cutter and feed direction
   a up-cut milling
   b down-cut milling

16. outline the problems that can occur when preparing milling machines and the procedures for resolving them

17. describe the range, setting, method of use and characteristics of workholding methods and devices
    a clamping work to machine table
    b machine vice
    c tilting table
    d sine bar and sine table
    e rotary table
    f angle plate
    g vee blocks
    h dividing head plain and universal
        i methods of workholding
        ii indexing calculations
            A simple
            B compound
            C differential and angular
        i fixtures

18. state the purpose of workholding
    a locate workpiece
    b restrain workpiece against cutter forces

19. explain the potential movement of the workpiece along and around the x, y, and z axes of the machine

20. state the types of defects that can be found on equipment

21. state the types and applications of arbor mounted cutters
    a side and face
    b cylindrical cutters (slab mill
    c saws
    d angular cutters
    e concave and convex cutters
    f radius
    g form cutters
    h fluting cutters

22. describe arbors, stub arbors and methods of mounting
    a construction
    b mounting procedures
    c setting cutters
    d support brackets
    e knee braces

23. describe the types and application of collet held cutters
    a types
        i end mill
        ii slot drill
        iii fly cutters
        iv tee slot, woodruff key and dovetail cutters
    b shank styles
        i screwed
        ii straight
        iii flatted

24. describe the types and applications of spindle held cutters
    a face mills
    b inserted blade

25 explain the operation and application of collet chucks
    a types of locking devices
    b ease of changeability

26. state cutter materials, including coated, uses and their effects on cutting speed and surface

27. describe the types and method of securing of other cutters
    a drills taper, parallel and taper shank
    b machine reamers
    c machine taps
    d boring tools

28. explain the tool geometry of milling cutter
    a factors affecting penetration of material by cutting edge
        i hardness of cutting tool material in relation to material being cut
        ii sharpness of cutter
        iii wedge form of cutter
    b angle of wedge shape and their function and terminology
        i rake angle
            A positive
            B negative
            C neutral

29. calculate the cutting forces applied during material removal

Outcome 2 Manufacture the component and monitor the processes

Practical Activities

The candidate will be able to
1. produce an operation sheet: (for all of them)
2. carry out safety checks on machine, tools and equipment and record results
3. mount and secure work piece
4. set tool parameters, produce a component to specifications, using a range of machining methods, single and multiple tool settings (minimum of **three**), surface texture to be of an appropriate standard; BS EN 20286-1
5. monitor the milling process, cutting, measurement, dimensions, geometrical accuracy and surface texture
6. change cutters and set up as required
7. maintain and adjust variables to ensure to operation is completed

Underpinning Knowledge

The candidate will be able to
1. explain the methods of starting, stopping, including emergency stop procedure, the milling machine

2. describe the basic care and maintenance of the machine

3. explain the process variables that could occur when milling

4. explain the relationship between depth of cut and feed rate and effect on material removal rate

5. explain the possible problems likely to occur whilst machining the product and the remedial action required
   - a machine
   - b tooling
   - c material
   - d specifications
     - i dimensions
     - ii surface finish
   - e operational procedures
   - f machining times
   - g cutting fluids

6. outline operational procedures and how they can be varied to improve efficiency

7. determine the workrate that should be achieved

8. explain the factors to be considered for effective production of components
   - a correct sequence of machining operations to maximise production
   - b eliminating unnecessary tool changes
   - c eliminate unnecessary materials handling
   - d eliminate making out and ensure conformity of components using
     - i fixtures
     - ii stops and guides

e adjust parameters to improve quality and production efficiency

9. outline production problems encountered and possible remedies
   a oversize/undersize products
      i tool wear
      ii slackness in slides
      iii deflection
   b inconsistency of product shape
      i deflection
      ii clamping
      iii stops
      iv alignment of fixtures
   c vibration
      i condition of machine
      ii tooling
      iii set up
      iv speeds and feeds
   d surface damage of component
      i blunt tools
      ii clamping
   e product schedules not being met

10. explain the need to comply with statutory health and safety legislation to protect the health and safety of self and others within the vicinity of the machining operations
   a safety check on ALL parts of the machine and equipment
   b ensure all guards are in working order, in place and in use
   c wear the correct personal protective equipment (PPE)
   d ensure materials handling is carried out safety at all times
   e obtain COSHH information prior to commencing and adhere to it throughout with regard to
      i lubricants
      ii cutting fluids
      iii cleaning materials

Outcome 3 Reinstate the work area

Practical Activities

The candidate will be able to

1. identify and comply with relevant health and safety legislation
2. produce a plan for reinstatement of the work area
3 restore work area used for machining to specified requirements
4. sign off recognition slips by returning tools, equipment, measuring instruments and materials to appropriate storage units
5. identify, dispose of and record hazardous substances which may have been used
6. identify remedial actions required to solve any problems in restoring work area and record actions taken

Underpinning Knowledge

The candidate will be able to

1. explain health and safety and environmental legislations for waste disposal, and implications of not following legal requirements

2. outline the importance of maintaining the safety and cleanliness of machinery, tools, equipment and the work area
   a isolate machines
   b manual cleaning
   c machine assisted cleaning
   d use and correct storing of cleaning agents
   e identify and label products
   f inspection of components, tools and equipment on the completion of work
   g sort items in ‘f’ into reusable, rework, waste and return to store
   h clean and store personal protective equipment

3. explain the correct procedures for dealing with waste materials
   a types of waste produced
   b storage and waste removal
   c disposal methods
      i recycle
      ii solid waste
      iii liquid waste

4. describe the potential problems that may occur during restoring the work area and actions to be taken

5. describe the actions to be taken in the event of a spillage
   a barriers and safety signs
   b use of personal protective equipment
   c aids to containment and prevention of spillage reaching watercourse
   d aides for cleaning
   e who should be notified

Unit 041 Grinding

Rationale
This unit is concerned with the requirements necessary to successfully machine by grinding, it includes the preparation of the machine, selection and the preparing of the required methods of work holding, the selection and the correct mounting of cutting tools. It also covers the operations required and safe working practices to complete the machining operations.

The workpiece MUST be produced to BS EN 20286-1 with a surface texture of an appropriate standard.

Outcomes
There are three outcomes to this unit. The candidate will be able to
1 prepare the machine for machining
2 manufacture the component and monitor the processes
3 reinstate the work area.

Connection with other awards
This unit relates to units 001-003, 022-027, 052 of the City & Guilds NVQ in Mechanical manufacturing engineering (1682).
It also relates to the *OSCEng ECS* 2.01, 2.02 and 2.03.

Assessment
The outcomes from this unit will be assessed using evidence from a centre devised assignment which will cover both practical activities and underpinning knowledge.

Outcome 1 Prepare the machine for the machining

Practical Activities

The candidate will be able to

1. select and set up a suitable grinding machine to meet component and production specifications
2. inspect and commission the grinding machine, (including safety mechanisms)
3. carry out relevant alignment checks
4. set feed
5. select and balance the grinding wheel
6. ensure the grinding wheels are dressed/formed
7. select, prepare and mount workholding devices
8. estimate the approximate times for machining the component, including down times

Underpinning Knowledge

The candidate will be able to

1. identify factors affecting preparation

2 state the purpose of grinding
   a remove material from pre-hardened surfaces
   b to produce high standard surface finishes to high dimensional accuracy

3. explain the range and type of grinding machines
   a surface
      i horizontal (reciprocating and rotating work)
      ii vertical (reciprocating and rotating work)
   b cylindrical
      i external
      ii internal
   c universal
   d centreless
   e thread

4. state the, parts, applications and reasons for the choice of grinding machines
   a surface
   b cylindrical
   c universal
   d centreless
   e thread

5. explain the methods of feeding the work relative to the wheel when setting

6. explain the relationship between and calculate wheel and work speeds

7. state who is authorised to use the equipment and what training is required

8. state the checks required for safety and the machine
   a. oil levels
      i. wheelhead and workhead
      ii. lubrication points
   b. ensure no end play in spindle
   c. security of pipes and couplings
   d. safety devices and interlocks are working
   e. emergency stops
   f. alignment
   g. traverse stops are functional
   h. guards in position and secure

9 define the wheel enclosure angles

10. define speeds, feeds and cutting times for grinding machines
   a. cutting speed as relative speed between point on grinding wheel and work surface in m/min
   b. how to maintain speed for reduced diameters
   c. factors affecting choice of cutting speed
      i. hard or soft work material
      ii. surface finish required
      iii. rate of feed
      iv. arc of contact between wheel and work
      v. diameter and thickness of work

11. state the type and care of cutting fluids

12. explain the purpose of cutting fluids
   a. absorption and carry away heat from the cutting zone, rapid cooling
   b. maintain clean cutting zone, flood contact zone
   c. to remove dust and particles

13. explain the filtering system for the cutting fluid

14. outline the problems that can occur when preparing and setting grinding machines and the procedures for resolving them

15. describe dust extraction equipment
   a. purpose and function
   b. checking
   c. removal of waste

16. describe the range, preparation, location, method of use and characteristics of workholding methods and devices
    a direct clamping
    b vices
    c fixtures
    d chucks
        i three jaw self centring
        ii four jaw independent
        iii collet
        iv magnetic
    e spigots
    f between centres
    g rests
    h guides

17. state the purpose of workholding
    a restrain workpiece against wheel force
    b locate workpiece

18. outline the types of difficulty that can occur with preparation of equipment and possible resolutions

19. define the types of defects that can be found on equipment

20. explain the principle of material removal by the grinding wheel
    a the wheel as a multi-point self-sharpening cutting tool

21. describe the construction of a grinding wheels
    a abrasive materials
    b grain size
    c grade of the wheel
    d structure of the wheel
    e bonding materials

22. explain the EN/BS system of marking abrasive wheels

23. describe the types, identifying features of wheels to current standards
    a straight or plain – type 1
    b recessed – types 5 and 6
    c tapered – types 3 and 4
    d ring – type 2
    e cup – types 6 and 11
    f dish – type 12
    g saucer – type 13
    h wheels under 55mm diameter used for internal grinding
    i segmental

24 state the factors affecting wheel selection
    a material to be ground
    b amount of material to be removed
    c arc/area of contact
    d type and condition of machine
    e wheel and work speeds
    f dry or wet cutting

25. explain the methods of mounting wheels
26. explain the way wheels are balanced using mandrel and knife edges

27 describe the effects of an unbalanced wheel

28. explain the difference between truing and dressing of an abrasive wheel

29. explain the requirements of guards and state the specified enclosure angles for each grinding machine

30. describe the function and construction of the control wheel

31. describe the selection, mounting setting of the grinding wheel for internal grinding

32. explain the setting of the rest for centreless grinding

33. explain the methods of and settings for centreless grinding
    a through feed
    b in feed
    c end feed

34. explain the methods of and setting for thread grinding
    a pass over
    b plunge

35. describe the methods of wheel forming
    a pantograph wheel dresser
    b crushing

36. describe the method of examining, handling and storing of abrasive wheels
    a visual examination
    b ring test for cracks and soundness
    c handling abrasive wheels
        i careful manual handling
        ii do not roll
        iii use trucks with support for large wheels
    d storage own store and within racks

37. describe the method of truing and dressing wheels
    a fixed installation diamond
    b portable diamond

Outcome 2 Manufacture the component and monitor the processes

Practical Activities

The candidate will be able to
1. produce an operations sheet
2. carry out safety checks on machine, tools and equipment and record results
3. mount and secure work piece
4. set parameters, produce a component to specifications, using a range of machining methods, surface texture to be of an appropriate standard; BS EN 20286-1
5. monitor the process, grinding, measurement, dimensions, geometrical accuracy and surface texture
6. change grinding wheel and set up as required
7. maintain and adjust variables to ensure to operation is completed

Underpinning Knowledge

The candidate will be able to
1. explain the methods of starting, stopping, including emergency stop procedure, the grinding machine

2. describe the basic care and maintenance of the machine

3. explain the process variables that could occur when grinding

4. state the process of grinding as a cutting process using abrasive cutting material bonded in the form of a wheel

5. describe the methods to produce and measure both roughing and finishing cuts
   a external diameters: parallel and tapered
   b internal diameters: parallel and tapered
   c horizontal and vertical faces
   d angular and parallel faces
   e shoulders and steps both internal and external
   f profiles including threads
   g chamfers
   h thin sections

6. explain the reasons for/and how to prevent distortion

7. explain the reason for ‘sparkout’

8. explain the reasons for the ‘warm up’ period of the machine

9. outline operational procedures and how they can be varied to improve efficiency

10. explain the setting of
    a traverse stops
    b centres
    c rests
    d guides

e control wheel

11. describe the possible problems and rectifications required whilst grinding the component in terms of
    a grinding wheel
    b machine
    c material
    d specifications
        i dimension
        ii geometrical
        iii surface finish
    e operational procedures
    f cutting fluids

12. describe the care of grinding wheels in use
    a cause and effects of wheel loading and glazing
    b methods of correcting loading and graving
        i change wheel
        ii amend work speed
        iii cutting conditions
    c application of cutting fluids

13. explain the effects of heat when grinding
    a expansion/dimensional accuracy
    b overheating/wheel life and additional costs

14. state operational procedures and how they can be varied to improve efficiency

15. describe the factors to be considered for effective production of components
    a correct sequence of machining operations to maximise production
    b eliminate unnecessary wheel changes and material handling
    c application of stops and guides to ensure conformity of component
    d adjust parameters to improve quality and production efficiency

16. outline production problems encountered and possible remedies
    a over and undersize components: wheel wear, slackness in slides deflection
    b inconsistency of component shape: deflecting and stops
    c vibration: condition of machine, set up, speeds and feeds
    d surface finish of component: wheel fault and camping

17. explain the need to comply with statutory health and safety legislation at all times to protect self and other within the vicinity of the machining operations
    a ensure all guards are operational, in place and in use
    b safety checks on machine, set up and equipment

Outcome 3 Reinstate the work area

Practical Activities

The candidate will be able to
1. identify and comply with relevant health and safety legislation
2. produce a plan for reinstatement of the work area
3 restore work area used for machining to specified requirements
4. sign off recognition slips by returning tools, equipment, measuring instruments and materials to appropriate storage units
5. identify, dispose of and record hazardous substances which may have been used
4. identify remedial actions required to solve any problems in restoring work area and record actions taken

Underpinning Knowledge

The candidate will be able to
1. explain health and safety and environmental legislations for waste disposal, and implications of not following legal requirements

2. outline the importance of maintaining the safety and cleanliness of machinery, tools, equipment and the work area
   a isolate machines
   b manual cleaning
   c machine assisted cleaning
   d use and correct storing of cleaning agents
   e identify and label products
   f inspection of components, tools and equipment on the completion of work
   g sort items in ‘f’ into reusable, rework , waste and return to store
   h clean and store personal protective equipment

3. explain the correct procedures for dealing with waste materials
   a types of waste produced
   b storage and waste removal
   c disposal methods
      i recycle
      ii solid waste
      iii liquid waste

4. describe the potential problems that may occur during restoring the work area and actions to be taken

5. describe the actions to be taken in the event of a spillage
   a barriers and safety signs
   b use of personal protective equipment
   c aids to containment and prevention of spillage reaching the watercourse
   d aides for cleaning
   e who should be notified

Unit 042 CNC machining

Rationale
This unit is concerned with the requirements necessary to successfully machine by CNC, it includes the preparation of the machine, selection and the preparing of the required methods of work holding, the selection and the correct mounting of electrode. It also covers the operations required and safe working practices to complete the machining operations.

The workpiece MUST be produced with a surface texture of an appropriate standard.

Outcomes
There are six outcomes to this unit. The candidate will be able to
1 describe the operating principles of CNC machines
2 prepare documentation for CNC operations
3 investigate program formats used in CNC part programming
4 produce a manual part program for a CNC machine
5 produce components on a CNC machine
6 reinstate the work area.

Connection with other awards
This unit relates to units001-003,030-052,093-096 of the City & Guilds NVQ in Mechanical manufacturing engineering (1682)

It relates to *OSCEng ECS* 2.01, 2.02, 2.03, 2.05, 2.13, 2.15 - 2.18, 3.02 and 3.04.

Assessment
The outcomes from this unit will be assessed using evidence from a centre devised assignment which will cover both practical activities and underpinning knowledge.

Outcome 1 Describe the operating principles of CNC machines

Practical activities

The candidate will be able to
1. produce block diagrams showing the elements of open and closed loop control systems
2. investigate the methods used to control tool movements on CNC machines
3. produce line diagrams to identify primary and secondary axes of motion for vertical and horizontal spindle CNC machines indicating positive and negative movement
4. investigate tool holding systems on CNC machine tools
5. investigate work holding systems on CNC machine tools

Underpinning Knowledge

The candidate will be able to
1. state the main structural elements of CNC machine tools and recognise the importance to accurate performance in milling and turning of
   a strength
   b rigidity
   c vibration damping
   d correct alignment
   e feedback transducers
   f re-circulating ball and leadscrew

2. state the operating principles of linear and rotary transducers used in CNC systems

3. describe the differences between open and closed loop control systems in terms of
   a positional feedback
   b drive method

4. explain different types of machine control and the application to which they are suited
   a type
      i point to point control
      ii linear (paraxial) control
      iii continuous path control
   b application
      i point to point drilling and tapping operations
      ii linear profiles and slots
      iii curved profiles and slots

5. describe the X Y and Z conventions used for primary axis motion for various CNC machine configurations

6. state the U V and W conventions used for secondary axis motion for various CNC machine configurations

7. state the A B and C conventions used for rotation about the primary axes

8. describe the types of manual and automatic tool change systems

9. explain the importance of correct procedures when loading tools in
   a manual tool change systems
   b indexing turrets or magazines in automatic tool change systems

10. outline the benefits of using
    a preset tooling
    b qualified tooling
    c modular cutting unit systems
    d tool adapter systems

11. describe the benefits of establishing a tool library containing
    a tool identification number.
    b tool geometry
    c tool offset values
    d speed feed and tool life data

12. explain the use of sensing devices and electronic probes for monitoring:
    a tool life and cutting conditions
    b tool breakage detection
    c tool offset measurements
    d tool identification
    e torque variations
    f acoustic output

13. describe the function of work holding and setting devices used on CNC machines in terms of
    a conventional work holding devices modified to suit CNC operation
    b positioning work datums relative to machine datums
    c the need for zero shift controls and how they are used
    d the use of air and hydraulic work holding devices for gripping delicate components

14. describe the methods of setting work holding devices accurately relative to machine slide movements

15. explain problems of swarf removal and the methods used to overcome them including
    a volume produced
    b conveyor systems
    c slant bed design
    d cutting fluid reclamation

Outcome 2 Prepare documentation for CNC operations

Practical Activities

The candidate will be able to
1. re-dimension component drawings using absolute, incremental and polar co-ordinates
2. interpret component specifications
3. prepare an effective task plan
4. calculate speeds and feeds for different work/tool combinations
5. calculate cutter path co-ordinates using Pythagoras theorem and trigonometry
6. prepare documentation for CNC machining operations to include co-ordinate dimension table, operation sheet giving operation sequence with speed and feed values and operator instructions for work holding methods and datum setting

Underpinning Knowledge

The candidate will be able to
1. explain the documentation required for CNC operation as
   - a component drawings
   - b operation sheet
   - c tool holding and work holding data sheets
   - d part program

2. describe the importance of dimensioning component drawings from suitable datums using absolute, incremental and polar co-ordinates

3. describe the factors that must be considered when planning a part program
   - a importance of identifying and planning for:
     - i component material
     - ii dimensions and tolerances
     - iii required surface finish
     - iv appropriate datum settings
     - v roughing and finishing operations
     - vi grouping of similar operations
     - vii relevant canned cycles, loops, macros and subroutines
   - b work holding methods to give accurate location and secure clamping/work holding
     - i CNC milling machines including
       - A direct clamping
       - B vices
       - C fixtures
       - D devices modified for CNC operations
     - ii CNC lathes including
       - A three jaw chucks, including the use of soft jaws
       - B four jaw chucks
       - C collets

4. outline the benefits of producing tables of co-ordinate dimension taken from specified datum positions

5. describe the characteristics of cutting tool material and factors affecting tool life

6. explain tool geometry requirements for effective material removal

7. describe the characteristics and applications of different types of
   a milling cutters
   b turning tools

8. describe the principles of mounting/clamping systems for
   a milling cutters
   b turning tools

9. explain the essential information required on operation sheets and operator instructions including
   a work material
   b work datum position
   c work holding requirements
   d tooling requirements including pre-setting data
   e sequence of operations
   f speeds and feeds

10. define the methods used to calculate speeds and feeds for CNC machine tools
    a spindle speed
       i define cutting speed as relative linear speed between work surface and tool point
       ii use cutting tool manufacturers data for work/tool combinations allowing for
          A type of cutting operation
          B surface finish requirements
          C use of coolant
    b feed rate
       i define feed rate as distance moved per minute (mm/min) or distance moved per revolution (mm/rev)
       ii use of manufacturers' feed rate data allowing for:
          A type of cutting operation
          B surface finish requirements
          C cutting tool geometry
          D work/tool material combinations
          E delicacy of work piece and work holding method

11. explain the importance of modifying feed rates when profiling internal and external radii

12. define the methods of calculating component cutter path co-ordinates using
    a sine rule
    b Pythagoras' theorem
    c basic trigonometrical ratios

Outcome 3 Investigate program formats used in CNC part programming

Practical activities

The candidate will be able to
1. investigate and compare different programming formats including ISO word address and other formats used by Fanuc, Heidenhain and other machine manufacturers
2. investigate and compare word address, conversational and graphical programming
3. write part programmes for given components

Underpinning Knowledge

The candidate will be able to
1. explain the principles of computer numerical control as the control of machine movements and management functions through coded instructions

2. describe the basic type of program format as
   a fixed sequence/block
   b word address

3. describe the meaning of the part programming terms
   a character
   b word
   c block
   d modal and non-modal functions

