NIULPE, INC.
(NATIONAL INSTITUTE FOR UNIFORM LICENSING OF POWER ENGINEERS, INC.)

REFERENCE SYLLABUS

For

THIRD CLASS POWER ENGINEER
Introduction

This syllabus has been approved by the NATIONAL INSTITUTE FOR UNIFORM LICENSING OF POWER ENGINEERS, INC. (NIULPE)

This Syllabus is intended to assist candidates studying for the Third Class Power Engineer Examination.

Recommended Study Program:

It is recommended that, before undertaking this examination, the candidate completes the Third Class Power Engineering Course offered through a recognized technical institute or training provider.

In addition to the foregoing course, it is recommended that the candidate becomes familiar with the publications listed in the Reference Material for Power Engineering Students and Examination Candidates, which is obtainable from the various technical institutes or from the NIULPE Website.
REFERENCE SYLLABUS FOR THIRD CLASS EXAMINATION CANDIDATES

1, Thermodynamics:

Explain theories, define terminologies and perform problem-solving calculations involving the following topics:

i) Temperature measurement units/scales.
ii) Expansion of solids (linear, area and volume) and liquids.
iii) Quantities of heat; specific heat.
iv) Changes of State: sensible and latent heat; heat content in mixtures of water, ice and steam; saturated and superheated steam.
v) Steam tables; temperature-enthalphy charts; critical temperature and pressure; dryness fraction; equivalent evaporation, factor of evaporation.
vi) Methods of heat transfer; conduction, convection, radiation.
vii) Work and heat; mechanical equivalent of heat; laws of thermodynamics.
viii) Expansion and Compression of Gases: Boyle's and Charle's laws of perfect gases, general gas law, characteristic gas constant; isothermal, adiabatic and polytropic processes; pressure-volume diagrams; work done in cylinders; indicated horsepower; thermal efficiency.

2, Applied Mechanics:

Explain theories, define terminologies, and perform problem-solving calculations involving the following topics:

i) Applications of forces; vector diagrams.
ii) Friction on level and inclined surfaces.
iii) Linear and angular velocity and acceleration.
iv) Work, power and energy.

3, Applied Science:

a) Basic Chemistry:

i) Typical industrial applications of chemistry: water treatment, combustion; corrosion.

b) Metallurgy and Engineering Materials:

i) Corrosion principles; types of corrosion, corrosion monitoring and prevention methods and devices, corrosion inspection.

4, Industrial Legislation and Codes:

a) General knowledge of the purpose, content and application of the boiler and pressure vessel codes and regulation, including the Power Engineers' Regulations in the student's jurisdiction.
5, **Fuels and Combustion:**

a) Requirements for efficient combustion of boiler fuels; complete and incomplete combustion.

b) Classification, properties and combustion characteristics of coal, fuel oil and natural gas; other (non-fossil) fuels.

c) Fuel analysis; proximate, ultimate, fuel heat value; calorimetry.

d) Combustion chemistry; combustion equations for coal, oil, and gas; molar masses for combustion products.

e) Combustion calculations; oxygen, air and excess air required, given fuel analysis.

f) Flue gas analysis methods and devices; CO; CO₂ and O₂

g) Control of emission standards: NOₓ, SO₂, particulates.

6, **Piping:**

a) Codes and standards for pressure piping: ASME, ANSI, ASTM; identification and sizes of piping.

b) Ferrous piping materials and methods of manufacture; specifications and service ratings; non-ferrous materials.

c) Strength of piping; effects of temperature on piping.

d) Piping connection methods: threaded, flanged, welded; design, materials, selection and installation of gaskets.

e) Designs and applications of expansion devices, supports and anchors.

f) Types of steam traps; trap sizing and selection; trap installation configurations; trap inspection installation configurations; trap inspection and maintenance; trap flow calculation.

g) Water hammer: effects; causes; design and operational preventions.

h) Insulation: purposes; benefits; characteristics; common materials and their uses; methods of application; cladding; care of insulated piping systems; calculations using coefficient of thermal conductivity.

i) Common and specialty valves: purpose, design, operation and applications; valve flow configurations; valve trim; actuator types.

