



# **REFERENCE SYLLABUS**

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**For**

**REVISED SECOND CLASS**

**POWER ENGINEER'S**

**CERTIFICATE of QUALIFICATION**

**EXAMINATION**



**BOILER & PRESSURE VESSEL SAFETY PROGRAM  
REFERENCE SYLLABUS  
for  
FIRST CLASS  
CERTIFICATE OF QUALIFICATION  
EXAMINATION**

REVISION   1    
DATE 2006/01/01  
PAGE   2   OF  25 



**Note: Please ensure that this is the appropriate reference syllabus for the examination applied for.**

**GENERAL INFORMATION**

**Implementation of the Revised 2<sup>nd</sup> Class Syllabus**

On January 01, 2005, a revised second class syllabus for Power Engineer examinations came into effective. This revised second class syllabus brought about major changes in the layout of the second class examinations.

This change is so substantial that examination papers already successfully completed at the second class certificate level under the (old) second class syllabi can not be integrated into the revised second class program.

However, to assist in this transition, the examinations for both the (old & revised) second class syllabi will be available and run concurrently for 5 (five) years. This will give examination candidates, who have already successfully completed at least one examination paper under the (old) second class syllabus, ample time to finish up their examinations and earn their certificate of qualification.

For your information there will be a transition period from January 01, 2005 to December 31, 2005. During this transition period, candidates will have the option of starting examinations under either the (old or revised) syllabus for second class. By January 1, 2006, all applicants who have not successfully completed at least one examination paper under the (old) second class syllabus will be required to start writing second class examinations under the new revised second class program.

If you have any comments, concerns, or questions concerning the revised second class syllabus, please feel free to telephone Fred Golar, Certification & Licensing Analyst, at 604-660-6245 or email [Fred.Golar@safetyauthority.ca](mailto:Fred.Golar@safetyauthority.ca) .



**BOILER & PRESSURE VESSEL SAFETY PROGRAM  
REFERENCE SYLLABUS  
for  
SECOND CLASS  
CERTIFICATE OF QUALIFICATION  
EXAMINATION**

REVISION   1    
DATE 2006/01/01  
PAGE   3   OF 25



### **Introduction**

This syllabus has been approved by the Standardization of Power Engineers Examinations Committee (SOPEEC) and the Association of Chief Inspectors (ACI). It is intended to assist candidates studying for the (NEW) Second Class Power Engineer's Certificate of Qualification Examinations.

Please also access our website at <http://www.safetyauthority.ca/> and the national examination website at [www.sopeec.org](http://www.sopeec.org).

The requirements to qualify for a Second Class Examination are outlined in the *Safety Standards Act* and the *Power Engineers, Boiler, Pressure Vessel and Refrigeration Safety Regulation*.

#### Application to Undertake Examination

In order to be registered for an examination and receive a confirmation examination date a candidate must submit an application and the prescribed fee and have the application approved prior to the registration cut off date. Please access our website to view the Power Engineer Examination Schedule.

#### Examination Instructions

The Second Class Certificate of Qualification certification consists of six (6) examination papers. Each paper consists of seven (7) questions, of which only the first five (5) attempted will be marked. (Note: Part B, Paper One (1) also consists of seven (7) questions, but included in these seven (7) questions, is a mandatory drawing question which must be attempted.

A candidate is allowed to bring into the examination room any of the ASME Codes except sections VI and VII. Normally only section I and VIII Division 1 are required for the 2<sup>nd</sup> class.



**BOILER & PRESSURE VESSEL SAFETY PROGRAM  
REFERENCE SYLLABUS  
for  
SECOND CLASS  
CERTIFICATE OF QUALIFICATION  
EXAMINATION**

REVISION   1    
DATE 2006/01/01  
PAGE  4  OF 25 



A dictionary, (scientific dictionaries are not permitted)

Non – programmable calculator. If your calculator is programmable, you must reset it in the company of the examiner so that the examiner is sure that all memories are clear. Or the examiner may request that you remove the battery to erase all memory. This may be done during your examination time, so be aware that you may have less time to complete your exam. Also, if your calculator fails to function after reset or battery removal, the examiner is not responsible, and you may be at a significant disadvantage.

Drawing instruments, Pens and pencils.

Note: The items referenced above must be shown to the examiner for approval.