4. explain the principles of absolute and incremental programming modes with additional data to be included
   a operation sequence
   b X, Y, Z, dimensional information
   c machine management information including
      i preparatory functions for:
         A rapid movement
         B time dwell
         C zero shift
         D feed rates
         E absolute/incremental dimensions
         F inch/metric units
      ii miscellaneous functions for:
         A end of program
         B spindle forward/reverse
         C tool change
         D coolant on/of
   d speeds and feeds
   e tooling requirements

Outcome 4 Produce a manual part program for a CNC machine

Practical Activities

The candidate will be able to
1. prepare the required documentation for CNC operation
2. produce an effective task plan
3. produce a dimensioned component drawing using suitable datums for manufacture
4 select correct tooling for the required machining operations
5. select suitable work holding for the required machining operations
6. calculate and produce a tabulated list of cutter path co-ordinates
7. calculate speeds and feeds for the work/tool material combinations and expected cutting conditions
8. write a part program in a format to suit the machine controller to be used

Underpinning Knowledge

The candidate will be able to
1. describe the factors to be considered when planning safe tool paths to ensure
   a safety of operator
   b collisions with component and work holding equipment are avoided
   c safe work and tool changing positions are specified

2. explain the advantages of using cutter diameter compensation for milling operations

3. state the role of assigned canned cycles
   a what is meant by an assigned canned cycle
   b the benefits of using assigned canned cycles

4. describe assigned canned cycles for milling operations
   a circular interpolation
   b rectangular/circular pocket milling
   c slot mill

5. describe assigned canned cycles for drilling operations
   a drilling
   b drill and dwell
   c deep hole drilling

6. explain the role of user defined cycles for:
   a loops
   b macros
   c subroutines

7. explain the translation and transformation commands for
   a mirror imaging
   b rotation
   c scaling
   d datum offset

8. state the benefits of using tool nose radius compensation for turning operations

9. state the constant surface speed mode for turning operations

10. explain circular interpolation and arc programming commands

11. describe assigned canned cycles for turning operations
    a stock removal in turning
    b stock removal in facing
    c thread cutting
    d peck drilling in Z axis

12. describe the role of defined areas to prevent collisions
    a safe zone
    b warning zone
    c prohibited zone

Outcome 5 Produce components on a CNC machine

Practical activities

The candidate will be able to
1. start a CNC machine in accordance with manufacturers' instructions
2. check that, guards, interlocking devices and fail safe mechanisms are operating
3. enter part program data into a CNC machine control system
4. set work datum and tool offset values
5. program proving and editing to check for program errors and to achieve optimum production performance
6. produce suitable components to required specifications
7. inspect finished component specifications

Underpinning Knowledge

The candidate will be able to
1. state the importance of personal safety and of using safe working practices at all times

2. describe the precautions to be taken to prevent accidents when setting and operating CNC machines

3. state the importance of using correct procedures when storing materials and equipment

4. state the relevant health and safety legislation and relevant manufacturers' safety recommendations

5. outline the potential human and environmental hazards when setting and operating CNC machines

6. state the importance to operator safety of guarding, interlock devices and fail safe systems used on CNC machines

7. describe the correct start up procedures for CNC machine tools

8. describe the procedures for data input to CNC machine controls using:
   a manual data input
   b portable systems
   c direct NC link

9. describe the methods used to set work datums and tool length offset values

10. outline the possible hazards during program proving and how they can be avoided using machine over-ride controls

11. outline the possible hazards when using the constant surface speed function on CNC lathes

12. state the location and function of emergency stop and program stop controls

13. describe the characteristics of preset and qualified tooling

14. state the importance of optimising production during program proving by
    a adjusting speeds and feeds to give maximum metal removal rates considering
        i surface finish requirements
        ii tool life requirements
    b reducing unnecessary tool movements
    c rearranging the machining sequence

15. describe methods of editing the part program:
    a manual data input (MDI)
    b off line using a text editor

16. describe the adjustments to compensate for errors and tool wear
    a tool offsets and length offset values
    b cutter radius/diameter compensation

17. explain the adjustment to compensate for dimensional error and tool wear

Outcome 6 Reinstate the work area

Practical Activities

The candidate will be able to
1. identify and comply with relevant health and safety legislation
2. plan for reinstatement
3 restore the work area to agreed requirements
4. identify reusable tools and equipment
5. dispose of waste
6. identify problems in restoring the work area

Underpinning Knowledge

The candidate will be able to
1. explain the relevant health and safety and environmental legislation for waste disposal and the implications of not following legal requirements

2. state the importance of maintaining the safety and cleanliness of machinery, tools, equipment and work area by
   a manual cleaning
   b machine assisted cleaning
   c using and correctly storing cleaning agents
   d labelling/identifying products
   e isolating machinery
   f inspecting components, tools and equipment on completion of work
   g sorting items in (f) into reusable and waste
   h cleaning and storing personal protection equipment

3. describe the correct procedures for dealing with waste materials
   a types of waste produced
   b storage and waste removal
   c disposal methods
      i recycling
      ii solid waste
      iii liquid waste

4. state the potential problems that may occur during restoring the work area and action to be taken

5. explain the actions to be taken in the event of a spillage
   a barriers and safety signs
   b use of personal protection equipment
   c aids to containment and prevention of spillage reaching the watercourse
   d aides for cleaning
   e who should be notified

Unit 043 Electrodischarge machining (EDM)

Rationale
This unit is concerned with the requirements necessary to successfully machine by EDM, it includes the preparation of the machine, selection and the preparing of the required methods of work holding, the selection and the correct mounting of electrode. It also covers the operations required and safe working practices to complete the machining operations.

The workpiece MUST be produced with a surface texture of an appropriate standard.

Outcomes
There are three outcomes to this unit. The candidate will be able to:
1 prepare the machine for machining
2 manufacture the component and monitor the processes
3 reinstate the work area.

Connection with other awards
This unit relates to units 001-003,020-021 of the City & Guilds NVQ in Mechanical manufacturing engineering (1682)
It also relates to the *OSCEng ECS* 2.01, 2.02, 2.03, 2.05, 2.15, 3.04 and 3.13.

Assessment
The outcomes from this unit will be assessed using evidence from a centre devised assignment which will cover both practical activities and underpinning knowledge.

Outcome 1 Prepare the machine for the machining

Practical Activities

The candidate will be able to
1. select and set up a suitable machine to meet component and production specifications
2. inspect machine to ensure mechanisms are in a safe condition
3. set machine in accordance with specifications
4. ensure relevant alignment checks
5. select, prepare and mount workholding devices
6. estimate the approximate times for machining the component, including setting times

Underpinning Knowledge

The candidate will be able to
1. identify factors affecting preparation
   a machine capacity
   b electrode size and condition
   c workholding devices

2. state the types of machine
   a ram feed
   b wire feed

3. describe the feature, parts, applications and reasons for the choice of machine
   a the process
      i movement of electrode
      ii action and duration of the spark
      iii maintenance of the spark gap
      iv use of dielectric fluid
   b dielectric fluids
   c pulse generator
   d forms of electrode
   e electrode material
   f wire feed
   g safety precautions to be observed
      i use special purpose personal protective equipment
      ii avoid contact with hydrocarbon dielectric fluids

4. state who is authorised to use the equipment and what training is required

5. outline the checks that are carried out prior to machining
   a safety switches
   b emergency stops
   c guards
   d dielectric levels
   e electrode/wire alignment
   f wire tension
   g current density
   h spark frequency

i linear speeds and feeds
j extraction/ventilation units
k filters

6. describe the types, function, and methods of supply, of dielectric fluid
    a types
        i hydrocarbon
        ii deionised water
        iii blended fluids
    b function
        i to provide the correct condition for spark discharge
        ii absorption and carry away heat from the electrode
        iii carry away eroded particles from the discharge area
    c method of supply
        i jet
        ii flood
        iii static
        iv suction

7. explain the function and cycle of the pulse generator
    a roughing
    b finishing

8. explain the ram vertical feed technique
    a mechanisms used to maintain the gap
        i servo
        ii dc motor
        iii stepping motor
        iv linear motor
        v electro-hydraulic
    b electrode
        i materials
            A copper
            B brass
            C graphite
        ii type
            A plain
            B profile
            C hollow
    c machine applications
        i die insert/cavity sinking
        ii drilling
        iii orbiting
        iv texturing
    d filtration system

9. explain the wire feed technique
   a process
      i form of electrode
      ii direction of work feed
      iii electrode feed system
   b electrode
      i materials
         A copper
         B brass
         C tungsten
         D zinc coated
      ii wire diameter
      iii gap with workpiece
   c machine movement
      i single axis
      ii multi axis: CNC control
   d filtration system

10. state the range of
   a accuracy
   b speeds
   c surface finish

11. describe the positioning and methods of securing the workpiece and electrodes
   a chucks: three and four jaw
   b collets
   c direct to the machine table
   d magnetic and pneumatic tables
   e vices: machine, swivel and universal
   f vee blocks/clamps
   g fixtures
   h angle plates

12. outline the problems that can occur when preparing EDM machines and the procedures for resolving them

13 describe the potential movement of the machine axes (x, y, z)

14. state the removal rates of different materials
   a aluminium alloys
   b brasses
   c steel
   d harden steel
   e nimonic/stainless
   f sintered carbide

Outcome 2 Manufacture the component and monitor the processes

Practical Activities

The candidate will be able to
1. produce an operation sheet (for all of them)
2. carry out safety checks on machine, tools and equipment and record results
3. mount and secure work piece
4. set tool parameters, produce a component to specifications, surface texture to be of an appropriate standard
5. monitor the electro-discharge process, maintain and adjust variables to ensure to operation is completed
6. inspect component against specifications

Underpinning Knowledge

The candidate will be able to
1. explain the methods of starting, stopping, including emergency stop procedure the electrical discharge machine

2. describe the basic care and routine maintenance of the machine

3. explain the process variables that could occur when electro-discharge machining

4. describe the procedures used to produce and inspect roughing and finishing cuts for both internal and external forms
   a form
      i arcs
      ii radii
      iii circular
      iv square
      v rectangular
      vi holes
      vii slots
      viii cavities
   b accuracy
      i dimensions
      ii parallelism
      iii squareness
      iv angular/tapers
      v profile
      vi surface finish

5. state the benefits and limitations of electro-discharge machining
   a benefits
      i hardness and toughness of workpiece not important
      ii geometrically complex shapes can be produced
      iii curved holes can be produced
      iv heat treatment can be carried out prior to machining
      v workpiece not subjected to mechanical stress during machining
      vi non-directional surface texture
      vii process auto controlled

- viii small diameter holes and fine slots can be machined
- ix multi-technique process

c limitations
- i only electrical conductive materials machinable
- ii deep small diameter holes difficult to hold accuracy
- iii skilled labour required to produce electrodes

6. state the range of typical removal rates
   a roughing
   b finishing

7. state the range of typical surface texture
   a roughing
   b finishing

8. explain how to handle electrodes

9. explain the methods used to mount and set the workpiece in/on the workholding device

10. describe how different types of electrodes and wire are selected, prepared and mounted

11. state the factors that determine
    a current density
    b spark frequency
    c linear feeds
    d linear speed
    e wire feed
    f wire speed

12. explain how the various types of materials will affect the speeds and feeds used

13. outline the problems and rectifications that can occur whilst machining the component and state how they can be overcome
    a machine
    b tooling/electrode
    c material
    d specifications
       i dimensional
       ii surface texture
    e production times

14. describe the procedures for inspecting the completed product
    a inspection equipment
       i gauges
       ii optical
    b surface texture
    c recording results

15. explain the need to comply with statutory health and safety legislation to protect the health and safety of self and others
    a safety check on ALL parts of the machine and equipment
    b ensure all guards are in working order, in place and in use
    c wear the correct personal protective equipment (PPE)

d ensure materials handling is carried out safely at all times

Outcome 3 Reinstate the work area

Practical Activities

The candidate will be able to
1. identify and comply with relevant health and safety legislation
2. produce a plan for reinstatement of the work area
3 restore work area used for machining to specified requirements
4. sign off recognition slips by returning tools, equipment, measuring instruments and materials to appropriate storage units
5. identify, dispose of and record hazardous substances which may have been used
6. identify remedial actions required to solve any problems in restoring work area and record actions taken

Underpinning Knowledge

The candidate will be able to
1. explain health and safety and environmental legislations for waste disposal, and implications of not following legal requirements

2. outline the importance of maintaining the safety and cleanliness of machinery, tools equipment and the work area
   a isolate machines
   b manual cleaning
   c machine assisted cleaning
   d use and correct storing of cleaning agents
   e identify and label products
   f inspection of components, tools and equipment on the completion of work
   g sort items in ‘f into reusable, rework, waste and return to store
   h clean and store personal protective equipment

3. explain the correct procedures for dealing with waste materials
   a types of waste produced
   b storage and waste removal
   c disposal methods
      i recycle
      ii solid waste
      iii liquid waste

4. describe the potential problems that may occur during restoring the work area and actions to be taken

5. describe the actions to be taken in the event of a spillage
   a barrier and safety signs
   b use of personal protective equipment
   c aids to containment and prevention of spillage reaching the watercourse
   d aids for cleaning
   e who should be notified

Unit 044 Detailed fitting

Rationale
This unit is concerned with the principles and processes that are essential for detailed fitting being carried out safely and efficiently. It includes the preparation of preparation of equipment, materials, service supplies, works areas, together with quality and cost analysis.

Outcomes
There are four outcomes to this unit. The candidate will be able to:
1 identify tools, equipment and evaluate the requirements for fitting operations
2 apply analyses, cost control and monitor quality control
3 plan and carry out fitting operations
4 reinstate the work area.

Connection with other awards
This unit relates to units 001-003,060-065,072-073 of the City & Guilds NVQ in Mechanical manufacturing engineering (1682).
It relates to *OSCEng ECS* 2.04, 2.11, 2.15, 2.16 and 5.05.

Assessment
The outcomes from this unit will be assessed using evidence from a centre devised assignment with will cover both practical activities and underpinning knowledge.

Outcome 1 Identify tools, equipment and evaluate the requirements for fitting operations

Practical Activities

The candidate will be able to
1. select tools and equipment
2. identify type and quantity of components to required to carry out the fitting/assembly
3. identify the range of auxiliary services

Underpinning Knowledge

The candidate will be able to
1. describe the features, uses and operating principles of
    - a spanners
    - b wrenches
        - i socket
        - ii torque
        - iii impact
    - c screwdrivers
    - d hammers and mallets
    - e files
    - f chisels
    - g saws
        - i band
        - ii mechanical
    - h scrapers
    - i levers and pullers
    - j drills
        - i parallel shank
        - ii morse taper shank
    - k reamers
        - i hand
        - ii taper
    - l taps and tap wrenches
        - i standard set
        - ii special types
    - m dies and die-stocks
        - i circular split
        - ii rectangular loose
        - iii solid die nut
        - iv pipe thread
    - n guillotines
    - o folders
    - p oxy-fuel gas
        - i heating
        - ii cutting

2. describe joining devices
    - a threaded
    - b mechanical

3. describe the functions of equipment and systems
    a bearings, bushes and seals
    b shafts and couplings
    c pins and keys
    d power transmission and pulley mechanisms
        i gears
        ii chains and sprockets
        iii belts and pulleys
    e fabrications and castings
    f gaskets
    g locking devices
    h springs
    i linkages/rollers

4. state the sources of supply of components

5. state the equipment used for measuring and checking
    a dimensions
        i micrometers
        ii verniers
        iii gauges
            A feeler
            B blocks
            C thread
    b angles
        i protractors
        ii vernier protractors
    c position, alignment and levels
        i dial test indicators
        ii laser devices
        iii surface plate/table
        iv straight edge
        v parallels and vee blocks
        vi spirit level
    d surface texture
        i standard blocks
        ii special equipment

6. outline the auxiliary services required
    a electricity
    b compressed air
    c gas
    d water
    e steam

7. describe factors affecting accuracy
    a misalignment of work and measuring equipment
    b parallax error

8. explain the affects of temperature variation when
   a measuring
   b joining by co-efficient of expansion/contraction

9. state the forces exerted on pins and keys
   a axial
   b radial
   c shear

Outcome 2 Apply analysis, cost controls and monitor quality control

Practical Activities

The candidate will be able to
1. produce a report on the analysis methods used to cost the activities
2. produce a list of costs for a given activities
3. identify defects as critical or non-critical
4. check components against specifications

Underpinning Knowledge

The candidate will be able to
1. state how to apply the analysis methods and techniques to different problems

2. state what type of difficulties can occur when using analysis methods and techniques

3. describe the main type of cost elements
   - a fixed
   - b variable
   - c overheads

4. describe the labour, material and overhead costs associated with fitting/assembling operations in terms of
   - a personnel
   - b machines tools and equipment
   - c components, materials and consumables
   - d maintenance requirements

5. state the source of information on which cost estimates are based
   - a technical data
     - i working drawings
     - ii worksheets
     - iii specification
     - iv special data
   - b historical data
     - i schedules
     - ii time sheets
     - iii operation sheets
     - iv internal and external departmental records

6. outline the stages in compiling a cost estimate
   - a collect and analyse information
   - b clarify any outstanding points with customer
   - c produce operation plan
   - d produce estimate showing
     - i labour costs
     - ii material, component and consumable costs
     - iii overhead costs direct and indirect

7. state the methods and techniques used for checking compliance with specification
   a visual
   b measurement
   c testing

8. state how to check compliance with different types of specification by inspection
   a component shape and size
   b material finish

9. explain the different type of defects that can arise
   a critical
      i cracked
      ii distorted
      iii brakeage
   b non-critical
      i surface finish
      ii surface damage
      iii size outside tolerance

10. state how to check alignment and freedom of movement

11 describe which defects can be rectified and how

12. state the accuracy required by production and quality functions

13. explain how to check a system operation against specification

14. state which details need to be recorded and the method of recording

15. describe why it is important to maintain records of the inspection process

Outcome 3 Plan and carry out fitting operations

Practical Activities

The candidate will be able to
1. plan sequence of operations for fitting activities
2. select appropriate workholding devices
3 carry out fitting operations, scraping, chiselling and the fitting/assembling of components
4. sharpen tools on grinding machine
5. check systems against specifications

Underpinning Knowledge

The candidate will be able to
1. describe the purpose of workholding
   a locate work
   b restrain the forces exerted by the tool

2. state the appropriate workholding devices

3. describe the type and features of machines
   a bench/pillar drills
   b portable drills
      i mains operated
      ii battery
      iii pneumatic
   c grinding machines
      i bench
      ii angle

4. describe the different thread terms
   a pitch and lead
   b left and right hand threads
   c single and multi-start

5. state the application of screwthreads
   a as a fastening device
   b to transmit motion

6. describe the manual methods cutting threads
   a internal taps
   b internal special taps and thread inserts
   c external dies
   d external solid die nuts

7. explain the reaming of holes
   a parallel through
   b blind
   c tapered

8. state the procedures for scraping
   a flat surfaces
   b bearings

9 state the correct angles for chiselling line of inclination

10. describe the procedures for fitting shafts and plain bearings
    a correct clearances
    b methods of obtaining clearances by
       i filing
       ii scraping
       iii shimming
    c checking clearance
       i feeler gauges
       ii dial test indicator (DTI)
       iii lead wire
    d lubrication and methods of distribution

11. describe the types and procedures for fitting ball and roller bearing systems
    a factors influencing cleanliness
       i personal cleanliness hands, tools and work surfaces
       ii cleaning journals and housings prior to fitting
       iii retaining bearings in protective wrapping until required
    b classes of fit
       i inner race fits tightly on shaft, outer race slides into housing
       ii inner and outer races both tightly fitting
    c methods of positioning by
       i pressing into the housing
       ii tapping
       iii heating and sliding onto the shaft (oil bath or electrically
       iv cooling
    d types of self-alignment bearings
    e how to distinguish between thrust bearings designed to take
       i axial loads only
       ii axial and radial loads
    f tools used for fitting ball and roller bearings
       i drifts
       ii special spanners
       iii extractors
    g methods inspecting bearings for faults
       i pitting
       ii crazing
       iii discolouration
    h assessing the necessity for replacement

12. state the methods of sealing bearing assemblies lubricated by grease or lubricating oils
    a felt and synthetic rubber ring seals
    b minimum machined clearance between bearing housing and shaft
    c labyrinth seals

13. describe the different types of seal
    - a metallic
    - b non-metallic
    - c combination of metallic and non-metallic

14. state the methods of selecting and fitting different types of seal
    - a applications
    - b temperature and pressure
    - c speed of moving parts
    - d replacement period and corrosion

15. state the procedures for fitting flanges
    - a flanges clean and parallel
    - b checking 'O' rings for size, shape and depth/condition of recesses
    - c tightening flange bolts in the correct sequence

16. describe the methods of two shafts are parallel

17. explain the procedure for fitting gear assemblies
    - a how to obtain
        - i contact area of tooth surfaces
        - ii alignment of gear faces
        - iii tooth surface clearance
    - b methods of obtaining positive clearance by
        - i increasing the centre distance between gears
        - ii reducing tooth profile one gear
        - iii reducing tooth thickness of both gears

18. explain the methods of fitting gears on shafts
    - a press fit
    - b push fit

19. state the procedures for fitting transmission systems
    - a methods of tensioning belt/pulley systems
        - i idler pulleys
        - ii adjustment of the centres between shafts
        - iii hinged mounted pulleys
    - b methods of tensioning chain/sprocket systems
        - i idler wheel
        - ii adjustment of sprocket by set screws

20. state the type, construction and fitting of cylinders/actuators
    - a single acting
    - b double acting

21. list the types of pump
    - a gear
    - b vane
    - c piston

22. describe types of valves and their method of actuation
    a manual
    b mechanical
    c pilot
        i directional control values, spool and rotary
        ii non-return
        iii pressure control
        iv flow control

23. state the auxiliary components
    a reservoirs
    b accumulators
    c filters

24. state the methods of isolating equipment
    a removal of fuses from electrical prime movers
    b disconnect drive shaft
    c closing and locking-off valves
    d closing auxiliary supplies
    e drain down pipework

Outcome 4 Reinstate the work area

Practical Activities

The candidate will be able to

1. identify and comply with relevant health and safety legislation
2. produce a plan for reinstatement of the work area
3 restore work area used for fitting operations
4. sign off recognition slips by returning tools, equipment, measuring instruments and materials to appropriate storage units
5. identify, dispose of and record hazardous substances which may have been used
6. identify remedial actions required to solve any problems in restoring work area and record actions taken

Underpinning Knowledge

The candidate will be able to

1. explain health and safety and environmental legislations for waste disposal, and implications of not following legal requirements

2. state the importance of maintaining the safety and cleanliness of machinery, tools equipment and the work area
   a isolate machines
   b manual cleaning
   c machine assisted cleaning
   d use and correct storing of cleaning agents
   e identify and label products
   f inspection of components, tools and equipment on the completion of work
   g sort items in ‘f’ into
      i reusable
      ii rework
      iii waste
   h clean and store personal protective equipment

3. describe the correct procedures for dealing with waste materials
   a types of waste produced
   b storage and waste removal
   c disposal methods
      i recycle
      ii solid waste
      iii liquid waste

4. state the potential problems that may occur during restoring the work area and actions to be taken

5. describe the actions to be taken in the event of a spillage
   a barriers and safety signs
   b use of personal protective equipment
   c aids to containment and prevention of spillage reaching watercourse
   d aides for cleaning
   e who should be notified

Unit 045 Electrical equipment and systems

Rationale

This unit is concerned with basic electrical theory and its relationship with installation and maintenance practices. It is most suitable for engineers who are involved with electrical apparatus and systems but who are not specialist installation contractors. It covers the types and uses of basic electrical components, electrical equipment and machinery and distribution systems. It also covers fault identification and the procedures and techniques involved for safely installing and isolating systems, removing and replacing electrical components, and bringing a system to a full working condition.