7, **Electrotechnology:**

a) Alternating Current Theory:

i) Generating an alternating EMF; sinusoidal wave forms; phase relationships.

ii) Resistance in AC circuits; inductive and capacitive reactance; impedance; power and power factor; single and multi-phase circuits.

b) AC Systems, Switchgear, Safety:

i) Components, layout, and peration of a typical industrial AC power system

ii) Components of an AC generator panel
iii) circuit protective and switching equipment, fuses, safety switches; circuit breakers; circuit protection relays; automatic bus switchover (emergency supply to normal supply); grounding; lightning arresters.

iv) Electrical safety for operators

8, Electrical Calculations:

Explain theories and perform calculations for:

i) current, voltage, resistance in series and parallel circuits; using Ohm’s Law and Kirchhoff’s Laws; Wheatstone Bridge.

ii) temperature coefficient of resistance.

iii) work, energy, power: relationship between electrical, mechanical and heat units.

iv) relationship between poles, frequency, speed for AC machines

9, Control Instrumentation:

a) Control loops and strategies:

i) applications of pneumatic, electric and electronic (digital) control systems; components and operation of typical control loops; .

b) Instrument and Control Devices: design and principles of common temperature, pressure, flow, and level instruments

10, Boilers

a) Boiler Classification:

i) Definitions and designs of typical Watertube Boilers: multi-drum bent tube; D, A, O configurations; packaged, once-through, forced circulation, critical vs. super-critical boilers

ii) Special Boiler Designs: describe the design, components and operation of the following designs:

   (1) fluidized bed boilers, heat recovery steam generators (HRSG), black liquor boilers, waste heat boilers, refuse boilers, Bio-mass, high-pressure/high-temperature hot water boilers

b) Boiler Construction:

i) Designs, fabrication, construction methods, and Code requirements for: shells, drums, tubes (include attachment methods), nozzles; headers; handholes/manholes

ii) field assembly of a large watertube boiler

iii) boiler metals – applications and purpose

c) Boiler Heat Transfer Components:

i) Watertube boiler settings (brickwork and refractory), baffles; integral furnace designs and waterwalls: studded tubes; water-cooled walls: fin-tube, tangent-tube, flat-stud tube

ii) Superheaters: primary, secondary, convection, radiant, integral and separately-fired; operating characteristics;

iii) Reheater designs
iv) Economizers: integral and separate; tube styles, advantages/ disadvantages
v) Air Heaters: plate, tubular, rotary regenerative designs; heater corrosion control; advantages/disadvantages
vi) Sootblowers: stationary and retractable, locations, shot cleaning
d) High Pressure Boiler Fittings
   Design, installation/location, operation, testing and Code requirements for each of the following boiler fittings:
i) water columns and gauge glasses; types of remote level indicators; illumination; safety shut-off
ii) safety valves; setting
iii) low-water fuel cut-offs; float and probe designs
iv) steam outlet fittings and non-return designs
v) pressure gauges; feedwater connections; vents; and blowdown valve designs; blowdown procedures; blowdown tank
vi) Drum Internals: baffles, scrubbers, separators, driers, piping circulation and separation of steam and water
e) Fuel, Draft, and Flue Gas Systems
   i) Coal firing equipment: mechanical, underfeed, crossfeed and overfeed stokers; pulverizers -impact, ball, ball-race and bowl mills; burner and furnace designs – turbulent vertical, tangential, cyclone; coal feed systems; ash handling systems - hydro and air, bottom ash
   ii) Oil burning equipment: oil burner designs - steam, oil and mechanical atomizing; components of large oil burner systems; start-up/shut-down of large oil burners; cleaning and maintenance
   iii) Gas burning equipment: burner designs – spud, multi-spud and ring; burner gas supply system; start-up sequence for gas burner; high-efficiency, low NOx burners;
   iv) Draft equipment: natural, forced, induced, balanced draft; draft fan designs, control methods; fan performance curves; draft measurement; windbox and air louvers; primary and secondary air
   v) Flue gas clean-up methods and equipment: precipitators, filters, ash handling systems; SO₂ recovery systems