The following exam material is provided by the BC Safety Authority:

- Safety Standards Act & Regulations
- CSA B-51 Boiler, Pressure Vessel & Pressure Piping Code
- CSA B-52 Mechanical Refrigeration Code
- Four Figure Tables & Constants
- Steam & Refrigeration Tables

The candidate must show picture I.D. at the examination.

Recommended Study Programme



**BOILER & PRESSURE VESSEL SAFETY PROGRAM  
REFERENCE SYLLABUS  
for  
SECOND CLASS  
CERTIFICATE OF QUALIFICATION  
EXAMINATION**

REVISION   1    
DATE 2006/01/01  
PAGE  5  OF 25 



It is strongly recommended that Candidates complete an approved formal course of study offered by a recognized technical Institute or training provider, before undertaking to write any of the "Standardized Power Engineers' Certificate of Qualification Examinations".

In addition to the foregoing and in order to prepare for the BCSA examinations, it is recommended that the candidate becomes familiar with the pertinent publications listed in the "Reference Material for Candidates of Power Engineer Examinations", which is obtainable from the various technical institutes, colleges, or from the SOPEEC website

Candidates would be well advised to have a good basic knowledge of Mathematics, Science, and English, before enrolling in an approved college, technical, vocational, or correspondence course.

## Reference Material for Candidates of Power Engineer Examinations

The publications listed here are intended to supplement the course material for students studying for Fourth, Third, Second or First Class Power Engineering Certificate of Qualification Examinations. Inquiries regarding the above mentioned course materials should be directed to Pan Global, Power engineering Training Systems, 1301 – 16<sup>th</sup> Ave., N.W. Calgary, Alberta T2M 0L4, toll free 1-866-256-8193, fax 403-284-8863 or email [customer\\_service@powerengineering.ca](mailto:customer_service@powerengineering.ca) .

The following listed publications can be ordered through most bookstores or directly from the publisher using the ISBN number. The Code books listed are quite expensive, and they may change annually. Therefore, it is suggested that candidates use the codes located at their company library or at public libraries to obtain the necessary information.



**BOILER & PRESSURE VESSEL SAFETY PROGRAM  
REFERENCE SYLLABUS  
for  
SECOND CLASS  
CERTIFICATE OF QUALIFICATION  
EXAMINATION**

REVISION   1    
DATE 2006/01/01  
PAGE   6   OF 25



Candidates should be aware that the following list of publications are "Reference Material Only" and although candidates do not have to purchase all these publications, they should have access to them. This list was compiled and approved by SOPEEC and the Interprovincial Power Engineering Curriculum Committee (IPECC). It is intended to assist candidates in achieving an excellent working knowledge of related topics, and to contribute to attaining passing grades on the standardized examinations.

Candidates who are entering into the Power Engineering field should realize that as they progress through their career it becomes necessary to build a good personal library. Candidates should start building their library at the Fourth Class level and regard their library as a necessary tool of their career. IPECC would also like to remind candidates that they may also supplement their course material by purchasing periodicals and special reports from engineering and power related magazines.

Candidates should refer to the appropriate SOPEEC reference syllabus for the level of examination that they are preparing to attempt, as well as receive assistance from their local technical institute before commencing their studies.

#### Code Books

The following Code books are used from the Fourth Class level to the First Class level. The candidates must be aware that although there will be questions on all levels of examinations from the following codes, the difficulty and depth of questions will increase significantly as the candidate advances in levels. We wish to repeat at this point, these Code books are quite expensive and some are revised on an annual basis. Therefore we recommend to students that they use Code books from their company library or from public libraries to assist with their studies.



**BOILER & PRESSURE VESSEL SAFETY PROGRAM  
REFERENCE SYLLABUS  
for  
SECOND CLASS  
CERTIFICATE OF QUALIFICATION  
EXAMINATION**