Outcomes

There are four outcomes to this unit. The candidate will be able to:

1 identify the components and features of electrical systems
2 plan and prepare for the maintenance or installation operation
3 carry out monitoring, inspection and maintenance or installation work.
4 commission or re-commission the system, restore the work area and resources

Connection with other awards

This unit relates to units 001-003,014,023,025,028-030of the City & Guilds NVQ in Engineering maintenance (1688) also units 201,209-210,302,309-310,312,314 of the City & Guilds NVQ in Electrical and electronic servicing (1687).
It relates to the *OSCEng ECS* 1.12, 6.02 and 6.08.

Assessment

The outcomes from this unit will be assessed using evidence from a centre devised assignment with will cover both practical activities and underpinning knowledge.

Outcome 1 Identify components and systems used with electrical equipment, their principles and operation

Practical Activities

The candidate will be able to
1. identify electrical system components by visual examination in conjunction with system drawings
2. determine the function of electrical components and the way in which they can be assembled into circuits
3. select components to meet specified functions in terms of required voltage, power rating and safe practice using manufacturers' catalogues, or other given data,

Underpinning knowledge

The candidate will be able to
1. state the basic electrical units, their significance and applications
   - a voltage, the different forms of supply and uses at 12V, 24V, 110V, 230V and 40V (with reasons for selection)
   - b current, magnetic and heating effects
   - c resistance, effect on conductors and resistors (insulation and heating)
   - d capacitance – how the level of charge affects the voltage potential
   - e inductance – the relationship between magnetic and electrical fields

2. calculate combined resistance of series and parallel groups

3. state the relationship between current, voltage and resistance (Ohms law) and carry out simple calculations

4. calculate power from voltage and current values

5. state the principles of electro-magnets
   - a magnetic materials, magnetising force, flux density
   - b the factors that determine the emf of self or mutual induction
   - c energy and eddy current losses, and how they can be minimised
   - d requirements for magnetic shielding

6. state the principles of capacitors
   - a electrolytic capacitors, merits and limitations
   - b safety precautions in use and importance of voltage rating
   - c how to calculate combined capacitance in series and parallel groups
   - d need for discharge resistors

7. describe the operating characteristics of dc circuits
   - a the effects of resistance and inductance
   - b show graphically the use of current in a circuit containing L and R
   - c the concept of LR time constant
   - d the effects of resistance and capacitance when connected in series
   - e show graphically charge and discharge curves
   - f the concept of CR time constant

8. describe the operating characteristics of ac circuits
   a the effects of resistance, capacitance and inductance connected in series and how
      i to sketch circuit diagrams
      ii sketches can be used to illustrate the different V_C and V_L relationships
      iii to calculate resonant frequency and resultant current
      iv to solve circuit problems by calculation with reference to phasor diagrams and/or impedance triangle
   b the effects of resistance, capacitance and inductance connected in parallel and how
      i to sketch circuit diagrams
      ii sketches of phasor diagrams illustrate the conditions of parallel resonance
      iii to solve circuit problems by calculation with reference to diagrams
      iv to make the connections required for power factor improvement
   c the power in three phase balanced loads (star and delta connections)
      i how the power is measured using a wattmeter
      ii how to calculate the power

9. state the action of semi-conductor devices in simple rectifier circuits
   a basic principles of operation of diode, thyristor and triac, half, full wave and bridge rectification
   b the need for heat sinks
   c the action of smoothing circuits
   d switching acting of a single thyristor circuit

10. state the types and function of transformers and their component parts
   a principle of operation and relationships between input, output and losses
   b types of winding and constructional features of auto and double wound transformers: shell, ring or core: single or three phase and lamination details
   c the calculations relating current, voltage and turns for ideal transformers
   d the rating of transformers is given as kVa and how to calculate maximum line current of a three phase transformer from this
   e auto transformers
      i identify input and output terminals
      ii calculate current distribution from given data
      iii merits and hazards when used for – motor starters, grid transformers, ariacs and discharge lighting applications.

11. describe electrical transmission and distribution methods
   a typical factory systems using
      i flexible and rigid conduits
      ii trailing cables and overhead collector
      iii busbar and cable trunking
      iv underfloor ducting
      v rising mains
      vi PILSCWA, PVSCWA and MIMS cables
   b merits and limitations of the methods listed in 11a
   c methods and equipment used in joining and terminating
   d correct cable sizes and voltage drops using IEE tables
   e interpret IEE Regulations regarding voltage drop and connection of loads on low and medium voltage systems

12. describe the main constructional features and applications of
    - a circuit breakers
    - b switches
    - c isolators

13. describe earthing and protection systems
    - a earthing paths, resistance and earth fault loop impedance
    - b conditions against which protection is required
        - i voltage rises
        - ii reverse power
        - c methods of protection using lightning arresters, surge absorbers and reverse power relays: the principles and constructional details of each
        - d fuses, ‘no-volt’ release and residual current devices

14. state the principles of dc rotating machines
    - a types, constructional features and applications of motors and generators
    - b classes of machines in terms of
        - i ‘intermittent’ and ‘continuous’
        - ii insulation materials
        - iii enclosure
    - c dc generators
        - i effect of altering output voltage resistors
        - ii failure to excite and tests to determine reasons
    - d dc motors
        - i different field connections and the significance in terms of application
        - ii differences between shunt, series and compound machines
    - e manual starter methods, connections required, function of components, protective devices and applications
    - f speed control methods: the range of speed control using field and armature resistance
        - i from ac sources using controlled output rectifiers
        - ii Ward-Leonard system
    - g reversal of rotation: factors controlling direction and methods of reversal
    - h armature reaction: its effect on the main field, commutation (and the effects of brush position), purpose, polarity, construction and methods of use of interpoles

15. state the principles of ac rotating machines
    a types, constructional features, function and applications of motors and generators to include
        i frame, core and winding, salient pole rotor, rotor body and their attachments, slip rings
        ii stationary field system types
    b power factor in ac plant with reasons why
        i low power factor is undesirable
        ii industrial equipment often takes lagging current
    c methods of controlling load and power factor (use of static capacitors
    d three phase ac motors, the principles of operation, characteristics and applications of the following types
        i cage rotor
        ii wound rotor
        iii synchronous induction
    e single phase ac motors, the principles of operation, characteristics and applications of the following types
        i series wound
        ii split phase
        iii capacitor start
        iv capacitor run
    f for all types of ac motor factors listed above
        i governing direction of rotation and methods of reversing
        ii starting arrangements
        iii speed control methods

16. state the types and use of test equipment
    a use of multimeters, insulation testers, wattmeters, tachometers and stroboscopes
    b pick ups and sensors connected to Cathode Ray Oscilloscopes

17. state the possible faults associated with ac and dc machines as appropriate
    a mechanical faults: bearings, cracked frames, proud laminations
    b electrical faults: brush gear and commutator, field and armature, insulation, continuity

Outcome 2 Plan and prepare for the maintenance or installation operation

Practical activities

The candidate will be able to
1. identify the type and extent of work to be carried out
2. relate current legislation and codes of practice to the given tasks
3. carry out a risk assessment by listing the procedures and requirements for setting up safe working conditions
4. collect manufacturers' information, related work records, circuit diagrams and other necessary data
5. check availability of materials, tools and equipment and prepare requisitions or works orders as required
6. assemble all tools, materials and other equipment that will be needed

Underpinning knowledge

The candidate will be able to
1. describe the layout, function of components and operational features of the electrical machinery or circuits to be installed or maintained
   a special considerations as prescribed by the manufacturer
   b the methods of lifting, supporting, or otherwise making system components safe
   c how the work to be undertaken may interact with or affect other systems or production facilities

2. state the specific implications of Statutory Regulations, Codes of Practice related to installing or maintaining electrical systems
   a disposal of toxic waste and other such substances as defined by COSHH and Environmental Protection Acts
   b pressure systems and portable gas containers
   c working at heights and in confined spaces
   d electrical installations and testing of equipment and appliances according to the IEE and Electricity at Work Regulations

3. describe the methods of the equipment or system safe
   a isolating switches
   b removal of fuses
   c closing and 'locking off' of control panels and switch boxes
   d testing circuits for any residual power

4. state the need for providing equipment to deal with
   a spillage and contamination (including special PPE such as breathing apparatus)
   b fire
   c personal injury

5. state the emergency shut down and evacuation procedures for the work area

Outcome 3 Carry out the monitoring, inspection and maintenance or installation activity

Practical Activities

The candidate will be able to
1. carry out a maintenance OR pre-installation inspection on factory/plant equipment or systems
2. diagnose and repair a faulty system and/or components OR install a system

Underpinning knowledge

The candidate will be able to
1. describe the methods used to avoid distortion and damage to trunking or conduit when
   a disconnecting
   b aligning
   c connecting

2. state the precautions needed to avoid danger from, or damage to, components whilst installing, dismantling and assembling from
   a misalignment
   b use of wrong tools or excessive force
   c uncontrolled release of springs
   d scoring of surfaces.

3. identify the need for protection of dismantled components or systems from contamination by
   a blanking off or sealing points to prevent entry of moisture or foreign particles
   b using correct cleaning agents and lint free cloths.
   c storing removed parts in appropriate containers

4. state methods of making identification (witness) marks on components so that they can be correctly reassembled or re- aligned)

5. list the essential points to be checked when inspecting components or equipment
   a bearing or other contact surfaces
   b signs of corrosion (internal and external)
   c erosion and pitting
   d split or worn seals
   e signs of overheating (colour changes)

6. describe how to remove, fit and replace
   a bearings
   b seals
   c springs
   d circlips
   e keys
   f brushes

7. describe how to prepare or make new gaskets or joints (including preparation of surfaces and/or housings) and repack glands

8. list the procedures for re-assembling components to avoid damage using the approved sequence for tightening bolts and applying specified torque and the application of lubrication to seals

9. describe methods of bench testing re-assembled components.

10. state the need for correctly labelling re-built components for replacement in a system or returning to stores

11. state what information needs to be supplied when completing a report following a maintenance or installation activity

12. list the different ways of presenting information that can be used to appraise the outcome of a maintenance or installation activity

Outcome 4 De-isolate, commission or re-commission the system, restore the work area and resources

Practical Activities

The candidate will be able to

1. bring the system on line and adjust as required until the working parameters have been fully met
2. restore work areas to a clean and safe condition on completion of maintenance or installation
3. identify hazardous substances that may have been used or discovered during the work and give the approved method of disposal for each such substance.
4. specify any work needed for the restoration of work areas.
5. hand over the system to the authorised persons
6. complete a report on the actions taken.

Underpinning knowledge

The candidate will be able to

1. state the precautions to be taken before
   - a re-connecting to mains supplies
   - b opening up the system to the sources of pressure or possible movement

2. state how to set up and test interlocks, sensors and limit switches

3. list the sequence of bringing systems back to the specified working conditions by
   - a removal of protective covers and blanks
   - b opening appropriate valves or switches
   - c operating the system under gradually increasing power or loads

4. describe methods of securing pipework, cables and safety fittings (guards, handrails)

5. identify any materials used that are classified as hazardous and those that can be recycled

6. state the necessity for, and methods of, reporting any damage caused by the maintenance or installation activity where additional restoration work may be needed
   - a brickwork
   - b grouting
   - c plastering
   - d decorating

7. describe methods of replacing insulation, lagging and other protective coverings

8. state methods of applying identification markings to different parts of a system
   - a colour identification of pipework to BS1710
   - b using appropriate and approved codings for electrical connections and components

9. state the need to let all interested parties know of any changes that may affect the operation of the system, or of any new conditions that could exist in the work area

10. state the procedure for terminating any ‘Permits to Work’ that have been implemented

11. explain how any work termination documents or reports that may be required are completed and passed on to an authorised person

Unit 046 Computer Integrated Engineering

Rationale
This unit is concerned with the underlying process technology and practices involved in the design and manufacture of components using computer aided design and production techniques. Although the unit covers the common processes for metals and plastics materials it is demanding in terms of the technological content and the process variables candidates are expected to cover. The unit broadly covers health and safety, computer controlled equipment and consumables (ie steels, non-ferrous alloys and polymers) and the practicalities of producing a quality, machined/formed component to a profile and size of given specification.

Outcomes
There are four outcomes to this unit. The candidate will be able to

1. identify the factors that influence the design and manufacture by computer aided processes
2. identify the working parameters and the principles of control for computer aided engineering processes
3. apply data preparation, design and produce components that conform to specification
4. monitor and control safe computer aided operations to provide a finished component to specification.

Connection with other awards
This unit relates to units 001-003,030-051 of the City & Guilds NVQ in Mechanical manufacturing engineering (1682).
It also relates to the *OSCEng ECS* 1.18, -1.20, 3.01 and 3.02.

Assessment
The outcomes from this unit will be assessed using evidence from an assignment, which will cover both practical activities and underpinning knowledge.

Outcome 1 Identify the factors that influence the design and manufacture by computer aided processes

Practical Activities

The candidate will be able to
1 read and interpret instructions, technical drawings and technical data to determine the computer numerical control requirements
2 select design packages and plan layouts around a component specification
3 identify the range of computer aided processes

Underpinning Knowledge

The candidate will be able to
1. state importance of CAD/CAM as an integrated approach to the use of computers in the total production process

2. explain the functions of CAD in the activities involved with computer aided production using engineering data
   a drawings
   b geometric models
   c finite element analysis
   d parts lists
   e work schedules

3. state the applications of computers to a wide variety of manufacturing functions
   a process planning
   b production scheduling
   c CNC
   d quality control and assembly
      i CAM

4. explain the integration of CAD/CAM to aid the use of information from the first design stage through to final production

5. explain the advantages of CAD compared to conventional design methods
   a speed
   b time compression' (checking and editing)
   c lead-time
   d memory facility
   e storage
   f quality
   g cost (competitiveness)
   h 'right first time'

6. state the importance of CAD/CAM to company's
   a policies
   b management teams
   c procedures and practices
   d systems

7. explain the operation of CAD systems displaying 2, 2½ and 3D modes

8. explain the essential differences between working drawings for conventional machines and those required for CNC machine operation
   a selection of datum
   b co-ordinate dimensioning in absolute and incremental

9. state the range of computer controlled processes
   a machining
   b milling
   c turning
   d spark erosion
   e robotics
   f inspection
   g process control
   h project management

10. state the advantages of computer numerically controlled machines compared with conventional machines
   a for high volume production
   b complex work
   c ability to repeat operations/reproduce parts with consistent accuracy
   d dispenses with jigs
   e optimisation of material use

11. describe the problems associated with 'remote' control and the reduction in operator sense of feel

12. describe the development of CAD/CAM with other processes, such as rapid prototyping

13. state the types and benefits of rapid prototyping machines and their software
   a Laminated object manufacturing process (LOM)
   b Selective laser sintering (SLS)
   c Stereolithography and thermojet systems
   d Fused deposition modelling process (FDM)
   e IMI rapid prototyping (including HERF)

14. state the range of materials used with rapid prototyping machines
   a plastics materials
   b waxes
   c metals

15. describe the applications of rapid prototyping processes for
   a aerospace parts
   b automotive parts

16. state the formulation of rapid prototyping materials to improve
   a strength
   b hardness
   c ductility
   d resistance to UV
   e flow characteristics

Outcome 2 Identify the design requirements, working parameters and principles of control for computer aided engineering processes

Practical Activities

The candidate will be able to

1. select and use CAD packages appropriate to the design specification
2. produce block diagrams showing the relationship between computer inputs, outputs, CPU and memory
3. produce line diagrams identifying axes
4. demonstrate an understanding of absolute, incremental and polar co-ordinate systems
5. re-dimension working drawings using absolute, incremental and polar co-ordinate systems from suitable datums
6. identify and naming axes of motion for horizontal and vertical spindle CNC machines
7. identify and name the axes of motion for robotic arms

Underpinning Knowledge

The candidate will be able to

1. describe the range of computer hardware as
    - a input devices
        - i keyboard
        - ii mouse
        - iii digitiser
        - iv joy stick
        - v light pen
        - vi tape reader
    - b output data devices
        - i printer
            - A laser
            - B inkjet
            - C dot matrix
            - D electrostatic
        - ii VDU
        - iii Plotter
            - A drum
            - B flatbed
            - C pinch roll
            - D electrostatic
        - iv punch tape
    - c storage and transmission
        - i magnetic
        - ii disks
            - A hard
            - B FDD
            - C zip
            - D CD
            - E CD-rewrite (linewriters)
        - iii tape

    A cartridge
    B streamer
  d central processing unit (CPU)
  e memory storage
    i RAM
    ii ROM
    iii PROM
    iv EPROM

2. describe the direct numerical control (DNC) operating process)

3. explain the methods and applications of inputting data
   a menutablet (pen & mouse)
   b alphanumeric keyboard
   c digitiser
   d joystick
   e cursor control
   f combinations

4. describe the software requirements for CAD/CAM
   a graphics and design
   b operational
   c application
   d user
   e post processing

5. explain the use of databases
   a database
   b database management system

6. describe the classification of computer systems
   a mainframe
   b mini
   c micro
      i stand alone
      ii lap top
      iii palm top

7. describe the difference between computer systems
   a physical size
   b memory size
   c benchmark speed
   d cost

8. state the importance of system compatibility
   a hardware/hardware
   b hardware/software
   c software/software

9. state the conventions used for axis motion in terms of standard X, Y and Z-axes

10. state the conventions used for positive and negative movement

11. describe the principle of co-ordinate dimensioning of working drawings for CNC applications
    a conventional
    b absolute
    c incremental

12. explain how to determine and tabulate co-ordinate dimensions in absolute and incremental terms from engineering drawings

13. explain the importance of dimensioning working drawings to suit
    a CNC machining operations
    b re-programmable multifunction manipulators
    c flow charts and systems

14. state the benefits of producing co-ordinate dimension tables

15. state the meaning of the terms character, word and block of data

16. explain the difference between modal and non-modal functions

17. describe the characteristics of ISO, EIA and ASCII tape coding systems for numerical and functional information

18. explain the structure of binary notation.

Outcome 3 Apply data preparation, design and produce components that conform to specification

Practical Activities

The candidate will be able to
1. produce a computer aided image of a component from a drawing specification
2. re-dimension working drawings/model design using absolute, incremental and polar
3. co-ordinate techniques from suitable datums
4. produce the required documentation for a CNC/DNC operation
5. produce a part programme using ISO word address format

Underpinning Knowledge

The candidate will be able to
1. outline the concepts of computer controlled operations
   a open loop
   b closed loop

2. explain what is meant by and the application of
   a machine code
   b assembly language
   c high level language

3. describe computer aided systems
   a dedicated
   b shared host

4. explain the term data format

5. state examples of common formats

6. recognise shorthand notations used in data formats
   a leading and/or training zero suppression
   b decimal point within a word

7. describe the principles of part programming
   a ISO word address
   b the requirements for
      i N: operation sequence number
      ii G: preparatory functions
      iii XYZ: co-ordinate
      iv I, J: positional data
      v F, S: feed/speed data
      vi T: tooling detail
      vii M: miscellaneous functions

8. state the terms associated with the motion of multifunctional manipulators
   a degrees of freedom
   b translation
   c prismatic
   d revolute

e articulated
f orientation

9. explain the programming methods for multifunctional manipulators
   a off-line
   b lead-through
   c walk-through
   d telemanipulation

10. describe the principles of part programming multifunctional manipulators

11. state the essential information required on operation sheets and operator instructions

12. explain the basic procedure for part programming in ISO word address format for a suitable component

13. describe the procedure for establishing communications between the computer and the machine for downloading a part program

14. state the advantages of using assigned canned cycles for common machining processes

15. explain the meaning of error messages, their possible causes and significance to basic principles of computer operation

16. state the importance of correct handling and storage procedures when using
   a Manual Data Input (MDM)
   b CD/FDD
   c magnetic tape and disk
   d direct CNC link

17. describe the function and basic operating principles of CNC machines
   a millers
   b lathes
   c robotic arms
   d spark erosion
   e wire erosion

18. explain the role of
   a positional transducers
   b limit switches

19. describe the relationship of CNC axes in terms of
   a xyz definitions for different machine configurations
   b axis definitions for machine tool and robotic arms
   c the need for datum(s on the machine

20. state the advantages of using cutter diameter compensation for tool diameter and length and tool nose radius

21. explain the use of canned cycles for repetitive work

Outcome 4 Monitor and control safe computer aided operations to provide a finished component to specification

Practical Activities

The candidate will be able to
1. prepare and the correct operating procedures to carry out a CAD/CAM operation
2. undertake and monitor the operations correctly and safely
3. checking the finished product against specification using the appropriate inspection method(s) and equipment

Underpinning Knowledge

The candidate will be able to
1. state the current regulations in regard to the safe working and handling of computer controlled systems and machinery
   a HSaW
   b COSHH
   c PUWER

2. state the meaning of geometrical and dimensional deviation and its application to component tolerances

3. explain the importance of verifying part programs during pre-operational checks to protect
   a operator
   b work
   c tooling

4. state the benefits of CAD/CAM
   a productivity
   b product quality
   c accuracy
   d operational requirements
   e repeatability

5. describe the procedures for monitoring and maintaining control of computer aided design and production processes

6. describe the operating principles, structural elements and main configurations of co-ordinate measuring machines

7. state the benefits of co-ordinate measuring machines in Computer Integrated Engineering

8. state the benefits of automatic inspection using microprocessors and sensor technology

9. state the classification and operating principles of inspection probes in co-ordinate measuring systems

10. state the benefits of using inspection probes in Computer Aided Manufacture

11. state the benefits of using electronic probes in
    a tool management
    b process measurement
    c post process measurement
    d computerised inspection

12. state the factors to be considered in the implementation of a CNC, rapid prototyping manufacturing unit
    a companies manufacturing requirements and future development
    b machine manufacturers support and technical back-up
    c economic analysis
    d installation scheduling
    e programmes/operator training

Unit 047 Computer aided design (CAD)

Rationale
This unit covers the computer aided design engineering function, in terms of aspects of 2D and 3D CAD, including 3D modelling methods. The unit consists of practical activities and the knowledge that underpins it.