11, Boiler Operation and Maintenance
   a) manual start-up and shut-down procedure for large, industrial boilers;
b) initial start-up (commissioning) of a new boiler
c) routine and emergency operations
d) causes and prevention of boiler furnace and pressure explosions
e) chemical and mechanical boiler cleaning methods; boiling out
f) methods of cleaning and preparing a boiler for inspection
g) inspection: fire and water sides; safety
h) hydrostatic test
12, Boiler Control Systems:
   a) Boiler Water Level Control: components, purpose and operation of single-element, two-
      element, and three-element control systems; explain swell and shrinkage
   b) Combustion control:
      i) design and operation of each of the following combustion control systems: direct
         pressure control of fuel and air, steam flow – air flow control, fuel flow – air flow
         control, air flow – fuel flow, multi-element control
      ii) safety devices and interlocks
      iii) flame failure detection: continuous, intermittent, interrupted pilots; photo-electric cells
      iv) automatic, programmed boiler start-up and shut-down sequence
   c) Steam temperature control: desuperheating control, attemperation, gas recirculation, gas
      bypass, tilting burners

13, Feedwater Treatment:
   a) Feedwater impurities and their effects on boiler operation
   b) External, feedwater treatment: Explain the purpose, physical and/or chemical operating
      principles, system/equipment design and operation for each of the following: settling,
      coagulation and filtering, hot and cold lime-soda softening, hot phosphate softening,
      sodium and hydrogen zeolite softening, demineralization, dealkalization, mechanical
      deaeration, evaporation (multi-effect evaporators), reverse osmosis
   c) Internal Boiler Water Treatment:
      i) causes, effects and controls for boiler internal water problems
      ii) pH control – magnetite layers, acidic and caustic corrosion
      iii) sludge conditioning and dispersion; modern sludge dispersants
      iv) chemical deaeration – oxygen corrosion; sulphite programs; hydrazine
      v) carryover – priming, misting, foaming
      vi) dissolved solids – blowdown control; conductance; simple and heat recovery
          blowdown systems; automatic blowdown systems
      vii) return line corrosion – neutralizing and filming amines
      viii) scale control – phosphate and chelate programs
   d) Chemical feed systems: shot and continuous feed systems; chemical feed pumps
   e) Feedwater and boiler water testing methods: automatic sampling systems and monitors;
      boiler and steam system parameters and test locations

14, Pumps
   a) Theory of pumping: define and explain pump head terms, perform pump head and
      pressure calculations, explain cavitation
   b) Reciprocating pumps: pump drivers; single and double-acting designs; plunger type;
      diaphragm type; pump protection
   c) Centrifugal pumps:
i) Classification and principles of operation for volute, diffuser and turbine pumps; axial and mixed flow

ii) Construction and components: single and multi-stage, impeller types; wear rings; shaft sealing arrangements - stuffing box, lantern ring, mechanical seals; balance disc, drum; opposed impellers

iii) Operation: starting and stopping, priming

iv) Typical pump installation; auto-recycle valve

d) Rotary pumps: design and operation of gear, lobe, screw

15, Pressure Vessels

a) explain design, construction, operation and repair regulation of pressure vessels, including stamping and nameplate details

b) head, nozzle, manway designs

c) typical components/fittings on a pressure vessel

d) safe operating and maintenance consideration, including hydro and pneumatic testing; inspection

16, Prime Movers

a) Steam Turbines:

i) impulse and reaction principles; nozzles; blade shapes;

ii) Turbine arrangements: staging and compounding: principles and p-v diagrams for pressure, velocity and pressure-velocity compounding

iii) Turbine components: purpose, design, operation of the following: casings, disc and drum rotors, dummy pistons, journal and thrust bearings, barring gear, blade and shaft sealing glands, couplings, interceptor valves on reheat turbines

iv) explain purpose and arrangements of condensing, bleeder, topping, extraction, cross and tandem compounded turbines

v) turbine governor types; speed-sensitive, pressure-sensitive, nozzle, throttle, bypass; mechanical, mechanical hydraulic, electronic-hydraulic; droop and isochronous operation

vi) Starting and shutting down condensing and extraction turbines

vii) Steam turbine condensers: types, air-cooled, water-cooled, Panier style; condenser auxiliaries; condenser operation; feedwater heater system