REVISION   1    
DATE 2006/01/01  
PAGE   7   OF 25   



	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	4 <sup>th</sup>
<b>Safety Standards Act and Applicable regulation</b>	X	X	X	X
<b>Canadian Regulation (C. S. A. B-51, For the Construction and Inspection of Boilers and Pressure Vessels (Latest edition)</b> ISSN # 0317-5669	X	X	X	X
<b>Canadian Regulations (C. S. A.) B-52, Mechanical Refrigeration Code, (latest Edition)</b> ISSN # 0317-5669	X	X	X	X
<b>A.S.M.E. Code. Section I Power Boilers (Latest edition)</b> LCCCN # 56-3934	X	X	X	
<b>A.S.M.E. Code Section IV Heating Boilers (Latest edition)</b> LCCCN # 56-3934	X	X	X	
<b>A.S.M.E. Code Section VI Recommended Rules for Care and Operation of Heating Boilers (Latest edition)</b> LCCCN # 56-3934	X	X	X	X
<b>A.S.M.E. Code Section VII Recommended Rules for Care and Operation of Power Boilers (Latest edition)</b> LCCCN # 56-3934	X	X	X	X
<b>A.S.M.E. Code Simplified (Power Boilers-Section 1- Latest edition)</b> LCCCN # 56-3934	X	X	X	X

One of the most comprehensive and complete sets of books for Power Engineer Candidates to study from, is the Reed's Marine Engineering Series. It is recommended that Candidates start to compile this series from the beginning of their Power Engineer career. However, by the time a Candidate begins to study for the Second Class examination; they should have or have access to all Of these books. This series does not cover all topics in the syllabus, however it is very useful.

	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	4 <sup>th</sup>



**BOILER & PRESSURE VESSEL SAFETY PROGRAM  
REFERENCE SYLLABUS  
for  
SECOND CLASS  
CERTIFICATE OF QUALIFICATION  
EXAMINATION**

REVISION   1    
DATE 2006/01/01  
PAGE   8   OF 25   



Vol. 1 Mathematics <b>ISBN # 0-947-637-90-7</b>	X	X	X	X
Vol. 2 Applied Mechanics <b>ISBN #0-901-281-55-7</b>	X	X		
Vol. 3 Applied Heat <b>ISBN #0-947-637-51-6</b>	X	X		
Vol. 6 Basic Electrotechnology <b>ISBN #0-900-335-96-3</b>	X	X	X	
Vol. 7 Advanced Electrotechnology <b>ISBN #0-901-281-65-4</b>	X	X		
Vol. 8 General Engineering Knowledge <b>ISBN #0-947-637-76-1</b>	X	X	X	
Vol. 9 Steam Engineering Knowledge <b>ISBN #0-900-335-58-0</b>	X	X	X	X
Vol. 10 Instrumentation and Control Systems <b>ISBN #0-947-637-86-9</b>	X	X		

**The following books will cover other topic areas in the syllabus from Fourth Class to First Class Power Engineering Exams.**

	<b>1<sup>st</sup></b>	<b>2<sup>nd</sup></b>	<b>3<sup>rd</sup></b>	<b>4<sup>th</sup></b>
Applied Engineering Mechanics First Canadian, Jensen, Chenoweth Snail & Stassen-(Latest edition) <b>ISBN#007-032-492-1</b>	X	X		
National Board Inspection Code <b>LCCCN #52-44738</b>	X	X		
Applied Thermodynamics for Engineering Technologists. T.D. Eastop (Latest edition) <b>ISBN #0-582-09193-4</b>	X	X	X	
Blueprint Reading and Technical Sketching for Industry Thomas P Olivo (Latest edition) <b>ISBN#0-8273-5077-5</b>	X	X	X	



**BOILER & PRESSURE VESSEL SAFETY PROGRAM  
REFERENCE SYLLABUS  
for  
SECOND CLASS  
CERTIFICATE OF QUALIFICATION  
EXAMINATION**

REVISION   1    
DATE 2006/01/01  
PAGE   9   OF 25   



Electric Circuits & Machines Lister, Golding (Latest edition) <b>ISBN#0-07-552603-4</b>	X	X	X	
Process/Industrial Instrumentation and Control Handbook-Considine (Latest edition) <b>ISBN#0-07-012445-0</b>	X	X	X	
Standard Handbook of Power Plant Engineering-Elliot, Chen, Swanehart (Latest edition) <b>ISBN#0-07-019435-1</b>	X	X	X	
Engineering Manual of Automatic Controls <b>Purchased through Honeywell Offices</b> I-P Edition	X	X	X	
Trane Air Conditioning Manual (780) 454-4905 The Trane Company	X	X	X	
Metals and How to Weld Them T.B. Jefferson, Gorham Woods (Latest edition) <b>LCCCN# 54-2508</b>	X	X	X	X
Betz Handbook of Industrial Water Conditioning (Latest edition) <b>LCCCN# 62-21097</b>	X	X	X	X
Steam Babcock and Wilcox (Latest edition) <b>LCCCN# 92-074123</b>	X	X	X	X

*Note: Texts other than those listed above, which are current and are of a similar technical content may be considered equivalent.*

Students preparing for Standardized Power Engineer Examinations will find the "Periodicals" and "Special Reports" from Engineering and Power related magazine(s) very beneficial not only for examination preparation, but also for current general engineering knowledge.