Outcomes
There are four outcomes to this unit. The candidate will be able to
1 set-up to produce CAD drawings
2 produce Two dimensional computer aided design (2D CAD)
3 produce Three dimensional computer aided design (3D CAD)
4 produce hard copies of CAD drawings.

Connection with other awards
This unit combines and extends the knowledge and understanding contained in units:
This unit relates to units 001-003 of the City & Guilds NVQ in Mechanical manufacturing engineering (1682)
2303 – Computer Aided Engineering – Part 2 Computer Aided Drafting
2303- Computer Aided Engineering – Part 3 Advanced Computer Aided Drafting and Design
This unit also relates to City & Guilds Level 3 Certificate in Computer-aided design (4353)
It also relates to the *OSCEng ECS* 1.11 and 1.14.

Assessment
The outcomes from this unit will be assessed using evidence from a centre devised assignment which will cover both practical activities and underpinning knowledge.

Outcome 1 Set-up to produce CAD drawings

Practical Activities

The candidate will be able to

1 power up the computer system
2 locate and identify CAD software and user files
3 start up a CAD system
4 recognise the features of the screen display
5 identify system menus and command prompts
6 use the input device
7 use main menu drawing commands to produce a variety of different shapes
8 set drawing limits to suit component dimensions
9 set drawing aids
10 create layers
11 load a variety of line types
12 create a variety of prototype drawings
13 save prototype drawings with suitable file names
14 load prototype drawings
15 set suitable drawing parameters

Underpinning Knowledge

The candidate will be able to

1. recognise the hardware components of a CAD system
    - a effects of hardware specifications on efficiency of the system
    - b processor type and speed
    - c available RAM
    - d video processor card
    - e VDU resolution and screen size

2. recognise the methods of data input
    - a keyboard
    - b mouse
    - c digitising tablet and puck
    - d light pen
    - e combinations of the above
    - f scanning
    - g downloading
    - h uploading

3. identify methods of data storage
    - a hard disk
    - b floppy disks
    - c magnetic tape
    - d CD ROMs
    - e CD writers
    - f other storage media

4. identify methods of data output
    - a VDU
    - b printers
    - c plotters

5. state the software requirements of a CAD system
   a memory allocation
   b scheduling
   c driving input and output devices
   d CAD software
   e graphics creation
   f manipulation
   g editing
   h storage
   i user software
   j customising menus and parameter
   k symbols library
   l macros
   m applications software including
   n parts listing
   o costing
   p stress analysis

6. identify the operating system commands to
   a create directories
   b list the contents of directories
   c locate, copy, delete and rename files

7. recognise the importance of backup files and saving drawings at regular intervals

8. recognise the importance of maintaining careful filing systems for manual reference and disk storage
   a creation and maintenance of manual reference files for ease of access
   b index system for storage of disks

9. identify methods of restricting user access using passwords where required

10. state the advantages and disadvantages of CAD systems compared with conventional draughting in terms of
   a speed of drawing creation
   b checking and editing
   c quality and consistency of finished drawing
   d memory facility
   e storage and retrieval of finished drawings
   f cost
   g compatibility with CAM systems

11. identify the correct procedure for
   a powering up the computer system
   b logging on
   c locating and calling up
      i CAD software
      ii user files

12. recognise the layout of the screen display and identify
    a screen layout
        i graphics/text area
        ii command area
        iii status line
    b menu areas
        i screen menu
        ii pull down menus
        iii icons
        iv dialogue boxes
    c command line prompts

13. identify methods of command input and menu selection
    a screen menus
    b dialogue boxes
    c icons
    d direct keyboard entry

14. recognise the purpose of the input device
    a command input
    b cursor moves
    c selecting menu items

15. state the correct procedure to login and start up a CAD system to create a new drawing
    a locate and identify CAD software and user files
    b recognise menu items and system prompts on screen display

Outcome 2 Produce two dimensional computer aided designs (2D CAD)

Practical Activities

The candidate will be able to
1. produce 2D drawings on a CAD system
2. save drawings using appropriate file names
3. load and edit existing drawings

Underpinning Knowledge

The candidate will be able to
1. identify commands using screen menus, dialogue boxes and direct keyboard entry
   a line
   b polyline
   c circle
   d arc
   e polygon
   f rectangle
   g ellipse
   h doughnut

2. identify the erase command on
   a single drawing entities
   b multiple drawing entities using the window command

3. identify the correct procedure to configure a CAD drawing
   a set drawing limits to suit component dimensions and paper size
   b set appropriate drawing aids to draw entities accurately
      i grid spacing
      ii snap interval
      iii object snap mode
      iv orthogonal mode
      v units
   c explain the advantages of using the drawing aids listed in b.

4. state the reasons for using structured layers and how they are created
   a apply meaningful names
   b assign line types
   c assign colours
   d control the visibility of layers

5. state the purpose of prototype drawings and how they are used

6. identify commands to save/file drawings for subsequent use

7. state the role of drawings in communicating technical information

8. state the role of detail and assembly drawings

9. identify essential information including
   - a projection
   - b units
   - c scale
   - d shape
   - e size including tolerance
   - f surface finish
   - g number off
   - h material
   - i special treatments

10. identify conventions for
    - a pictorial projection
      - i isometric
      - ii oblique
    - b orthographic projection
      - i first angle
      - ii third angle

11. identify standard conventions from BS EN 8888/2000
    - a types of line
    - b representation of common features

12. identify software commands needed to create graphical data
    - a line
    - b polyline
    - c polygon
    - d rectangle
    - e circle
    - f arc
    - g point
    - h segment
    - i ellipse

13. differentiate between absolute, relative (incremental) and polar co-ordinate systems

14. identify points using absolute, relative and polar co-ordinates

15. identify software commands needed to edit and manipulate graphical data in
    a new drawings
    b existing drawings
        I zoom in/zoom out
        ii pan
        iii erase
        iv copy
        v mirror
        vi offset
        vii move
        viii array (rectangular and polar)
        ix trim
        x extend
        xi scale
        xii stretch
        xiii break
        xiv fillet
        xv chamfer

16. identify modify properties including
    a line type
    b colour
    c layer

17. differentiate between world and user co-ordinate systems

18. identify text into a drawing
    a position
    b font style
    c font height
    d rotation

19. state the advantages of using blocks during the creation of a drawing
    a create blocks to given specifications
    b save blocks to disk for use in future drawings
    c insert blocks into a drawing using different scale and insertion angles

20. state the purpose of setting and using different drawing layers
    a create meaningful layers
    b assign layer names
    c select appropriate line styles
    d select appropriate colours
    e control visibility of layers

21. identify conventions relating to dimensioning
    a linear
    b aligned
    c angular
    d diameters
    e radii
    f leader

22. identify methods of editing existing dimensions using the update command

23. state the advantages of using the dimensioning options
    a baseline
    b continuous
    c meaning of associative dimensions

24. identify the conventions for cross-hatching complex areas
    a pre-defined hatch patterns
    b user defined hatch patterns

Outcome 3 Produce three dimensional computer aided design (3D CAD)

Practical Activities

The candidate will be able to
1 produce 3D drawings on a CAD system
2 manipulate 3D views on a CAD system
3 shade and render 3D drawings on a CAD system
4 save drawings using appropriate file names
5 load and edit existing drawings

Underpinning Knowledge

The candidate will be able to
1. describe commands using screen menus, dialogue boxes and direct keyboard entry
   a line
   b polyline
   c circle
   d arc
   e polygon
   f rectangle
   g ellipse
   h doughnut
   i extrude
   j revolve
   k 3D primitives
   l slab (box, cuboid)
   m sphere
   n cylinder
   o cone
   p torus
   q wedge

2. identify methods to combine primitives using Boolean operations
   a addition, union, join
   b subtraction, cut
   c intersection

3. identify surfacing commands

4. identify the erase command on
   a single drawing entities
   b multiple drawing entities using the window command

5. state the purpose of prototype drawings and how they are used

6. state the role of detail and assembly drawings

7. state software commands needed to create graphical data in the form of
   a isometric projection
   b wire frame modelling
   c extruded forms
   d solid modelling
   e surface modelling

8. differentiate between the forms of solid modelling
   a B-REP
   b CGS
   c hybrid

9. state the advantages of solid modelling

10. state the advantages of parametric and variational geometry

11. identify the software commands needed to edit and manipulate graphical data in
   a new drawings
   b existing drawings
      i shade
      ii hide
      iii render
      iv rotate (orbit)
      v camera
      vi dynamic viewing
      vii 3D views
      viii 3D viewports (multiple views)
      ix model space
      x paper space

Outcome 4 Produce hard copies of CAD drawings

Practical Activities

The candidate will be able to

1. plot different sized new or existing drawings to different scales and where appropriate different colours

Underpinning Knowledge

The candidate will be able to

1. identify standard values for paper size

2. state the commands required to produce a hard copy in accordance with specification
   a print/plot command
   b printer/plotter configuration settings
   c device selection
   d paper size and orientation
   e paper source
   f portrait/landscape
   g print quality
   h pen assignments where appropriate
   i display parameters
   j extents
   k limits
   l view
   m window
   n text resolution
   o units
   p scale
   q rotation and origin

3. state how to activate the print preview command

4. state how to send copies of document to print/plot

5. state the need for types of printer/plotter

6. describe how to transfer data to a computer-aided manufacturing (CAM) system

7. describe the principles of CAD/CAM

Unit 048 Finishing surface coatings

Rationale
This unit is concerned with the underlying process technology to provide a surface finish on engineering components using coatings. It covers the selection of hand/manual, machine and automated finishing processes to produce improvements to the surface of components. Included is the identification and selection of materials, consumables and ancillary equipment necessary to carry out, control and maintain quality assurance of surface coating operations. Safe working practices will be reinforced at all times.

Outcomes
There are four outcomes to this unit. The candidate will be able to
1 identify and select a surface coating process
2 identify and use correct procedures for surface preparation prior to coating
3 commission and quality control the surface coating operation
4 reinstate the work area and store resources correctly after use.

Connection with other awards
It relates to units 001-003 of the City & Guilds NVQ in Mechanical manufacturing engineering (1682) and units 029-049 of the City & Guilds NVQ in Materials processing and finishing (1683)
It also relates to *OSCEng ECS* 1.01, 1.02, 1.12, 1.13, 1.21, 2.08, 3.14, 7.04-7.06, 8.01 and 8.02.

Assessment
The outcomes from this unit will be assessed using evidence from a centre devised assignment which will cover both practical activities and underpinning knowledge.

Outcome 1 Identify and select a surface coating process

Practical Activities

The candidate will be able to
1 investigate and evaluate surface coatings
2 investigate surface coating processes
3 select a surface coating process appropriate to specified surface requirements
4 select ancillary equipment, materials and consumables appropriate to the application

Underpinning knowledge

The candidate will be able to
1 identify the reasons for applying surface coatings in terms of
    a corrosion resistance
        i types of corrosion cell that lead to surface deterioration
        ii electrolytic cell
        iii anode
        iv cathode
        v half reaction
        vi standard electrode potential
        vii implications of electrochemical series for surface behaviour
    b wear resistance
        i abrasion of surfaces
        ii hardness
        iii softness
        iv measurement of wear
    c texture
        i smooth
        ii roughened
        iii measurement of surface finish
    d aesthetics
        i colour
        ii grain
        iii appearance – dull/bright
    e conducting properties
        i electrical
        ii thermal
        iii measurement of electrical and thermal conductivity

2. outline the engineering use of
   a ferrous materials
      i low carbon and low alloy steels
      ii cast iron
      iii 12/10 and 18/8 stainless steels
      iv Monel/Nimonic alloys
   b non-ferrous materials
      i copper
      ii brass
      iii bronze
      iv aluminium
      v aluminium alloys containing silicon/zinc/copper/magnesium
   c non metallic materials
      i thermoplastic and thermosetting plastics materials
      ii composites
      iii ceramics
      iv natural

3. identify a range of surface coating processes
   a galvanising
   b tinning
   c painting
   d electroplating
      i copper
      ii nickel
      iii chromium
      iv zinc
   e anodising
   f cladding and tiling
   g sherardising
   h metal spraying
      i hot
      ii vacuum
      iii chromating
      iv phosphating
      v powder

4. explain the criteria used to select a surface coating process
   - a operating conditions
     - i type and quality of surface finish required
     - ii condition of surface
     - iii location
   - b type of material
   - c service requirements
     - i corrosion resistant
     - ii aesthetics
     - iii temperature resistant
     - iv wear resistant
   - d cost
     - i financial implications of selecting specific coating techniques and materials
     - ii right first time
     - iii materials, resources and planning
     - iv batch and continuous process
   - e relevant British/European Standards and terminology relating to
     - i material type
     - ii component shape and size
     - iii working environment
   - f process characteristics and limitations
     - i equipment
     - ii tools
     - iii material type
     - iv section and thickness
     - v position
     - vi location
     - vii application
   - g materials handling requirements
     - i set up
     - ii movement
     - iii isolation
     - iv storage
   - h regulations applicable to the use of surface coating equipment and materials
     - i HSaW
     - ii COSHH
     - iii Regulations for the Disposal of Dangerous Substances
     - iv PUWER

Outcome 2 Identify and use correct procedures for surface preparation prior to coating

Practical Activities

The candidate will be able to
1 apply correct preparation procedures and application sequence
2 monitor and control a safe working operation
3 position and manipulate component correctly
4 adjust and recalibrate machinery and equipment as required
5 prepare component surface to specification.

Underpinning knowledge

The candidate will be able to
1 explain the current regulations and issues in regard to health and safety and handling of equipment and materials
   a HSaW
   b COSHH
   c fumes
   d sparks
   e chemicals
   f flammable substances

2. describe the safety precautions, protective equipment and clothing specific to the operations used to prepare a component surface to comply with appropriate BS/EN regulations
   a guards
   b rotating and reciprocating machinery
   c pressure systems
   d enclosed cabinets/chambers
   e vessels and containers
   f personal protective equipment
   g respiratory protective equipment
   h isolators
   i extraction systems
   j chamber interlock mechanisms
   k methods for storing, handling and using chemicals and toxic substances
   l hand tools
   m portable power tools

3. explain the care and correct handling of process consumables
    a abrasive wheels
    b polishing wheels
    c beads
    d shot
    e rotary high speed cutting tools

4. describe how to minimise potential movements of components during operation
    a jigs and positioners
    b vices
    c rollers
    d cradles
    e straps and harnesses
    f slings

5. outline the potential defects that could jeopardise the surface preparation operation(s)
    a material defects
    b faulty equipment
    c incorrect consumables
    d incorrect use of tools and equipment
    e environmental conditions

6. describe the requirements for treatments prior to surface coating
    a material removal
    b surface abrasion
    c pickling
    d etching
    e sizing
    f machining
    g steaming
    h brushing
    i grinding
    j polishing

7. describe the range, types and care of consumables used with preparation processes
    a abrasives
    b chemicals
    c compounds

8. describe the types of disruption that can present working hazards
    a physical objects
    b equipment
    c other activities
    d unauthorised personnel
    e visitors
    f breakdowns
    g alarms
    h unauthorised activities
    i loss of power
    j operator error
    k breakage of consumables or ancillaries

9. describe equipment, tools and materials and explain how to operate and use them in a safe manner
    a chemical solution vessels
    b rotating equipment
    c grit/bead blasting machines
    d compressed air
    e gases
    f electric power

10. describe the principles underlying the use of procedures for preparing component surfaces
    a consumables specification
    b process parameters
    c correct set up and calibration
    d operator skill
    e environmental conditions
    f inspection techniques

Outcome 3 Commission and quality control the surface coating operation

Practical Activities

The candidate will be able to
1 identify and select a coating process appropriate to the specified surface requirements
2. select, set up and commission machines and equipment
3. check and adjust equipment for effective and efficient operation
4. select ancillary equipment, materials and consumables appropriate to the application
5. set up component for surface coating operation
6. remedy problems as necessary to maintain efficient operation

Underpinning knowledge

The candidate will be able to
1 outline how to identify components and special instructions using
   a engineering drawings
   b technical drawings
      i sections
      ii exploded views
      iii special treatments
      iv diagrams
   c manufacturer's parts and treatment data
   d data sheets and charts
   e graphs
   f function and operational requirements
   g surface texture requirements

2. explain the operating features of surface coating machinery and equipment
   a hot dipping
      i galvanising
      ii tinning
   b plastics coating
   c spraying
      i acrylics
      ii cellulose
   d metal spraying
      i oxy-fuel gas
      ii arc plasma
   e electroplating
      i copper
      ii chromium
      iii nickel
      iv zinc
   f anodising
   g chromating
   h phosphating
   i painting
   j cladding and tiling

3. describe the range of ancillary equipment
   a guards
   b hand tools
      i brushes
      ii rollers
      iii spray guns
   c personal protective clothing and equipment
   d splash screens
   e masks
   f respiratory protective equipment
   g compressed air and equipment
      i harnesses
      ii pressure guns
      iii secure area (BS4575) Fluid Transmission and Control Systems
   h robots
   i emulsion and solution tanks
   j extractors

4. explain the procedures for testing and proving the condition of consumables
   a material composition
   b viscosity
   c temperature
   d fluidity
   e density
   f resistivity
   g pH values

5. explain the care and correct handling of surface coating process consumables
   a paints
   b powders
   c granules
   d chemicals
   e compounds
   f metals
      i powders
      ii wire
      iii sheet
   g gases

6. describe the use of jigs, fixtures, positioners and manipulators for
   a rigidity
   b movement control
   c improved productivity

7. outline the methods to minimise potential movements of the component during the coating operation
   a jigs
   b positioners
   c vices
   d rollers
   e cradles
   f straps
   g harnesses
   h slings

8. describe the potential defects that could jeopardise the coating operation
   a material defects
   b faulty equipment
   c incorrect consumables
   d incorrect set up of equipment and machinery
   e incorrect operating parameters
   f environmental conditions

9. describe the regulations applicable to the use of surface coating machinery and equipment
   a HSaW
   b COSHH
   c Regulations for the Disposal of Dangerous Substances
   d PUWER

Outcome 4 Reinstate the work area and store resources correctly after use

Practical Activities

The candidate will be able to
1. plan the reinstatement procedure
2. restore the work area to specified requirements
3. inspect and monitor the storage of equipment, tools and materials
4. collect and dispose of all waste substances to comply with Health and Safety requirements

Underpinning knowledge

The candidate will be able to
1 describe the requirements for restoring a work area to a safe and clean condition
   a machine and equipment isolation
   b tool inspection and storage
   c waste disposal
   d cleaning agents

2. describe the correct procedure for achieving a safe, clean and tidy area
   a labelling waste
   b returning equipment, tools and consumables
   c cleaning techniques
   d remedial action required to deal with accidents and spillages
   e notify authorised person if requirements cannot be met

3. explain the implications of not following legal requirements
   a HSaW
   b COSHH
   c Environmental legislation

4. identify appropriate assistance with the activities
   a type of assistance others are likely to request and the importance of help
   b the roles and responsibilities of key personnel in an organisation who can provide assistance with difficult situations
   c communication systems in an organisation
   d importance of feedback to authority
   e procedures for completing organisational and engineering activities in an organisation

Unit 049 Organising and managing engineering operations

Rationale
This unit is concerned with identifying the basic principles of organisation and management and the ways in which engineering activities can be efficiently planned and implemented. It covers the following topics relationships between installation, production and maintenance operations, the necessity for good planning in order to provide an efficient and cost effective service and why good recording processes are needed and how data is collected, used to forecast and/or solve problems It also covers the main sources of labour and physical resources and developing good relationships with all levels of personnel, and the ways in which their duties need to be carried out.

The candidate is not expected to have an in-depth understanding of all engineering activities and strategies but should be familiar with the events/terminology that they will come into contact with during normal working conditions.

Outcomes
There are four outcomes in this unit. The candidate will be able to
1. organise and schedule engineering activities
2. analyse the costs associated with engineering installation, production and maintenance
3. use records and research methods to assist the installation, production or maintenance process.
4. develop and contribute to improving working relationships and practices.