17, Gas Turbines:

i) Applications, advantages and disadvantages of gas turbines

ii) Basic cycle and improvements: open and closed cycles defined, regeneration, dual shaft arrangement, intercooling and reheating, typical gas turbine operating parameters and efficiency, combined steam and gas turbine cycles

iii) Main gas turbine components: radial and axial compressors, combustor arrangements and operation, turbine rotor designs
iv) Gas turbine support systems: fuel supply systems; lubrication; barring gear; steam injection; intake and exhaust components
v) Supervisory, protective, and control systems
vi) Starting and stopping procedures and sequences; turbine washing

18, Cogeneration:
Purpose, advantages, components of cogeneration systems; simple and combined cycle, using gas turbines and internal combustion engines; single and dual shaft arrangements; control strategies and components; environmental considerations; heat recovery boilers and water heaters; operating procedures; typical industrial cogeneration applications

19, Compressors:
- Theory of Compression:
  - Adiabatic and isothermal compression; pressure volume relationships; compression ratio, capacity, multi-staging; effect of altitude and moisture applications for compression, including air and gas.
- Positive Displacement Compressors: design, operating principles
  - Reciprocating compressors: clearance volume; indicator diagrams; calculations for displacement and volumetric efficiency.
  - Free piston compressor
  - Rotary Compressors: sliding vane, lobe, and screw types (industrial screw type in detail, including control panel)
- Dynamic Compressors:
  - Design and operation of centrifugal and axial flow compressors; application as blowers
  - Compressor surge: causes and prevention; P-V curve; surge line, anti-surge system and control Starting and stopping procedures for positive displacement and dynamic compressors
- Compressor Auxiliaries:
  - Intercoolers / aftercoolers; moisture separators
  - Compressor control systems and devices: start and stop, variable and constant speed; safety devices
  - Lubrication: internal and external
  - Compressor installation and piping layouts
- Compressed air system components:
  - Typical system layout; air receivers (wet and dry) fittings and operation; filters
  - Air dryers: system design, flows, operation; dewpoint monitoring

20, Refrigeration:
- Refrigerant classifications, properties, characteristics;
b) Compression systems:
   i) principle of compression refrigeration; typical system temperatures and pressures for simple refrigeration systems
   ii) multi-stage systems: 2-stage with duplex compressors; 2-stage with booster compressor; low-temperature multi-stage
   iii) direct vs. indirect systems
   iv) typical refrigeration applications

c) Absorption system: ammonia absorption system description and operating parameters

d) Refrigeration system auxiliaries:
   e) system controls: expansion valves, low-side float, high-side float, capillary tube
   f) compressor controls: temperature and pressure-actuated
   g) condenser cooling water control
   h) safety devices and controls: pressure relief devices, high-pressure cut-out, low pressure lube oil cut-out
   Regulations: overview of the code for the safe operation, installation and repair of refrigeration equipment
   i) System Operation: leak testing, charging, purging, troubleshooting (condenser, regulator, refrigerant strength, compressor discharge temperature); effects of moisture in system; effects of oil in the refrigerant; oil removal using oil separators, oil traps, oil still; operating and maintaining brine systems

21, Special Industrial Equipment:
   a) Describe the general applications, designs, components, operation for the following:
      i) Heat exchangers: double pipe designs; shell-and-tube configurations, head designs, reboiler and feedwater heater fittings; plate frame; overhead aerial coolers; aerial steam condensers, including operation and control
   b) Cooling towers: natural draft, atmospheric, hyperbolic; mechanical draft designs; operation and control
   c) Fired Heaters: multi-burner vertical designs; burner components and styles; fuel supply and control; interlocks and safety devices; indirect-fired heaters; horizontal designs; startup and shutdown procedures

22, Wastewater Treatment:
   a) Purpose of WWT; typical wastewater pollutants and systems
   b) Theory and equipment for specific treatment process: removal of suspended solids (screening, floatation, sedimentation); removal of colloidal solids (chemical coagulation, flocculation, clarification); biological treatment (activated sludge, rotating biological contactors, trickling filters)
   c) operating parameters, controls and tests: nutrients, BOD, COD, pH, settleability
   d) safety in wastewater treatment plants

23, Plant Maintenance and Administration
Explain the purpose, typical design and administration of the following plant functions:

a) scheduled and preventative maintenance programs
b) record keeping; logbooks; logsheets
c) operating standards and procedures