Connection with other awards
This units relates to all NVQs
It relates to the *OSCEng ECS* 1.17-1.28, 7.04-7.09, 8.01 and 8.02.

Assessment
The outcome from this unit will be assessed using evidence from a centre devised assignment which will cover both practical activities and under pinning knowledge.

Outcome 1 Organize and schedule engineering activities

Practical Activities

The candidate will be able to
1. produce labelled block diagrams to show the management structure for a typical large or medium company that deals with production, maintenance and installation and how the structure relates to other departments
2. prepare a list of operations and responsibilities that are carried out by engineering management teams
3. produce worksheets or job cards for typical engineering tasks
4. prepare flow and Gantt (bar) charts for planning, scheduling and checking on progress

Underpinning knowledge

The candidate will be able to
1. describe how an organisation is structured
   - a roles and responsibilities of key people
   - b communication systems
   - c decision making and implementation procedures
   - d the structure of associated organizations

2. state the work carried out by different engineering sections for different maintenance or installation related activities
   - a installation
     - i site preparation
     - ii installing new or modified equipment and systems
     - iii commissioning machinery and systems
   - b production
     - i preparation of drawings and specifications
     - ii ensuring that appropriate machinery, manpower and materials are available
     - iii producing work allocations and rotas to ensure efficient operation
     - iv dealing with production problems and shortages
   - c maintenance
     - i carrying out routine servicing schedules
     - ii repair and replacement following breakdowns
     - iii monitoring and performance testing of machinery, equipment and systems

3. describe the procedures for organising and running meetings
   - a duties of the chairperson
     - i preparation of agendas
     - ii allocating personnel to deliver agenda items
     - iii conduct and control meetings
   - b duties of the secretary
     - i arrange time, venue and catering requirements
     - ii take minutes during meeting
     - iii produce finalised minutes and distribute to concerned persons

4. explain how reliability can be achieved and production targets maintained by
   a good maintenance
   b identification of recurring problems or faults
   c initiating or modifying new procedures
   d updating systems, equipment and machinery

5. list the factors that need to be considered when planning installation, production maintenance or operation operations
   a obtaining specialist tools and equipment
   b manpower requirements
      i existing staff, specialist skills available and possible training needs
      ii temporary (sub contract)
      iii contingencies and overtime
   c items that must be considered when preparing contracts
      i working conditions and safety implications
      ii supervisory and legal responsibilities
      iii penalties for non compliance with conditions
      iv insurance cover
   d provision of materials and spares
   e effects on other departments or changes to working practices (permanent or temporary)
   f estimation of time needed for different activities

6. explain the need for reviewing production and maintenance procedures at regular intervals in order to ensure maximum efficiency and economy.

7. explain how flow and Gantt (bar) charts are prepared and used for planning, scheduling and checking on progress

8. state the need for establishing priorities and the most effective sequences of operations
   a outline Critical Path Analysis (CPA) and/or Performance Evaluation and Review Techniques (PERT) principles (using examples but without necessarily carrying out a analysis)
   b contingency plans for
      i inclement conditions
      ii shortage of materials or staff
      iii equipment failure

9. explain how ‘modification, repair or replace’ policies are determined by considering
   a plant history records
   b manufacturer’s recommendations
   c changes in production output
   d age of plant or equipment
   e technological changes

Outcome 2 Analyse the costs associated with engineering activities

Practical Activities

The candidate will be able to
1. estimate the cost of a production, maintenance or installation activity
2. produce a cost analysis to show ways in which production performance, maintenance or installation costs can be compared

Underpinning knowledge

The candidate will be able to
1. state what cost related information is needed when budgeting for a production, maintenance or installation activity
   a extent of the task(s
   b time allowed for completion
   c the skills and experience of personnel to be involved
   d machinery, equipment, materials and spares that will be needed
   e purchase or hire of specialist equipment

2. list the different elements that must be considered when estimating total life cycle costs of machinery
   a design features
   b maintenance
   c expected length of serviceable use
   d disposal value or costs that may be incurred during decommissioning and dismantling

3. state the factors that account for
   a direct costs
      i materials
      ii labour (company employed and sub-contract)
      iii overheads (rent, rates, taxes, energy consumption)
   b Indirect costs
      i organisation and management
      ii lost production
      iii depreciation of equipment
      iv training

4. explain how different costs for determining optimum levels of production or maintenance can by the use of histograms and/or pie charts

5. state the importance and significance on costs of machinery or different items held in stores as indicated by a simple Pareto analysis

6. state the commonly used cost ratios to determine the value of maintenance
   a overall production costs/maintenance costs
   b downtime/maintenance costs
   c planned preventative maintenance costs/breakdown costs

7. state the relationship between capital expenditure and depreciation for plant and equipment

8. explain the need to rationalise and minimise the quantity of materials or number spares and tools that should be carried in stores for economic and efficient operation and production.
   a a Just in Time (JIT) system
   b possible effects of using several different suppliers
   c contingency plans for shortages
   d size of storage area and security problems

Outcome 3 Use records and research methods to assist the installation, production or maintenance process

Practical Activities

The candidate will be able to

1. collect data and use it to report on installation, production or maintenance requirements
2. produce an algorithm to help trace a fault
3. use available data to decide whether to repair or replace equipment

Underpinning knowledge

The candidate will be able to

1. state the benefits and limitations from using computers to get access to records and product information
   a increased number of access points
   b ease of updating
   c wide range of information available (including access to Internet)
   d appropriate siting and cost of installation
   e maintaining security of data and limiting access to authorised persons only
   f training of personnel

2. describe the uses and limitations of automatic data collection and recording methods for controlling operations

3. explain how feedback data can be used to improve planning and scheduling

4. list ways of recording and analysing test results

5. list the information required to determine the prime cause of a fault or production problem
   a detailed knowledge of the principles of the plant and equipment
   b observed and measured data
   c information obtained from operators
   d history of the equipment
   e details of changes in running conditions or modifications made
   f information from suppliers or manufacturers

6. describe different trouble shooting aids for determining causes of production and maintenance problems
   a algorithms, logic or decision trees
   b fault finding charts
   c built in test equipment

7. state the importance of collecting and recording information following the failure of equipment or machinery for calculation of Mean Time Between (or To)Failures (MTBF and MTTF)

Outcome 4 Develop and contribute to improving working relationships and practices

Practical Activities

The candidate will be able to
1. define personal current competence and areas of development required
2. set objectives, review performance, reset objectives
3. seek feed back and advice
4. make action plans
5. establish and maintain work relationships
6. deal with difficulties
7. assist others

Underpinning Knowledge

The candidate will be able to
1. describe areas of responsibility
    - a who is responsible for training, welfare and supervision
    - b personal responsibilities
        - i gathering evidence
        - ii completing work from development and/or training plan
        - iii using appropriate behaviour, dress and language
        - iv acting in a professional manner to customers and other staff

2. explain the meaning of competence
    - a how to identify the competencies required
    - b where to find information that describes competence requirements.

3. identify the objectives of training and development
    - a how company training is organised
    - b setting personal targets for the future
    - c opportunities available for updating (engineering training courses and qualifications)
    - d which skills can be developed by different courses
    - e the resources required and who will approve their use
    - f where advice can be obtained

4. explain the need for reviewing performance
    - a methods
    - b importance of constructive feedback

5. describe the way in which working relationships can affect output
    - a different relationships within an organisation
    - b what is required to maintaining effective working relationships
    - c how to work as a team member
    - d difficulties that can occur
        - i who to approach if there are problems
        - ii basic implications of current legislation involving Race Relations Act and Equal Opportunities Act
        - iii attitudes and requests that could cause conflict or create a negative response
        - iv how to obtain help, ensuring a positive response

Unit 050 Advanced mathematics and science

Rationale
This optional unit is designed for candidates who require a level of understanding of mathematics and science which goes beyond that of the underpinning knowledge required for the units in the award. It is primarily aimed at those candidates who wish to progress to higher education. It has been applied to practical engineering principles of mathematics topics.

Outcomes
There are thirteen outcomes to this unit. The candidate will be able to
1 use indices
2 use algebraic methods
3 use logarithms and number bases
4 use trigonometry
5 use calculus
6 use statistics
7 describe materials and their properties
8 perform tests in stress, strain and elasticity
9 describe the principles of kinematics (velocity and acceleration
10 describe the principles of dynamics (force, mass and acceleration
11 describe the principles of bending beams
12 describe effects on fluids
13 describe the effects of electromagnetism and alternating current.

Connection with other Awards
This unit relates to all NVQ’s

Assessment
The outcomes from this unit will be assessed using evidence from a centre devised assignment which will cover both practical activities and underpinning knowledge.

Outcome 1 Use indices

Practical Activity

The candidate will be able to

1 use formulae involving powers and roots to solve practical problems.

Underpinning knowledge

The candidate will be able to

1 state the meanings of the terms base, index, power, root and reciprocal
- a deduce that $a^0 = 1$
- b state that $a^{-n} = 1/a^n$
- c state that $a^{1/n}$ = nva
- d evaluate:
  - i $a^m.a^n$
  - ii $a^{(n + m)}$
  - iii a^m/a^n
  - iv $a^{m - n}$
  - v $(a^m)^n$
  - vi a^{mn}
  - vii $a^{m/n}$

2. express decimal fractions in standard form

3. solve algebraic problems involving transposition of terms with indices

Outcome 2 Use algebraic methods

Practical Activities

The candidate will be able to

1. apply graphical methods to solve practical problems
2. form and solve quadratic equations which are mathematical models of practical problems
3. calculate ranges of gear ratios suitable for use in reduction gearboxes
4. solve statistical problems requiring the use of factorial notation

Underpinning knowledge

The candidate will be able to

1. use algebraic and graphical methods to solve simultaneous and quadratic equations

2. define the roots of an equation

3. use a calculator to solve simultaneous and quadratic equations

4. recognise perfect squares and the difference of two squares

5. describe the use of simple arithmetic and geometric series

6. describe the use of factorial notation for combinations and permutations

Outcome 3 Use logarithms and number bases

Practical Activities

The candidate will be able to
1. use logarithms to manipulate and simplify algebraic functions and produce graphical solutions to problems involving logarithmic and exponential functions
2. apply binary and hexadecimal numbering systems to practical activities including data transmission and storage

Underpinning knowledge

The candidate will be able to
1 define a logarithm as a power applied to a base number

2. use logarithms to the base 10

3. use logarithms to the base 'e' stating its application

4. use logarithms to simplify calculations

5. describe the binary numbering system and its uses in data transmission and storage

6. describe the hexadecimal numbering system and its uses in data transmission and storage

7. perform calculations using binary and hexadecimal numbers

8. perform conversions of numbers between denary, binary and hexadecimal bases

Outcome 4 Use trigonometry

Practical Activities

The candidate will be able to

1. apply trigonometric solutions such as mensuration problems, simple structures, angular motion, phasors
2. use complex numbers to generate an argand diagram

Underpinning Knowledge

The candidate will be able to

1 solve problems involving trigonometric ratios for the four quadrants

2 apply the Sine Rule (A/sina + B/sinb + C/sinc) to practical problems

3 apply the Cosine Rule ($a^2 = b^2 + c^2 - 2.b.c.cosa$) to practical problems

4 plot graphs of the functions y = Rsin ($\omega t + \alpha$) and y = Rcos ($\omega t + \alpha$)

5 use a calculator to solve problems involving areas of
- a non right-angled triangles
- b angles between lines
- c true length of lines
- d true angle between planes

6 state the basic trigonometric identities
- a tan = sin/cos
- b cot = 1/tan
- c sec = 1/cos
- d cosec = 1/sin

7 explain that a complex number is a combination of j notation and a rational number

8 describe vector representation of
- a complex numbers
- b modulus
- c argument

9 describe polar representation of
- a complex numbers
- b argand diagrams
- c rotating vector
- d polar to cartesian form and vice-versa

Outcome 5 Use calculus

Practical Activities

The candidate will be able to

1 complete calculations that apply differentiation to problems such as velocity and acceleration
2 determine the minimum material required to produce a regular-shaped square or circular container of maximum volume
3 complete calculations that apply integration to problems such as summation of irregular areas, volumes of revolution, centroid of area and second moment of area

Underpinning knowledge

The candidate will be able to

1 state that $dy/dx = nx^{n-1}$

2 solve problems involving maxima and minima related to practical applications

3 differentiate
   a a product
   b a quotient
   c function of a function

4 show the general form of a second derivative

5 differentiate algebraic expressions including
   a polynomial expressions
   b exponential expressions
   c simple trigonometrical functions

6 determine the value of the dependent variable at turning points in
   a a quadratic equation
   b a cubic equation

7 apply Simpson's Rule to the calculation of areas of irregular sections

8 state that the ?$ax^n dx$ = $a/n+1(x^{n+1})$

9 apply the rules of integration for
   a polynomial expressions
   b exponential expressions
   c simple trigonometric functions

10 describe the process of integration by substitution and integration by parts

Outcome 6 Use statistics

Practical Activities

The candidate will be able to
1 determine mean and standard deviation for a sample of engineering artefacts
2 perform simple estimates of failure rates of engineering artefacts or systems

Underpinning Knowledge

The candidate will be able to
1 gather and collate data from various sources and solve problems involving:
  a frequency distributions (mean, median, mode, standard deviation
  b extrapolated data
  c interpolated data

2 use a scientific calculator to perform statistical calculations

3 define probability

4 define dependent and independent events

5 describe addition and multiplication laws of probability

6 describe how permutations and combinations are applied to probability

7 describe the normal probability distribution

8 describe confidence limits and statistical testing

Outcome 7 Describe materials and their properties

Practical Activities

The candidate will be able to

1 describe the probable reasons for failure of a number of material samples
2 describe the types of corrosion present in given samples
3 use micro-examination to describe the characteristics of chemically etched metal samples
4 select materials that are suitable for given engineering applications from a range of metals and non-metals

Underpinning knowledge

The candidate will be able to

1 a state what is meant by the terms
   i creep
   ii fatigue
  b describe the methods of measuring each of the above

2. describe the common causes and methods of prevention of the following types of corrosion/decay
   a atmospheric
   b chemical
   c electrolytic/dissimilar metals
   d fretting
   e stress
   f ultra-violet

3. describe the crystallisation process of metals and the formation of cubic and hexagonal lattices

4. with reference to the Iron/Carbon Thermal Equilibrium diagram:
   a describe the effects on microstructure of varying the amount of carbon in irons and steels
   b state the temperatures at which hardening, tempering and annealing for steels of varying carbon contents are carried out

5. describe typical properties and uses of the following non-ferrous metals:
   a aluminium and magnesium alloys
   b brasses
   c bronzes
   d zinc alloy
   e tin/lead alloys (solders/white metal)

6. describe the properties and uses of the following plastics and composite materials

- a Nylon
- b Kevlar
- c Phenol Formaldehyde (Bakelite)
- d Polytetrafluoroethylene (PTFE/Teflon)
- e Polyvinylchloride (PVC)
- f Polypropylene
- g compressed laminates (Tufnol/Formica)
- h polyester resin/fibre reinforced composites (FRP)
- i Polythene (Polyethylene)

7. describe the properties and applications of ceramic materials

Outcome 8 Perform tests in stress, strain and elasticity

Practical Activities

The candidate will be able to

1. perform tensile tests on a range of materials and deduce Young's Modulus for each material
2. perform shearing tests and deduce the modulus of rigidity of a sample of material

Underpinning knowledge

The candidate will be able to

1 a state what is meant by the terms
 - i direct stress
 - ii direct strain
 - iii elastic limit
 - iv yield point
 - v Modulus of Elasticity
 - vi factor of safety

 b perform calculations comparing the properties of different materials

2 a state what is meant by the terms
 - i shear stress
 - ii shear strain
 - iii Modulus of Rigidity
 - iv Poisson's ratio

 b perform calculations comparing the properties of different materials

Outcome 9 Describe the principles of kinematics (velocity and acceleration)

Practical Activities

The candidate will be able to
1 solve practical problems involving bodies in linear motion and trajectories
2 use vector addition to calculate achieved tracks (eg ships in tides, aircraft in winds) and relative velocities

Underpinning knowledge

The candidate will be able to
1 state the following
   a velocity is a vector quantity
   b velocity is the rate of change of distance with respect to time
   c the area under a velocity/time curve represents the distance travelled
   d acceleration is the rate of change of velocity with time
   e the area under an acceleration/time curve represents velocity

2. solve problems for linear and rotary motion both graphically and using the formulae
   a $s = {}^{1}/_{2}(u + v)t$ $\theta = {}^{1}/_{2}(\varpi_1 + \varpi_2)t$
   b $a = (v – u)/t$ $\alpha = (\varpi_2 - \varpi_1)/t$
   c $v = u + at$ $\varpi_2 = \varpi_1 + \alpha t$
   d $s = ut + {}^{1}/_{2}at^2$ $\theta = \varpi_1 t + {}^{1}/_{2}\alpha t^2$
   e $v^2 = u^2 + 2as$ $\varpi_2{}^2 = \varpi_1{}^2 + 2\alpha s$

3. use vector diagrams to calculate relative velocities of bodies subjected to linear motion

Outcome 10 Describe the principles of dynamics (force, mass and acceleration)

Practical Activities

The candidate will be able to
1 use observed data to calculate the acceleration due to gravity
2 verify the conversion of energy from one form to another
3 measure the strain energy in a helical spring

Underpinning knowledge

The candidate will be able to
1 state Newton's Laws of Motion

2 define the Earth's acceleration due to gravity as 9.81 ms^{-2}

3. state that the Newton is the force required to accelerate a mass of 1 kg at the rate of 1 ms^{-2}

4. solve problems for accelerating/decelerating masses both graphically and using the formulae f = ma

5. define momentum as the product of mass and velocity

6. define impulse as the product of force and time

7. solve problems involving colliding bodies

8. calculate the moment of inertia of disks and rimmed flywheels

9. calculate the momentum of flywheels of given shapes and masses

10. explain the term 'radius of gyration'

11. define potential energy P.E = mgh

12. relate work done in raising a body to potential energy

13. define linear and angular kinetic energy in terms of $^1/_2\,mv^2$ and $^1/_2 I\varpi^2$

14. solve energy conversion problems both graphically and using the formulae quoted above

15. define strain energy in terms of force and extension of an elastic body

16. solve problems associated with stored energy both graphically and using the formulae S.E = $^1/_2 fx$.

Outcome 11 Describe the principles of bending beams

Practical Activities

The candidate will be able to

1. calculate maximum bending and shear loading for beams and cantilevers under given load conditions
2. demonstrate the relationship between the loading and deflexion of a beam

Underpinning knowledge

The candidate will be able to

1. construct shear force and bending moment diagrams for simply supported beams and cantilevers

2. determine maximum bending moments for:
   a. point loads
   b. uniformly distributed loads
   c. combinations of a and b

3. identify points of contraflexure

4. state the assumptions made in calculating stress due to bending

5. derive the standard equation for bending $\sigma/y = M/I = E/R$

6. derive the second moments of area for rectangular and circular sections

7. define units of second moment of area as m^4

8. solve problems associated with the stresses produced in bending beams

9. compare the resistance in bending of 'T', 'I' and channel beam cross-sections

Outcome 12 Describe effects on fluids

Practical Activities

The candidate will be able to
1. demonstrate the relationship between pressure and volume of a given mass of gas
2. demonstrate the relationship between the temperature and volume of a given mass of gas
3. demonstrated the relationship between potential energy, kinetic energy and pressure energy of non-compressible fluid flow in inclined tapered conduits

Underpinning knowledge

The candidate will be able to
1 state Boyle's Law

2 state Charles' Law

3 state the Combined Gas Laws

4 solve problems associated with the above

5 define
   a velocity rate of flow
   b volume rate of flow
   c mass rate of flow

6 state the continuity equation for an incompressible liquid

7 solve problems associated with 6 above

8 state how fluid can possess potential, kinetic and pressure energy

9 describe how kinetic and pressure energy in a fluid can be expressed in terms of 'head'

10 describe Bernoulli's equation

11 use Bernoulli's equation to solve problems associated with incompressible fluid flow

12 describe the power developed by a jet in terms of velocity and mass flow rate

Outcome 13 Demonstrate the effects of electromagnetism and alternating current

Practical Activities

The candidate will be able to
1 demonstrate the effect of a magnetic field on a current carrying conductor
2 demonstrate the effect of a magnetic field on a moving conductor

Underpinning knowledge

The candidate will be able to
1 describe the effect on a current carrying conductor that is exposed to a magnetic field

2. use Fleming's Left-hand Rule to establish the direction of the force on a current flowing at right angles to the direction of a magnetic field

3. state that the units of magnetic field strength are the Tesla and the Weber

4. calculate the magnitude of the force on a current flowing at right angles to a magnetic field using the formula $F = B.I.l$

5. describe practical applications of force exerted on a current in a magnetic field
   a an electric motor
   b a moving coil loudspeaker

6. describe the effect of moving a conductor across a magnetic field

7. state Faraday's law of electromagnetic induction

8. state Lenz's law

9. use Fleming's Left-hand Rule to establish the direction of induced e.m.f.

10. calculate the value of an induced e.m.f. using the formula $E = Blv$

11. describe practical applications of electromagnetic induction:
    a an electric generator
    b an eddy-current brake

12. describe the method of generating an alternating e.m.f.

13. sketch the graph of instantaneous conductor e.m.f. against angular position of coil

14. define the period and frequency of an alternating current

Unit 051 Industrial communications

Rationale
This unit is concerned with the underlying principles and operation of industrial computer networking systems and field-bus technologies.

Outcomes
There are seven outcomes to this unit. The candidate will be able to
1 describe hardware and software requirements for typical Local Area Networks (LAN)
2 outline the functions of each layer of the open system integration (OSI) seven layer
model and the relationship of each to the transport control protocol/internet protocol (TCP/IP)
3 describe LAN topologies and access methods
4 compare various network linking/switching devices
5 connect and configure a simple LAN
6 identify and compare industrial field bus technologies including industrial Ethernet
7 install and configure field-bus systems.

Connection with other awards
This unit relates to all NVQ's unit 002
City & Guilds 7261 'Information Technology Diploma in Networking'
This unit relates to OSC *Eng* ECS 1.12, 1.15, 1.17, 2.17, 2.18 and 3.02.

Assessment
The outcomes of this unit will be assessed using evidence from a centre devised assignment which will cover both practical activities and underpinning knowledge

Outcome 1 List hardware and software requirements for a typical Local Area Network (LAN)

Practical Activities

The candidate will be able to
1 identify various types of network cables and connectors
2 make and test a network cable using the RJ45 connector

Underpinning Knowledge

The candidate will be able to
1. describe the difference between ISA and PCI connection standards for network interface cards
   a manually configured NIC: - IRQ, port memory address, base memory address
   b software configurable and plug and play (PnP) network cards
   c wake on LAN feature
   d Remote boot PROM

2. describe the different types of cable and connectors used in LANs
   a coaxial thin and thicknet
   b shielded twisted pair (STP)
   c unshielded twisted pair (UTP) – termination designations for RJ45 connectors
   d fibre optic cable
   e straight and crossover cables

3. describe the characteristics of other communications media
   a infra-red – line of site – limited range
   b radio LANs
   c Laser links

4. describe the form of typical connectors used to terminate LAN cables
   a BNC – T connectors – terminators
   b AUI
   c RJ45 plugs and sockets
   d Fibre optic

5. describe requirements for a networking operating system (NOS) and the purpose and features of NOSs
   a connection to peripheral devices
   b co-ordination of applications and network access
   c access to remote resources
   d security of sensitive data

6. describe the use of the network operating system to configure the network interface card (NIC)
   a loading driver software
   b troubleshooting operation – PING command
   c multiple NICs – gateway computer

7. describe types of signals and transmissions used
   a bandwidth and limitations on data transmission
      i baseband
      ii broadband
   b synchronous and asynchronous transmissions
   c parallel and serial transmissions of data – applications of each
   d simplex, half duplex, full duplex transmissions

8. list the correct steps to be taken when connecting together a small LAN and installing the Network software

Outcome 2 Outline the functions of each layer of the Open System Integration (OSI) seven layer model and its relationship to the Transport Control Protocol/Internet Protocol (TCP/IP)

Underpinning Knowledge

The candidate will be able to

1. state the purpose of each layer in the OSI model and the function of protocols at each layer
   a application
   b presentation
   c session
   d transport
   e network
   f data link
   g physical

2. describe the function of data packets in a network and how they are handled, the concept of encapsulation
   a data, segments, packets, frames, bits position of each in the layers
   b packet switched networks – advantages
   c connection oriented versus connectionless links

3. describe the functions provided by the TCP/IP protocol suite and its relationship to the OSI model
   a applications functions - FTP, SNMP, SMTP, Telnet
   b transport functions – TCP, UDP
   c internet functions – IP, ICMP, ARP, RARP
   d TCP/IP protocol allowing connections to all types of networks
   e suitability for LANs and WANs
   f functions map to all layers of the OSI model
   g support for e-mail, remote login, terminal emulation, file transfer
   h support for information transfer over the internet

4. state the difference between network card addresses and IP addresses
   a media access control address (MAC) consists of 48 bits
   b IP address, 32 bits dotted decimal octets
   c advantages of flat addressing and hierarchical addressing
   d network classes A, B, C
   e subnets

5. describe the process occurring by which data is encapsulated and transmitted through the layers

Outcome 3 Describe LAN topologies and access methods

Practical Activities

The candidate will be able to
1. identify types of network topology

Underpinning Knowledge

The candidate will be able to
1. describe the different types of LAN topologies
   a token ring
   b Bus
   c Star

2. state the benefits and limitations of the above
   a economic considerations
   b ease of use
   c configuration and maintenance

3. describe the access methods adopted for each of the main types of LAN
   a purpose of access methods – traffic control, contention resolution
   b token passing – deterministic
   c CSMA/CD – non-deterministic – collision domains
   d demand priority

4. state the design features and performance characteristics of Ethernet
   a propagation delay, bandwidth, transmission time,
   b specification for 10Mbps and 100Mpbs Ethernet
   c IEEE standard 802.3 comparison
   d frame format – error checking
   e maximum segment distance

5. describe token passing, Carrier Sense Multiple Access/Collision Detection (CSMA/CD) and demand priority methods of accessing a network to transmit data

Outcome 4 Compare various network linking devices

Practical Activities

The candidate will be able to
1 sketch LAN and WAN topologies with linking devices correctly indicated
2 identify network linking devices: eg repeaters, hubs, bridges, switches, routers and modems

Underpinning Knowledge

The candidate will be able to
1 describe the functions and features of network linking devices
   a repeaters
      i amplification and reshaping
      ii extending network segments
   b hubs
      i multiport repeaters
      ii broadcast devices
      iii convenience of cabling and installation
   c bridges
      i separate collision domains
      ii layer 2 device using MAC address table
   d switches
      i multiport bridges
      ii layer 2 device using MAC addresses
      iii traffic regulation
      iv increased bandwidth
   e routers
      i connecting networks of different types
      ii layer 3 device uses IP addresses
      iii connectable to the internet

Outcome 5 Connect and configure a simple LAN

Practical Activities

The candidate will be able to

1 select from a sample of components cables and connectors the correct ones to construct a working LAN
2 install Network Interface Cards into a PC with reference to safe practices and electrostatic discharge considerations
3 link two PCs with network cables, install driver software and configure networking
operating system components
4 troubleshoot a network using appropriate hardware and software tools to achieve a working system

Underpinning Knowledge

The candidate will be able to

1 describe the health and safety issues described in section 607 of BS7671 relating to protective conductor leakage currents

2 describe the correct cables, connectors and network interface cards to be used for
- a thinnet networks
- b UTP (unshielded twisted pair) networks
- c difference between ISA and PCI NIC cards

3 describe the correct ways to install network cards into a PC without damage
- a removing the cover
- b ESD considerations
- c insertion of NIC cards without damage
- d reinstate the computer

4 describe methods used to link PCs on a network
- a thinnet
  - i BNC connectors
  - ii coaxial cable handling
  - iii T piece positioning
  - iv terminator installation
- b UTP
  - i RJ45 connectors – terminations
  - ii recognize straight and crossover cables
- c connecting to the hub – power supply requirements, daisy chaining

5. describe the correct installation of the NIC driver software
- a updating to the latest software driver

6. describe the network software components required in a typical system
- a client packages
- b protocols
- c adapter
- d services

- file and printer sharing services

7. describe the facilities and tools available to troubleshoot networks
   a cable testers
   b time domain reflectometers (TDR)
   c Digital Multimeters (DMM)
   d software utilities
      i Ping
      ii Ipconfig
      iii Tracert
   e logical approach to fault finding
      i visual inspection
      ii NIC LED indicators
      iii software tests
   f network monitoring tools
      i CPU usage
      ii memory usage
      iii packet monitoring and collisions

Outcome 6 Identify and compare industrial fieldbus technologies including Industrial Ethernet

Practical Activities

The candidate will be able to

1 identify and compare a number of popular fieldbus systems in relation to speed, maximum number of nodes, maximum distances, arbitration methods, cable types, primary applications and main benefits

2 identify the hardware and software component requirements for the above technologies

Underpinning Knowledge

The candidate will be able to

1 describe the main application areas and industries for some of the most popular fieldbus networks

2 state the advantages of using fieldbus technologies
   - a reduced complexity
   - b speed of operation
   - c reducing wiring costs
   - d ease of installation
   - e remote calibration and parameterisation
   - f open technologies

3 describe the structure and architecture of a number of typical fieldbus systems

4 state access methods used by fieldbus systems to transfer data to the network
   - a master/slave
   - b multimaster
   - c peer to peer
   - d multicast
   - e polling

5 describe the characteristics and features of some typical intelligent sensors and actuators
   - a remote parameterisation
   - b remote calibration of zero and span
   - c error state communications
   - d degradation of performance monitoring

6. describe the principles of operation of popular fieldbus technologies

Outcome 7 Install and configure a fieldbus system

Practical Activities

The candidate will be able to
1 select transducers, cables, PLC interface to construct a fieldbus network
2 connect together the above components and using installed software, configure the communications, addressing and parameters for the network
3 troubleshoot communications, transducer and addressing problems using diagnostic software and appropriate tools.

Underpinning Knowledge

The candidate will be able to
1 state the types of cable and connectors used on a sample of field bus networks

2 state the types of PLC interface modules used to connect to the network
 a module configuration - DIL switch setting for baud rates etc
 b power supply settings

3 explain the need to use software to configure the interface modules to communicate with the bus
 a node addresses where required
 b communication settings
 c PLC memory area allocation for data and I/O

4 describe the use of software to parameterise intelligent actuators
 a loading standard electronic data sheet files (EDS Files)

5 describe the diagnostic software and hardware tools available to troubleshoot these networks
 a error codes
 b visual indicators
 c graphical machine interfaces

Unit 052 Mechatronics systems

Rationale
This unit is concerned with those principles involved in modern integrated engineering practice and operations. This includes the extraction, interpretation and use of technical information from a range of sources. It includes the use of basic calculations and engineering science enabling the candidate to better understand the interactions and relationships between multi-disciplined applications. It also includes the selection and setting up of engineering tasks to achieve total engineering solutions.

Outcomes
There are five outcomes to this unit. The candidate will be able to
1 understand the principles of the 'total engineering approach' to production systems
2 understand the principles of typical sensors
3 understand the principles of pneumatic, hydraulic, mechanical and electrical actuation systems
4 understand the principles embedded control
5 carry out fault finding techniques

Connection with other awards
This unit relates to units 001-003, NVQ(1682),also units 001-006,016-018,027-030 NVQ (1688**)**
This unit relates to OSC *Eng* ECS 1.12, 1.15, 1.17, 2.17, 2.18 and 3.02.

Assessment
The outcomes from this unit will be assessed using evidence from a centre devised assignment with will cover both practical activities and underpinning knowledge

Outcome 1 Understand the principles of the 'total engineering approach' to production systems

Practical Activities

The candidate will be able to

1. identify the components of various types of industrial systems. To include the types of inputs, controllers, correction elements, process, and outputs
2. construct block diagrams of industrial systems

Underpinning Knowledge

The candidate will be able to

1 state the basic building blocks of industrial systems in terms of
  - a typical input devices
  - b prime movers
  - c gearing
  - d controllers
  - e typical output devices

2 describe the architecture at the block diagram level of various types of industrial system, including the features of the following elements of a block diagram
  - a controller
  - b correction element
  - c process
  - d outputs.
  - e significance of logical sequence of events

3. compare a mechatronic system and a conventional system in terms of
  - a conventional system
    - i centralised control
    - ii hard wiring
    - iii sequence control
    - iv relay logic
    - v product change inflexibility
    - vi plant maintenance
  - b mechatronic system
    - i distributed control
    - ii networks
    - iii intelligent individual control
    - iv embedded control
    - v software programming
    - vi predictive maintenance

Outcome 2 Understand the principles of typical sensors

Practical Activities

The candidate will be able to
1. identify typical sensors used in industrial systems
2. interface contact and non-contact sensors into a control system

Underpinning Knowledge

The candidate will be able to

1 outline the operation and application of the following sensors
  - a micro switch
  - b snap action limit switch
  - c wobble stick
  - d pressure mat
  - e positively guided safety switch
  - f inductive proximity
  - g capacitive proximity
  - h optical proximity
  - i light curtain
  - j thermocouple
  - k strain gauge differential pressure
  - l impeller flow
  - m encoder (incremental and absolute)
  - n resolver

2 identify typical connections and outline tuning requirements for the following sensors
  - a micro switch
  - b snap action limit switch
  - c wobble stick
  - d pressure mat
  - e positively guided safety switch
  - f inductive proximity
  - g capacitive proximity
  - h optical proximity
  - i light curtain
  - j thermocouple
  - k strain gauge differential pressure
  - l impeller flow
  - m encoder (incremental and absolute)
  - n resolver

3 describe the action and importance of the following signal conditioning systems

a voltage to current
b current to voltage
c pressure to voltage
d pressure to current
e analogue to digital
f digital to analogue
g frequency to voltage
h frequency to current
i sink to source
j source to sink

4. state the importance of the following terms when applied to sensors used in an industrial system

a sensitivity
b repeatability
c resolution
d dead band
e alignment
f compatibility
g cross talk
h grounding
i calibration

Outcome 3 Understand the principles of pneumatic, hydraulic, mechanical and electrical actuation systems

Practical Activities

The candidate will be able to
1 design and implement a pneumatic control and actuation system
2 design and implement a hydraulic control and actuation system
3 design and implement an electrical control and actuation system

Underpinning Knowledge

The candidate will be able to
1 describe the operation and application of each part of a pneumatic power system in terms of
   a prime mover eg motor
   b compressor eg 2 stage reciprocating
   c silencer
   d filter
   e pressure relief valve
   f cooler
   g filter and water trap
   h air receiver
   i pipe work distribution system

2. outline the operation and application of the following
   a directional control valves (DCV
      i spool valve
      ii 3/2 valve
      iii 4/2 valve
      iv 5/2 valve
      v directly operated DCV
      vi pilot operated DCV
      vii solenoid operated DCV
      vii poppet valve
   b directional valve
      i one way
      ii one way restrictor return
   c pressure control valve
      i pressure regulating valve
      ii pressure limiting valve
      iii pressure sequence valves
      iv proportional valve
   d process control valves
      i pneumatic diaphragm actuator
      ii quick opening
      iii linear contoured
      iv equal percentage

- e linear actuators
    - i single acting
    - ii double acting
    - iii fluid muscle
    - iv tandem
    - v multi position
    - vi stick slip
- f rotary actuators
    - i use of linear actuator to produce rotation
    - ii vane type semi-rotary
    - iii vane motor

3. describe the operation and application of each part of a hydraulic power system in terms of
    - a prime mover eg motor
    - b pump
    - c non return valve
    - d pressure relief valve
    - e accumulator eg bladder type
    - f sump
    - g hydraulic oil
    - h pipe work distribution system and return

4. outline the operation and application of
    - a directional control valves (DCV)
        - i spool valve
        - ii 3/2 valve
        - iii 4/2 valve
        - iv 5/2 valve
        - v directly operated DCV
        - vi pilot operated DCV
        - vii solenoid operated DCV
        - viii poppet valve
    - b directional valve
        - i one way
        - ii one way restrictor return
    - c pressure control valve
        - i pressure regulating valve
        - ii pressure limiting valve
        - iii pressure sequence valves
        - iv proportional valve
    - d linear actuators
        - i single acting
        - ii double acting
        - iii fluid muscle
        - iv tandem
        - v multi position

e rotary actuators
  i use of linear actuator to produce rotation
  ii vane type semi-rotary
  iii vane motor

5. identify the correct symbols for
   a flow path
   b flow shut off
   c initial connections
   d push button operation
   e lever operation
   f roller operation
   g plunger operation
   h spring operation
   i solenoid operation
   j pedal operation
   k pilot operation
   l 2/2 valve
   m 3/2 valve
   n 4/2 valve
   o 5/2 valve
   p non return valve
   q pressure limiting valve
   r regulator
   s pressure source
   t exhaust
   u filter
   v single acting cylinder
   w double acting cylinder
   x rotary actuator

6. describe the operation and application of each part of a mechanical system in terms of
   a prismatic motion
   b revolute motion
   c sliding joints
   d revolving joints
   e force amplification eg levers
   f change of speed eg gears
   g transfer of rotation eg belts and chains
   h types of motion eg quick return mechanism
   i cams and cam followers
   j change of direction eg bevel and worm gear
   k linear to revolute/revolute to linear eg rack and pinion
   l bearings eg plain roller needle and ball

7. outline the operation and application of each part of an electrical system in terms of
   a switching devices
      i push buttons
      ii relays
      iii thyristor
      iv triac
      v solid state relay
   b solenoid devices
   c motors
      i series dc
      ii shunt dc
      iii separately excited dc
      iv stepper
      v servo
      vi single phase induction
      vii three phase induction
   d motor control
      i basic dc motor speed control eg inverter drives
      ii basic induction motor speed control eg inverter drives
      iii basic stepper motor controllers
      iv basic servo motor controllers
   e basic components of a fieldbus network
      i benefits over hard wired systems
      ii communications interface to control system
      iii basic requirements of wiring medium eg cat 5, grounding.
      iv types of distributed input output modules eg digital, analogue
      v termination requirements eg insulation displacement connection (IDC), RJ45, multi pin connectors (DIN), British Naval Connector (BNC)

Outcome 4 Understand the principles of embedded control

Practical Activities

The candidate will be able to

1 create block diagrams of lay out of controllers

2 explain the content of simple control programs

Underpinning Knowledge

The candidate will be able to

1 outline Programmable Logic Controller (PLC) architecture and explain the function of each of the main components
   - a control unit
   - b programming device
   - c input/output modules
   - d memory

2 describe ladder logic programming language used to programme PLC
   - a basic instructions in Ladder Logic
   - b examine if open/closed
   - c output
   - d latched output
   - e bit/flag instructions
   - f timers
   - g counters

3. outline Programmable Interface Controller (PIC) architecture and explain the function of each of the main components
   - a central processing unit (CPU)
   - b onboard analogue to digital converters (ADC)
   - c input output ports
   - d communication port
   - e timers
   - f memory

4. describe methods of programming PIC chips
   - a reduced instruction set computing (RISC) eg low level assembly language
   - b BASIC e.g high level language requiring compiler

5. describe operation and application of the following methods of embedded control
   - a intelligent sensors e.g on board processing facilities
   - b dedicated controllers eg three term controllers applying control to part of a centrally controlled process
   - c slave controllers e.g a welding effector communicating via a robot arm controller

6. describe operation and application of the following logic instructions
   a AND
   b OR
   c EXOR
   d NOT
   e NAND
   f NOR

7. describe how logic instructions can be used to control outputs for given inputs
   eg X = (A and B not) or (C not or D)

Outcome 5 Carry out fault finding techniques

Practical Activities

The candidate will be able to
1 carry out simple fault finding routines

Underpinning Knowledge

1 The candidate will be able to
state methods used to locate faults
- a half split
- b unit substitution
- c unit response
- d symptom
- e cause
- f pressure monitoring

2 outline the operation and application of
- a signal injector
- b logic probe
- c voltmeter
- d standard signal sources e.g 4 to 20 mA
- e data logger

3 state the safe isolation procedures on the following systems
- a electrical power
- b electrical control
- c pneumatic radial
- d pneumatic ring
- e hydraulic

4 state detrimental effects of faulty or inefficient industrial systems
- a pneumatic e.g cost of producing lost air, environmental effect
- b hydraulic e.g dangers of pressurised liquids, environmental effect

Unit 053 Robotics

Rationale
This unit is concerned with those principles underpinning modern integrated engineering practice and operations. This includes the extraction, interpretation and use of technical information from a range of sources. It includes the use of basic calculations and engineering science that enables the candidate to better understand the interactions and relationships between multi-disciplined applications. It also includes the selection and setting up of engineering tasks to achieve total engineering solutions.

Outcomes
There are seven outcomes to this unit. The candidate will be able to
1 state the industrial uses of robotic systems
2 describe the standard geometry of robotic systems
3 describe robotic drive systems
4 state the operation of internal and external sensors used in robotic systems
5 carry out basic robotic control and programming tasks
6 state the requirements for effective robot tooling design
7 carry out a robot cell design sequence.

Connection with other awards
This unit relates to units 001-003,of the City & Guilds NVQ in Mechanical manufacturing engineering(1682)
This unit relates to OSC *Eng* ECS 1.12, 1.15, 1.17, 2.17, 2.18 and 3.02.

Assessment
The outcomes from this unit will be assessed using evidence from a centre devised assignment, which will cover both practical activities and underpinning knowledge.

Outcome 1 State the industrial uses of robotic systems

Practical Activities

The candidate will be able to

1. identify the component parts of an industrial robot

Underpinning Knowledge

The candidate will be able to

1. state the role of a robotic system within modern manufacturing processes as
   - a physical construction
     - i jointed manipulator
     - ii end effector
     - iii controller
     - iv programming unit
   - b benefit of robot use against human operator with regard to
     - i repeatability
     - ii accuracy
     - iii speed
     - iv use in hazardous areas
   - c costs involved in robotic implementation with regard to
     - i jobs
     - ii capital costs
     - iii variable costs
     - iv maintenance and upgrades
   - d type of robot installation for different applications
     - i pick and place
     - ii loading and unloading
     - iii production

Outcome 2 Describe the standard geometry of robotic systems

Practical Activities

The candidate will be able to

1 produce sketches of robot arm configurations, using correct symbols

Underpinning Knowledge

The candidate will be able to

1. describe the action of a robot in 3D space with reference to the number of degrees of freedom it has

2. describe robot arm configurations

3. describe
   a linear movement as
      i X plane ‘width movement’
      ii Y plane ‘height movement’
      iii Z plane ‘depth movement’
   b revolving movement as
      i pitch
      ii roll
      iii yaw
   c linear joints as ‘Prismatic’
   d revolving joints as ‘Revolute’
   e line diagrams containing symbols for prismatic and revolute joints

4. describe listed robot configurations in terms of use, degrees of freedom types of joints and kinematic sketches
   a Cartesian
   b Cylindrical
   c Polar
   d Jointed arm
   e SCARA (The Selective Compliance Assembly Robot Arm)
   f Partial Spherical (pendulum)
   g Multiple Joint Robot or Spline Robot

5. describe wrist design as a means of achieving
   a three revolute degrees of freedom
   b accurate end effecter manipulation

6. describe robot design considerations in terms of
   a working envelope
   b payload
   c speed of operation
   d weight restrictions

Outcome 3 Describe robotic drive systems

Practical Activities

The candidate will be able to
1 select robotic actuators for a specific task

Underpinning Knowledge

The candidate will be able to
1. describe the application of fluid power in robotic systems

2. describe the application of electrical power in robotic systems

3. describe transmission systems used in robots

4. state the configuration of a typical robot control system with regard to
   a control element
   b actuator
   c transmission element
   d load
   e sensor
   f feed back
   g comparator

5. describe the production of
   a compressed air - 'pneumatic power'
   b compressed fluid - 'hydraulic power'

6. outline the operation of
   a pneumatic cylinder (single acting)
   b pneumatic cylinder (double acting)
   c hydraulic cylinder (double acting)
   d pneumatic rotary actuator
   e hydraulic rotary actuator
   f electro mechanical solenoid
   g spool valve
   h stepper motor

7. state the benefits of
   a pneumatic actuators
   b hydraulic actuators
   c electric actuators

8. outline the operation and application of transmission systems
   a spur gears
   b helical gears
   c straight bevel gears
   d spiral bevel gears
   e worm gears
   f rack and pinion
   g ball and roller screws
   h pulley drives and tendons
   i linkages
   j bearings

Outcome 4 Describe the operation of internal and external sensors used in robotic systems

Practical Activities

The candidate will be able to

1 select appropriate sensor for a given application

Underpinning Knowledge

The candidate will be able to

1. explain that sensors are used for
   - a measuring machine parameters for robot control loops
   - b determining the position of objects in 3-D space
   - c adjusting the robot control for the environment
   - d detecting and preventing failures
   - e detecting and avoiding collisions
   - f monitoring the interaction with the environment
   - g monitoring the environmental changes, temperature etc.
   - h inspecting the final product

2 state the difference between
   - a digital sensors
     - i limit switch
     - ii proximity switch
     - iii photo electric switch
     - iv hall effect switch
     - v float switch
     - vi ultrasonic switch
   - b analogue sensors
     - i temperature sensor
     - ii flow switch
     - iii load cell
     - iv laser
     - v pressure transducer
     - vi vision system
   - c safety
     - i gate plug
     - ii light curtain
     - iii safety mat

3. state how the listed sensors are used as internal sensors:
   - a potentiometer
   - b LVDT
   - c synchro
   - d resolver
   - e optical encoder
   - f load cell
   - g photoelectric sensor

4. state how the listed sensors are used as external sensors:
   a proximity sensor
   b limit switch
   c optical systems
   d hall effect switch
   e ultrasonic switch

5. state how sensors are used for quality control purposes

Outcome 5 Carry out basic robotic control and programming tasks

Practical Activities

The candidate will be able to
1. carry out simple programming of a robot

Underpinning Knowledge

The candidate will be able to
1. describe the use of control pendants as a programming tool

2. describe the use of software as a programming tool

3. describe the use of simulation as a programming tool

4. describe online programming in terms of
   a axis limit control
   b point to point
   c contouring
   d line tracking

5. describe offline programming in terms of
   a safety
   b 3D visualisation of robot arm
   c need for computing ability
   d specialist programming language
   e absolute and incremental co-ordinates
   f troubleshooting
   g planning
   h communication between CAD CAM systems (computer aided drawing, computer aided manufacture)

6. outline the process of effective robot program design, using flow charts and incorporating
   a symbols
   b labelling
   c inputs

7. describe performance specifications in terms of
   a payload
   b normal and maximum
   c static and rated
   d static and dynamic
   e repeatability
   f speed
   g limit on certain motion

Outcome 6 State the requirements for effective robot tooling design

Practical Activities

The candidate will be able to

1. carry out simple component design for robotic manipulation
2. specify an end effector to suit a particular component

Underpinning Knowledge

The candidate will be able to

1. describe methods of building 'design for automation' into components, with regard to component
   - a symmetry
   - b datums
   - c tangling
   - d feeding
   - e insertion
   - f alignment

2. describe end effector operation
   - a vacuum cup
   - b pneumatic gripper
   - c servo controlled gripper
   - d intelligent hand

3. outline types and application of end effectors for process operations
   - a welding
   - b grinding
   - c painting
   - d gripper end effector
   - e vacuum
   - f clamp
   - g intelligent hand

4. describe limitations of effector design regarding
   - a rated payload and gripper mass
   - b force required to accelerate and decelerate payload ($F = MA$ *Newton*)
   - c force required to change payload direction
   - d clamping force
   - e coefficient of friction between gripper and part

Outcome 7 Carry out robot cell design sequence

Practical Activities

The candidate will be able to
1. carry out simple cell design for robotic pick and place process
2. specify safety aspects for a specific cell orientation

Underpinning Knowledge

The candidate will be able to
1. describe the design sequence in terms of
    - a planning
        - i personnel involved
        - ii application
        - iii feasibility review
    - b development
        - i task
        - ii part presentation
        - iii handling equipment
        - iv process machines
        - v quality control process
    - c mock up and testing
        - i commissioning
        - ii de-bugging
        - iii trial runs
        - iv quality control checks
    - d installation
        - i pilot production runs
        - ii parallel running with manual cells
        - iii final implementation
    - e production and follow through
    - f future development

2. describe aspects of robot safety in terms of
    - a machine safety
        - i category B
        - ii category 1
        - iii category 2
        - iv category 3
        - v category 4
    - b operator safety
        - i competence
        - ii training
        - iii emergencies

3. describe physical layout and application of
    - a radial layout
    - b in line track mounted
    - c in line fixed

4. describe the content of a robot feasibility review in terms of
   a possible benefits
   b accuracy
   c speed
   d repeatability
   e workforce rationalization
   f safety
   g possible drawbacks
      i cost
      ii workforce rationalization
      iii maintenance downtime
      iv loss of production due to failures
      v type of automation
         A hard
         B flexible
      vi proposed layout
         A radial
         B inline
         C available space
         D safety

Unit 054 Automation systems

Rationale
This unit is concerned with the underlying principles of Industrial Control Systems and operation of Programmable Logic Controllers and Graphical Control Interface technologies in Integrated Environments.

Outcomes
There are six outcomes to this unit. The candidate will be able to

1 outline the architecture of a computer based automation system
2 describe the operation of the various types of control systems
3 apply connection and circuit technology for transducers
4 configure and use a PLC in an integrated control environment, with particular attention to safe practices
5 describe various modes of control and the techniques available to analyse their performance
6 configure and integrate into control systems computer based operator interfaces.

Connection with other awards
This unit relates to units 001-003,of the City & Guilds NVQ in Mechanical manufacturing engineering (1682)
This unit relates to OSC *Eng* ECS 1.12, 1.15, 1.17, 2.17, 2.18 and 3.02.

Assessment
The outcomes of this unit will be assessed by using evidence from a centre devised assignment which will cover both practical activities and underpinning knowledge.

Outcome 1 Outline the architecture of a computer based automation system

Practical Activities

The candidate will be able to

1. identify the components of various types of industrial automation systems, to include the types of inputs and outputs, the form of control and the feedback loops involved.
2. obtain characteristic responses for some simple types of control systems

Underpinning Knowledge

The candidate will be able to

1. describe the architecture at the block diagram level of various types of automation system including the
    a. features of the following elements of a block diagram
        i. process
        ii. inputs
        iii. outputs
        iv. energy source
        v. measurement system
        vi. controller
        vii. feedback loops
    b. variable names
        i. controlled variable
        ii. manipulated variable
        iii. measurement variable
        iv. disturbance variable
        v. error
        vi. set-point
        vii. controller output
    c. significance and use of mathematical modelling of system components and the concept of transfer functions

2. state the benefits of a well designed control system in terms of
    a. increased productivity
    b. improved quality
    c. increased efficiency
    d. better safety
    e. convenience
    f. power assistance

Outcome 2 Describe the operation of the various types of control systems

Underpinning Knowledge

The candidate will be able to

1. describe the difference between a regulatory and a following system and give examples of each type

2. describe the difference between numerical, servo and sequential control systems

3. describe the main elements of a Robotic control system

4. describe the main elements of a Process control system

5. state examples of and explain the operation of each type of control system

6. describe the classification of control systems in terms of
    - a set point changes
        - i infrequent change – regulatory system
        - ii frequently changed – following system
    - b industry in which used
        - i processing – process control
        - ii continuous system
        - iii batch system
    - c part manufacturing – machine control
        - i numerical control systems
        - ii robotic control systems
    - d category of controller or control
        - i programmable logic controller
        - ii sequential control
            - A event sequenced control
            - B time sequenced control
        - iii industrial PC controller

7. describe the main differences between Servomechanism control and other forms
    - a characteristics of servo devices
    - b types of servo device
    - c applications of servo devices

Outcome 3 Apply connection and circuit technology for transducers

Practical Activities

The candidate will be able to
1 wire a selection of transducers with different connection types into a control system
2 wire proximity switches to obtain AND and OR functions
3 wire proximity switches in sink and source mode

Underpinning Knowledge

The candidate will be able to
1 describe the various types of connections available with sensors and actuators
   a two wire DC and AC technology
      i normally open (NO and normally closed contacts
      ii grounding connections
      iii residual load current
   b three wire DC technology
      i Positive and negative switching outputs (PNP/NPN
      ii PNP normally open
      iii NPN normally open
      iv PNP normally closed
      v NPN normally closed
   c four wire DC technology
      i PNP normally open/closed connections
      ii NPN normally open/closed connections

2 describe the connection of sensors in parallel and series to achieve Boolean Logic external to the controller
   a parallel and series connection of proximity switches
      i benefits and limitations
   b parallel connection of proximity switches using two wire technology
   c parallel connection of proximity switches using three wire technology
   d series connection of proximity switches using two wire technology
   e series connection of proximity switches using three wire technology

3 describe connection technology under conditions of strong magnetic influence
   a need for screening
   b need for short cable lengths
   c voltage supply filtering
   d limit error signals at source

4. describe connection of controllers, relays and display elements to proximity sensors
   a current consumption considerations
   b resistance of load and sensor current requirements
   c protection for voltage peaks

5. describe sensor power supply considerations
   a switch on spikes
   b supply voltage ripple

6. describe the various types of connections available for transducers and the characteristics of each

Outcome 4 Configure and use a PLC in an integrated control environment

Practical Activities

The candidate will be able to
1 use ladder logic to program simple operations on a PLC controlled system
2 configure communications on a PLC controlled system
3 download/upload test and modify PLC programs
4 configure and use various modules in a PLC based control system.

Underpinning Knowledge

The candidate will be able to
1 outline PLC architecture and the describe the function of each of the main components
   a control unit
   b programming device
   c input/output modules
   d memory

2 outline programming languages used to programme PLCs
   a industrial standard languages and IEC 61131-3
   b examples of
      i statement list
      ii structured text
      iii function block
      iv sequential function chart
      v basic instructions in Ladder Logic
      vi examine if open/closed
      vii output
      viii latched output
      ix bit/flag instructions
      x timers
      xi counters
      xii move and logic
      xiii arithmetic and compare

3. describe the methods used to configure communications to go online with a programming device
   a upload programmes from a PLC
   b modify programmes both online and offline
   c test programmes and re-evaluate operation
   d use software and hardware to troubleshoot problems in a PLC based control system
   e document and save programmes

4. describe the range of different types of interface module and methods of configuring these devices
   a. digital I/O modules characteristics
   b. analogue modules characteristics
   c. modules used for remote I/O and configuration and addressing
   d. modules for connection to
      i. Radio frequency identification scanning systems (RFID)
      ii. bar code readers
      iii. camera vision systems

Outcome 5 Describe various modes of control and the techniques available to analyse their performance

Practical Activities

The candidate will be able to
1 program simple time/event driven processes using a PLC as the controller
2 tune simple control systems using standard techniques
3. analyse using frequency response methods the stability of various modes of control

Underpinning Knowledge

The candidate will be able to
1 state methods used to describe time driven sequential processes
 a statement algorithm
 b timing diagrams

2 state methods used to describe event driven sequential processes
 a ladder diagrams
 b Boolean expressions
 c sequential function charts
 d state diagrams
 e process timing diagrams

3 state the principles of proportional, integral and derivative control and the characteristics of systems employing various combinations of each (P, PI, PID)

4 state standard methods employed in industry to optimise/tune the response of a control system in various types of control mode
 a process reaction curve
 b ultimate cycling method
 c self tuning adaptive controllers

5 describe methods used to analyze the response of a control system to determine the levels of stability of the system
 a Bode diagrams for phase and gain
 b phase and gain margins

6. describe discrete control and the difference between event driven processes and time driven processes

Outcome 6: Configure and integrate into control systems, computer based operator interfaces

Practical Activities

The candidate will be able to
1 configure supervisory control and data acquisition (SCADA) or HMI systems to communicate with PLC based control systems
2 create a graphical interface to include the elements of control, animation, alarming, archiving and trends
3 create a link and exchange data between software and other software applications.

Underpinning Knowledge

The candidate will be able to
1 describe the main elements features and functions of PC based (SCADA) systems
 a linked animated graphics
 b PC control of system functions
 c display and logging of system errors
 d need for archiving of process data
 e alarm functions of variable priority
 f display of process variable trends in various graphical formats

2 describe the main features and functions of Human machine interface (HMIs) units

3 outline software data linking standards used to exchange data between software applications
 a dynamic data exchange DDE
 b object linking and embedding OLE

4 describe methods employed to link real I/O to PC based applications via database objects
 a I/O PLC based or HMI base

5 describe the use of functions and features available with HMI systems
 a function key control
 b touch screen control units
 c communication links available with typical systems
 d creation of graphical objects and configuring links to PLC and SCADA based systems

Unit 055 Control systems

Rationale
This unit is concerned with the underlying principles and operation of industrial instrumentation, classic control, and dynamic system technologies.

Outcomes
There are five outcomes to this unit. The candidate will be able to
1 describe open and closed loop control.
2 outline the operation of and implement listed sensors and actuators
3 identify Robot configurations and classifications.
4 describe the operation of digital and analogue motion control systems.
5 carry out simple programming tasks involving Robotic motion and motor drive control.

Connection with other awards
This unit relates to OSC *Eng* ECS 1.12, 1.15, 1.17, 2.17, 2.18 and 3.02.

Assessment
The outcomes from this unit will be assessed using evidence from a centre devised assignment, which will cover both practical activities and underpinning knowledge.

Outcome 1 Describe open and closed loop control

Practical Activities

The candidate will be able to
1. apply terminology to control systems
2. carry out experiments based around open and closed loop speed control
3. carry out simulated analysis of open and closed loop control systems
4 configure inputs to control systems
5 analyse outputs from control systems

Underpinning Knowledge

The candidate will be able to
1. describe the requirements of a measurement system in terms of
    - a true value input:
        - i measurement system
        - ii measured value of variable output
    - b functional elements transducer action
    - c signal conditioning
        - i Voltage to Voltage
        - ii Voltage to Current
        - iii Frequency to Voltage
        - iv Resistance to Voltage
    - d reliability
    - e repeatability
    - f range; reproducibility
    - g sensitivity
    - h stability
    - i response time
    - j rise time
    - k settling time
    - l steady state
    - m desired value
    - n under/over/critically damped
    - o loading effects/errors

2. identify and describe the actions of
    - a block diagrams
    - b open loop control
    - c closed loop control
    - d reliability
    - e repeatability
    - f range: reproducibility
    - g sensitivity
    - h stability
    - i response time
    - j rise time
    - k settling time
    - l steady state
    - m desired value

n under/over/critically damped
o loading effects/errors

3. state control in terms of
   a two step and continuous control
   b proportional band
   c dead band
   d off set
   e hysteresis
   f integral control - a controller output proportional to the integral to the error with respect to time
   g derivative control - a controller output proportional to the rate of change of the error with respect to time
   h Proportional gain (Kp):
   i Derivative gain (Kd):
   j Integral gain (Ki)
   k controller output = Kp(error + Ki × integral of error + Kd × derivative of error*(output = kp(e+ki?e + kd de/dt)*
   l tables and charts to provide system tuning

4 give typical examples of
   a the procedure for calibrating input transducers
   b the procedure for conditioning signals from input transducers
   c how digital and analogue signals are interfaced to control systems

5. describe the basic principles of output analysis including the use of
   a stepped: ramped: and sinusoidal inputs
   b PC based data loggers
   c storage CRO

Outcome 2 Outline the operation of and implement listed sensors and actuators

Practical Activities

The candidate will be able to
1. set up sensors
2. set up actuators

Underpinning Knowledge

The candidate will be able to
1. interpret and use technical information contained in manufacturers' specification sheets
    a thermocouple and pt100
        i zero
        ii range
        iii span
        iv junction compensation
        v type
        note iv and v relate to thermocouples
    b proximity: inductive, capacitive, optical
        i sensing range
        ii material tuning
        iii required output (sink source
        iv switching capability
        v banking capabilities
    c tachogenerator: resolver, encoders
        i setting of volts/rpm
        ii setting of volts/mm
        iii setting of data sequence
    d differential pressure: turbine, strain gauge, pizzo-electric, ultrasonic
        i resistive bridge trimming
        ii trimming of volt seconds
        iii trimming of power level

2. describe actions and calibration of actuators
    a proportional valves
        i trimming of input signals
        ii span
        iii zero
    b servo motors
        i methods of setting absolute datum - optical sensor, drive to stall
        ii methods of deriving maximum holding torque

Outcome 3 Identify robot configurations and classifications

Practical Activities

The candidate will be able to
1. under simulated conditions select a robot arm to match a specific task and cell design
2. use a teach pendent to move a robot arm through rectangular and polar space, store positions, and utilise step and move commands
3. create a software program simulate debug store and download to controller

Underpinning Knowledge

The candidate will be able to
1. define an industrial robot as a programmable manipulator
2. describe joints and movement
   a arm sweep
   b shoulder swivel
   c elbow extension
   d roll
   e pitch
   f yaw

3. state typical classification of robotic arms
   a Cartesian
   b cylindrical
   c polar
   d SCARA
   e pendulum
   f spline

4. describe the six degrees of freedom

5. describe prismatic and revolute joints

6. describe the use of
   a teach pendants
   b programming software

7. explain the choice of end effectors
   a vacuum
   b stepper motor driven
   c specialist design

8. describe use of kinematic and isometric diagrams to relay information on robotic systems

Outcome 4 Describe the operation of digital and analogue motion control systems

Underpinning Knowledge

The candidate will be able to

1. explain the operation of a digital motion control system in terms of
   a set point
   b gain
   c output signal
   d feed back
   e actuator types

2 identify and interpret error codes

3. state operation of feed back devices

4. state the benefits of digital motion control systems over analog systems

5. describe the layout of an analogue motion control system in terms of
   a rectification
   b dc bus
   c chopping circuit
   d output section

6. state the relationship between
   a frequency and speed
   b speed and torque
   c switching frequency and noise

7. compare types, speed, control method

Outcome 5 Describe simple programming tasks involving robotic motion and motor drive control

Practical Activities

The candidate will be able to
1. produce block diagrams
2. program an interaction sequence between a robot arm and motion control system

Underpinning Knowledge

The candidate will be able to
1. explain requirements of block diagrams regarding
   a layout
   b process
   c sequence

2. describe the relationship and interaction between
   a robot control system
   b motion control system

3. explain the safety implications of combined discipline systems with regards to
   a verification of inputs
   b collision detection
   c working envelope

Unit 056 Control electronics

Rationale
This unit concerns the technology of commercial electronics.

Outcomes
There are five outcomes to this unit. The candidate will be able to
1 demonstrate an understanding of power electronics
2 demonstrate an understanding of process control and transducers
3 demonstrate an understanding of drive systems
4 demonstrate an understanding of industrial automation
5 apply basic customer care.

Connection with other awards
This unit relates to units 302,309-310,312,314 of the City & Guilds NVQ in Electrical and electronic servicing (1687)
This unit relates to OSC *Eng* ECS 1.12, 1.15, 1.17, 2.17, 2.18 and 3.02.

Assessment
The outcomes from this unit will be assessed using evidence from an assignment which will cover both practical activities and underpinning knowledge.

Outcome 1 Demonstrate an understanding of power electronics

Practical Activities

The candidate will be able to
1 identify and test a range of power electronic components
2 use data sheets to explain the characteristics of power electronic components

Underpinning knowledge

The candidate will be able to

1. state that a local electricity sub-station transformer provides a 3-phase 4 wire supply of mains electricity

2. state that a single phase is used for domestic supply and three phases for most industrial premises

3. distinguish between line to line and phase voltages

4. describe graphically the three-phase mains supply

5. explain how to wire mains plugs for three-phase equipment

6. explain the difference between star and delta connections to a three-phase supply

7. explain why three-phase low voltage power supplies are used for outputs greater than 2kW or for a low output ripple

8. show how polyphase rectifier circuits are connected to a three-phase mains transformer to produce
   a half-wave rectification
   b full-wave rectification (bridge rectifier

9. state the relationship between the ac input and dc output for 8 parts a and b above

10. sketch the output ripple for 8 parts a and b above, to include ripple frequency

11. state the advantages of using a three-phase supply compared to a single-phase supply, with reference to power supplies and motors

12. explain the operation of the following heavy current components and give an example of their application
    - a capsule thyristor
    - b thyristor/diode module
    - c triac
    - d capsule rectifier diode
    - e stud mounting rectifier diode
    - f fast diode module
    - g insulated gate power FET
    - h Insulated Gate Bipolar Transistors (IGBTs)
    - i Integrated Gate-Commutated Thyristors (IGCTs)

13. list applications for the following low voltage modular heavy current power supplies
    - a single-phase switched mode
    - b three-phase switched mode

14. explain the emergence of flexible ac transmission systems (FACTS) and identify the need for Uninterruptible Power Supplies (UPS)

15. describe, with the aid of a block diagram, the operation of
    - a an on-line UPS
    - b an off-line UPS

Outcome 2 Demonstrate an understanding of process control and transducers

Practical Activity

The candidate will be able to
1. identify faults in process control systems

Underpinning knowledge

The candidate will be able to

1. list applications for the following types of control
   a ON/OFF control
   b proportional derivative (PD) control
   c proportional integral derivative (PID) control

2. with reference to control systems, explain the terms
   a critical damping
   b stability
   c proportional band
   d dead band
   e transport lag

3. describe, with the aid of a block diagram, a micro-controller based linear control system

4. distinguish between transducers and sensors in parts 5 to 7, below, and those which have analogue outputs, digital outputs or digitally encoded outputs

5. describe, with the aid of a block diagram, the working principles of temperature control systems

6. list the various transducers used in temperature sensing

5. describe, with the aid of a block diagram, the techniques for measurement of speed using
   a motion sensors
   b rotary encoders

6. describe, with the aid of a block diagram, the techniques for measurement of position using
   a optical transducers
   b displacement sensors (Linear Variable Differential Transformer – LVDT)
   c image sensors
   d proximity detectors

7. explain, with the aid of a block diagram, the working principles of fluid control and gas flow control

8. list transducers for both applications in 7.

9. explain how signal conditioners operate

10. describe the effects of both positive and negative feedback

11. state the various types of applied feedback as
    - a voltage derived series applied
    - b voltage derived shunt applied
    - c current derived series applied
    - d current derived shunt applied

Outcome 3 Demonstrate an understanding of drive systems

Practical Activity

The candidate will be able to
1. use instruments to measure torque/speed characteristics of drive systems

Underpinning knowledge

The candidate will be able to

1. state the applications, using diagrams, of dc motors using the following methods of excitation
   a series
   b shunt
   c split field
   d permanent magnet

2. state applications for the following types of ac motor
   a capacitor start induction run single-phase motor
   b three phase induction motor with direct on line starting
   c synchronous three-phase motor

3. describe the operation of ac and dc motor speed controller units

4. select ac or dc motors which can be considered for applications where the following is required
   a constant torque
   b high speed
   c low speed
   d minimum maintenance

5. outline the characteristics of the
   a permanent magnet stepper motor
   b variable reluctance stepper motor
   c hybrid stepper motor

6. identify**,** with the aid of a block diagram, the main components of stepper motor drive systems

7. state the applications for a stepper motor.

Outcome 4 Demonstrate an understanding of industrial automation

Practical Activity

The candidate will be able to:

1. program a Programmable Logic Controller (PLC) to perform a simple operation in response to an input from a sensor

Underpinning knowledge

The candidate will be able to

1. describe, with the aid of a block diagram, the function of PLCs in automated production

2. describe the operation of a PLC as a system

3. identify the inputs as
   a instruction inputs from selector switches and keypads
   b sensor inputs from limit switches, proximity switches and photosensors

4. explain that the output is the control of loads in response to these inputs
   a drive light loads such as solenoid valves, motors, electromagnetic clutches
   b indicators such as pilot lamps and digital displays
   c large loads such as three-phase electric motors and large solenoid valves

5. explain the process as stored software instructions in the programmable controller which control the relationship between output signals and the input signals

6. identify standard ladder diagram symbols

7. write a program for a PLC using a ladder diagram which includes
   a logic functions
   b latching
   c timers, markers and counters
   d shift registers

8. describe the operation of Actuator-Sensor-Interface (ASI) techniques for a given application

9. compare ASI and Profibus systems

Outcome 5 Apply basic customer care

Practical activity

The candidate will be able to
1. process documentation used in conjunction with servicing electrical and electronic equipment

Underpinning knowledge

The candidate will be able to

1 state the importance of using the customer's name, correctly spelt and with the correct form of address (Mr, Mrs, Miss, Ms)

2. state the procedures to be followed when responding to a service request
   a obtaining symptoms from the customer
   b making a record
   c importance of informative quotations provided promptly
   d obtaining agreement to proceed with a repair or installation
   e presenting acceptance documentation

3. state procedures to be followed when carrying out a service
   a respect for customers' possessions and property
   b keeping customer informed of progress
   c damage caused by misuse and attempts at repair by others
   d reporting unsafe situations

4. identify procedures to be followed when completing a service
   a issuing informative invoices with terms of business
   b methods for recording and responding to promises or proposals made to the customer
      i obligations under the terms of warranties
   ii warranty on repair
   iii guarantees
   iv service agreements

3. explain how to deal with differences of opinion or a difficult relationship with a customer
   a expression of concern as a first response to complaints
   b the negative outcome(s)of customer dissatisfaction
   c extent of own authority in dealing with complaints
   d when to seek assistance from others

4. describe telephone technique
   a avoiding over familiarity
   b speaking to the right person
   c leaving messages
   d follow-up

5. explain how to match communication to the customer's ability to understand
   - a technical aspects of servicing and installation
   - b selective use of technical jargon
   - c customers with Particular Requirements
   - d calling for assistance where communication difficulties arise

6. explain the value of questionnaires for seeking feedback and revealing unsatisfied needs

Unit 057 Analogue and digital electronics

Rationale
This unit concerns the characteristics and operating principles of dc power supply units, amplifiers and oscillators. It also deals with faultfinding techniques on these circuits to component level. The characteristics of logic families and sequential logic circuits are addressed, together with their uses. Faultfinding on prepared circuit boards is also covered.

Outcomes
There are five outcomes to this unit. The candidate will be able to
1 understand analogue circuits to component level
2 understand logic families
3 understand time division multiplex (TDM)
4 understand sequential logic
5 find common faults using fault-finding procedures and test equipment.

Connection with other awards
This unit relates to OSC *Eng* ECS 1.12, 1.15, 1.17, 2.17, 2.18 and 3.02.

Assessment
The outcomes from this unit will be assessed using evidence from an assignment which will cover both practical activities and underpinning knowledge.

Note: For this unit, in all practical and theoretical exercises, standard values should be used.

Outcome 1 Understand analogue circuits to component level

Practical Activities

The candidate will be able to
1 use electronic instruments to test electronic circuit functions
2 fault find, to component level

Underpinning Knowledge

The candidate will be able to

1 select appropriate dc power supplies for a given application

2. explain the operation of series and shunt regulator circuits

3. explain the use of feedback and reference levels to provide stabilization during circuit load changes

4. explain the operation of a voltage doubler circuit

5. outline the principles of switch mode power supplies (SMPS)

6. state the advantages and disadvantages of SMPS over conventional voltage and current regulators

7. describe the operation from a block diagram for
   a power switching
   b chopper control
   c start-up
   d feedback
   e over-voltage and over-current protection
   f dc outputs

8. state expected waveforms and voltages at relevant points on a circuit diagram

9. state, with reasons, the expected changes in waveforms and voltages for given fault conditions

10. describe typical symptoms for given fault conditions

11. describe methods of applying a dummy load to SMPS output

12. describe typical adjustment procedures

13. explain the principles of
   a inverter power supplies
   b voltage polarity inverters
   c dc-dc converters

14. describe the principles of voltage control by controlled rectification

15. describe ac pulsed gating signals applied to a silicon controlled rectifier (SCR)
16. describe applications of controlled rectification feeding a resistive load

17. explain the importance of safety-critical components

18. explain the need for radio frequency suppression in power supplies

19. explain the need for transient suppression in power supplies.

20. describe the operation of single and multi-stage transistor voltage amplifiers

21. describe how to use frequency response plots to determine bandwidth for voltage amplifiers

22. state typical values of components

23. explain the effect of varying the collector load resistor on a transistor voltage amplifier

24. describe from the output characteristics how distortion is produced

25. identify characteristics of amplifier Class A, AB, B, C operation

26. explain the effects of
    a dc negative feedback
    b ac negative feedback

27. explain the need for power amplifiers

28. describe the operation of bi-polar junction transistor (BJT) and MOSFET amplifiers

29. describe the operation of transformer-less push-pull amplifiers

30. explain why ac and/or dc feedback may be employed in power amplifiers

31. state the input and output requirements of an IC power amplifier

32. describe the function of operational amplifiers

33. state the requirements of an ideal operational amplifier

34. explain the existence of a ‘virtual earth’ at the input when feedback is applied

35. explain the terms ‘drift’ and ‘offset’

36. identify the following operational amplifier circuits and state a simple application of
    a an inverting amplifier
    b a non-inverting amplifier
    c integrator
    d differentiator
    e differential amplifier
    f comparator
    g Schmitt trigger
    h high pass and low pass active filters
    i calculate the gain and time constant

37. state the effects of positive feedback on amplifier gain and stability

38. state the conditions for oscillation

39. describe the operation of the following oscillators using
    a crystal
    b ceramic resonator
    c oscillator with divider chain
    d Wien bridge network
    e LC

    draw typical time related waveforms for the above circuits

40. identify the components responsible for timing control in a 555 timer operating as
    a astable
    b monostable
    c show how the basic astable circuit can be modified to produce a saw tooth waveform

41. describe the operation of a voltage-controlled oscillator (VCO) and its application in a phase locked loop (PLL) using a block diagram.

Outcome 2 Understand logic families

Practical Activities

The candidate will be able to

1 use a slowly changing voltage applied to a device in a number of different families to determine the threshold levels

2 investigate the result of leaving inputs floating by deducing the value from the gate output voltage

3. connect a gate to a variety of loads and drive a gate from a variety of input sources.

Underpinning Knowledge

The candidate will be able to

1 identify the main characteristics of digital logic devices that aid selection
   - a device numbering
   - b packaging SIL, DIL, surface mount
   - c pin numbering
   - d open collector

2 state the meaning and significance of the following terms
   - a supply voltages
   - b supply current
   - c high level input voltage
   - d low level input voltage
   - e noise margin
   - f input current (logic high and low
   - g output current
   - h rise and fall time
   - i propagation delay
   - j power dissipation
   - k absolute maximum ratings
   - l fan-out/fan in

3. identify the main characteristics of the logic families, to include benefits and limitations of the
   - a 4000 series
   - b 74LS series
   - c 74HC series
   - d 74HCT series
   - e 74AHC series

Outcome 3 Understand time division multiplex (TDM)

Practical Activities

The candidate will be able to
1 connect two digital circuits via a fibre optic link
2 use time division multiplexing to transmit a number of separate transmissions through a single transmission path
3 use logic tutors to investigate the operation and confirm data sheet information for each circuit

Underpinning knowledge

The candidate will be able to
1 identify the requirements of a communication link using time division multiplexing (TDM)
    a sampling and choice of sampling rate
    b multiplexing and de-multiplexing
    c transmission of data by copper cable and fibre-optic cable

2. state the purpose of encoding data transmissions and recognise the forms
    a RZ
    b Manchester
    c Gray code
    d Binary Coded Decimal

3. identify employment of parity bits in a transmission system including
a advantages and disadvantages
b odd and even parity using either data value of 0 or 1

4. explain the requirement for error detection and correction in digital transmission systems

Outcome 4 Understand sequential logic

Practical Activities

The candidate will be able to
1 assemble and test circuits using JK and D-type bistable integrated circuits
2 assemble and test shift registers using integrated circuits such as the 74XX194
3 assemble and test synchronous and asynchronous modulo-n counters using integrated circuits 74XX74, 74XX112, 74XX193 and 74XX390
4 use a counter to determine the degree of switch bounce occurring in a variety of toggle switches.

Underpinning knowledge

The candidate will be able to

1. define the circuit and waveforms associated with
   a JK bistable
   b D-type bistable
   c Master-slave JK bistable

2. explain ways of connecting bistables to provide modulo-n dividers and up/down counters

3. describe synchronous and asynchronous integrated counters
   a decade counters
   b modulo-n counters and dividers

4. sketch the associated timing diagrams and waveforms

5. explain the circuit of a:
   a ring counter
   b twisted ring
   c shift register, using a universal shift register

6. determine the associated timing diagrams and waveforms

7. explain the effects of contact bounce for mechanically operated switches and relays

Outcome 5 Find common faults using fault-finding procedures and test equipment

Practical Activities

The candidate will be able to

1 use suitable test equipment to locate faults in digital interfacing circuits involving remote controls, A-D and D-A conversion and seven segment displays
2 use suitable test equipment to locate faults in synchronous and asynchronous counters, shift registers and bistable circuits
3 use suitable test equipment to locate faults in systems involving combinational logic circuits.

Underpinning Knowledge

The candidate will be able to

1. explain the common causes of operational failure in integrated circuits due to
   a incorrect insertion into sockets
   b shorting of pins during measurements
   c poor soldering techniques
   d insertion and removal with power supplies connected
   e incorrect voltages
   f input pins left disconnected
   g electrostatic discharge

2. identify methods used to prevent damage due to electrostatic discharge
   a correct storage of ICs
   b correct choice of floor coverings, clothing and work surface
   c correct use of wrist straps, heel straps and conductive matting

3. state the use and limitations of the following items of test equipment
   a multi-meter
   b logic probe and logic clip
   c logic pulser
   d logic analyser
   e current tracer
   f signature analyzer

4. describe faultfinding techniques for
   a recording results of applied tests
   b simple checks – plugs, connectors and power supplies
   c one change at a time
   d half-split method
   e input to output and output to input methods

Unit 058 Engineering woodworking

Rationale
This unit is concerned with the underlying principles that enables the effective use of wood for the production of engineering components. It covers the selection of hand/manual, machine and automated processes to produce the finished component. Included is the identification of materials, consumables and ancillary equipment necessary to carry out, control and maintain quality assurance of woodworking and finishing operations. Safe working practices will be reinforced at all times.

Outcomes
There are four outcomes to this unit. The candidate will be able to
1 identify and select a woodworking process
2 identify and use correct procedures for marking out
3 commission and quality control the woodworking operation
4 reinstate the work area and store resources correctly after use.

Connection with other awards
This unit relates to units 004-008 of the City & Guilds NVQ in Engineering woodworking and pattern making (1685)
It relates to the OSC*Eng* ECS 1.12, 1.13, 2.04 and 3.03.

Assessment
The outcomes from this unit will be assessed using evidence from a centre devised assignment which will cover both practical activities and underpinning knowledge.

Outcome 1 Identify and select a woodworking process

Practical Activities

The candidate will be able to
1 investigate and evaluate materials
2 investigate woodworking processes
3 select a woodworking process appropriate to specified requirements
4 select ancillary equipment, materials and consumables appropriate to the application.

Underpinning knowledge

The candidate will be able to
1. outline the engineering use of
    a soft woods
    b hard woods
    c plywood
    d blockboard
    e hardboard
    f MDF

2. identify the reasons for using wood materials
    a wear resistance
        i abrasion of surfaces
        ii hardness
        iii softness
        iv measurement of wear
    b texture
        i smooth
        ii roughened
        iii measurement of surface finish
    c aesthetics
        i colour
        ii grain
    iii appearance – dull/bright
    d conducting properties
        i electrical
        ii thermal
        iii measurement of electrical and thermal conductivity

3. identify a range of hand and fixed/portable machines used for woodworking
    - a saw
        - i circular
        - ii band
        - iii jig
        - iv rip
        - v fret/bow
    - b sander
        - i face
        - ii belt
        - iii bobbin
    - c router
    - d planer/thicknesser
    - e morticer/tenoner
    - f combing
    - g wood miller
    - h spindle moulder
        - i single
        - ii double
    - i drill
        - i bench
        - ii pedestal

4. explain the criteria used to select a woodworking process
    - a operating conditions
        - i type and quality of surface finish required
        - ii condition of surface
        - iii location
    - b type of material
    - c service requirements
        - i moisture resistant
        - ii aesthetics
        - iii temperature resistant/flame retardant
        - iv wear resistant
    - d cost
        - i financial implications of selecting specific woodworking techniques and materials
        - ii right first time
        - iii materials, resources and planning
        - iv batch and continuous process
    - e relevant British/European Standards and terminology relating to material type
            - i component shape and size
            - ii working environment
    - f process characteristics and limitations
    - g equipment
        - i tools
        - ii material type
        - iii section and thickness
        - iv position
        - v location
        - vi application

h materials handling requirements
  - i set up
  - ii movement
  - iii isolation
  - iv storage

i regulations applicable to the use of woodworking equipment and materials
  - i HSaW
  - ii COSHH
  - iii Regulations for the Disposal of Dangerous Substances
  - iv PUWER
  - v RIDDOR
  - vi Management of Health and Safety Regulations
  - vii Noise at Work Regulations

Outcome 2 Identify and use correct procedures for marking out

Practical Activities

The candidate will be able to
1 interpret information for marking out
2 select appropriate marking-out equipment
3 apply correct preparation procedures and application sequence
4 monitor and control a safe marking out operation
5 adjust and recalibrate machinery and equipment as required

Underpinning knowledge

The candidate will be able to
1. state the range of information available for marking out
   a standards
   b specifications
   c drawings
   d sketches
   e verbal instructions

2. describe marking-out methods and techniques
   a direct marking
   b templates
   c tracing/transfer

3. state the range of equipment available for marking out
   a rules/tapes
   b pencils
   c straight edge
   d protractors
   e gauges
      i bevel
      ii marking
   f punches
   g squares
      i box
      ii centre
      iii mitre
   h scribers/knives
   i vee blocks
   j angle plates
   k dividers
   l trammels

4. describe the features used in marking out
    a lines
        i datum
        ii machining
    b profiles
        i square/rectangular
        ii angle
        iii contoured
    c positions
        i linear hole
        ii radial hole
        iii assembly
    d circles
    e joints

5. outline the potential defects that could jeopardise the marking out operation(s)
    a material defect
    b faulty equipment
    c incorrect consumables
    d incorrect use of tools and equipment
    e environmental conditions

6. describe how to minimise potential movements of workpiece during marking out
    a jigs and positioners
    b vices

Outcome 3 Commission and quality control the woodworking operation

Practical Activities

The candidate will be able to

1. identify and select a woodworking process and finishing operation appropriate to the specified requirements
2. select, set up and commission machines and equipment
3. check and adjust equipment for effective and efficient operation
4. select ancillary equipment, materials and consumables appropriate to the application
5. set up workpiece for woodworking operation
6. remedy problems as necessary to maintain efficient operation

Underpinning knowledge

The candidate will be able to

1. outline how to identify components and special instructions using
    - a engineering drawings
    - b technical drawings
        - i sections
        - ii exploded views
        - iii special treatments
        - iv diagrams
    - c manufacturer's parts and treatment data
    - d data sheets and charts
    - e graphs
    - f function and operational requirements
    - g surface texture requirements

2. explain the operating features of woodworking machinery and equipment
    - a saws
    - b drills
    - c planers
    - d shapers
    - e hand tools

3. explain the methods for producing features in components
    a diameters
        i parallel
        ii tapered
        iii profiled
        iv stepped
    b faces
        i flat
        ii tapered
    c holes
        i drilled
        ii bored
    d convex/concave profiles
    e radii and chamfers
    f external grooves/recesses

4. state the range of finishes applied to wood component surfaces
    a french polish
    b paint
        i water-based
        ii oil-based
        iii synthetic
    c lacquer
    d wax
    e varnish
    f stain
    g sealer

5. describe the range of ancillary equipment
    a guards
    b hand tools
        i brushes
        ii rollers
        iii spray guns
    c personal protective clothing and equipment
    d splash screens
    e masks
    f respiratory protective equipment
    g compressed air and equipment
        i harnesses
        ii pressure guns
    h non-pressure treatment
        i brushing
        ii spraying
        iii dipping
        iv steeping
    i pressure treatment
        i empty-cell process
        ii full-cell process

6. explain the procedures for testing and proving the condition of consumables
   a material composition
   b viscosity
   c temperature
   d fluidity
   e density
   f resistivity
   g pH values

7 explain the care and correct handling of finishing process consumables
   a paints
   b powders
   c chemicals

8. describe the use of jigs, fixtures, positioners and manipulators for
   a rigidity
   b movement control
   c improved productivity

9. describe the potential defects that could jeopardise the finishing operation
   a material defects
   b faulty equipment
   c incorrect consumables
   d incorrect set up of equipment and machinery
   e incorrect operating parameters
   f environmental conditions

10. describe the regulations applicable to the use of surface finishing machinery and equipment
   a HSaW
   b COSHH
   c Regulations for the Disposal of Dangerous Substances
   d PUWER

Outcome 4 Reinstate the work area and store resources correctly after use

Practical Activities

The candidate will be able to
1. plan the reinstatement procedure
2. restore the work area to specified requirements
3. inspect and monitor the storage of equipment, tools and materials
4. collect and dispose of all waste substances to comply with Health and Safety requirements

Underpinning knowledge

The candidate will be able to
1. describe the requirements for restoring a work area to a safe and clean condition
   a machine and equipment isolation
   b tool inspection and storage
   c waste disposal
   d cleaning agents

2. describe the correct procedure for achieving a safe, clean and tidy area
   a labelling waste
   b returning equipment, tools and consumables
   c cleaning techniques
   d remedial action required to deal with accidents and spillages
   e notify authorised person if requirements cannot be met

3. explain the implications of not following legal requirements
   a HSaW
   b COSHH
   c Environmental legislation

4. identify appropriate assistance with the activities
   a type of assistance others are likely to request and the importance of help
   b the roles and responsibilities of key personnel in an organisation who can provide assistance with difficult situations
   c communication systems in an organisation
   d importance of feedback to authority
   e procedures for completing organisational and engineering activities in an organisation

Further information

Further information regarding centre/scheme approval or any aspect of assessment of our qualifications should be referred to the relevant City & Guilds regional/national office:

Region	Telephone	Facsimile
City & Guilds Scotland	0131 226 1556	0131 226 1558
City & Guilds North East	0191 402 5100	0191 402 5101
City & Guilds North West	01925 897900	01925 897925
City & Guilds Yorkshire	0113 380 8500	0113 380 8525
City & Guilds Wales	02920 748600	02920 748625
City & Guilds West Midlands	0121 359 6667	0121 359 7734
City & Guilds East Midlands	01773 842900	01773 833030
City & Guilds South West	01823 722200	01823 444231
City & Guilds London and South East	020 7294 2820	020 7294 2419
City & Guilds Southern	020 7294 2724	020 7294 2412
City & Guilds East	01480 308300	01480 308325
City & Guilds Northern Ireland/ Ireland	028 9032 5689	028 9031 2917

City & Guilds Customer Relations Unit	020 7294 2800	020 7294 2400

Website www.city-and-guilds.co.uk

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