**Excerpts:**

**Power Engineers, Boiler, Pressure Vessel and Refrigeration Safety Regulation**



**BOILER & PRESSURE VESSEL SAFETY PROGRAM  
REFERENCE SYLLABUS  
for  
SECOND CLASS  
CERTIFICATE OF QUALIFICATION  
EXAMINATION**

REVISION   1    
DATE 2006/01/01  
PAGE  10  OF  25 



**Application for second class power engineer's certificate of qualification**

**15** (1) An applicant for a second class power engineer's certificate of qualification must

- (a) hold a first class marine engineer (motor) certificate of competency, or
- (b) hold a third class power engineer's certificate of qualification or a third class power engineer's standardized certificate of competency and have been employed, while in possession of a third class power engineer's certificate of qualification, for a period of not less than
  - (i) 30 months as a chief engineer of a power plant that has a boiler capacity that exceeds 150 m<sup>2</sup>,
  - (ii) 30 months as a chief engineer of a low pressure steam plant that has a boiler capacity that exceeds 500 m<sup>2</sup>,
  - (iii) 36 months as a shift engineer or as an assistant chief engineer of a power plant that has a boiler capacity that exceeds 250 m<sup>2</sup>,
  - (iv) 48 months as an assistant shift engineer or maintenance engineer of a power plant that has a boiler capacity that exceeds 1 000 m<sup>2</sup>,
  - (v) 60 months as an assistant engineer of a power plant that has a boiler capacity that exceeds 1 000 m<sup>2</sup> performing duties approved by a provincial safety manager as providing suitable experience, or



**BOILER & PRESSURE VESSEL SAFETY PROGRAM  
REFERENCE SYLLABUS  
for  
SECOND CLASS  
CERTIFICATE OF QUALIFICATION  
EXAMINATION**

REVISION   1    
DATE 2006/01/01  
PAGE 11 OF 25



(vi) one half of the period set out in subparagraph (i) or (ii) in the position and in the size and type of plant set out in that subparagraph, and have been employed for a period of not less than 48 months as a maintenance engineer.

(2) If an applicant has successfully completed a second class power engineering course that has been approved by a provincial safety manager, the required periods of employment referred to in subsection (1) (b) (i) to (v) are reduced by 9 months.

(3) If an applicant holds an engineering degree acceptable to a provincial safety manager, the required periods of employment for the positions and types of plants set out in subsection (1) (b) (i) to (v) are reduced by one half.

[am. B.C. Reg. 475/2004, Sch. 4, s. 2.]

**What a second class power engineer may do**

**16** A second class power engineer's certificate of qualification entitles the holder to be

- (a) chief engineer of a power plant that has a boiler capacity of 1 000 m<sup>2</sup> or less,
- (b) chief engineer of any low pressure steam plant, fluid plant, low pressure thermal fluid plant or low temperature low pressure fluid plant, or
- (c) shift engineer of any plant.



**BOILER & PRESSURE VESSEL SAFETY PROGRAM  
REFERENCE SYLLABUS  
for  
SECOND CLASS  
CERTIFICATE OF QUALIFICATION  
EXAMINATION**

REVISION   1    
DATE 2006/01/01  
PAGE  12  OF  25 



**Part "A" Examination**

**First Paper  
Morning Session  
3 ½ Hours**

1. A.S.M.E. Code, Sections 1 & 8, Calculations:  
**Design values to be computed for the following boiler and pressure vessel parts:**
  - a. **Cylindrical components; dished heads; unstayed flat heads, formed heads, shells and covers.**
  - b. **Openings and compensation: openings in shells, headers and heads; compensation required; strength of compensation, pressure vessel openings and reinforcements.**
  - c. **Stayed surfaces: dimensions and locations of staybolts, ligaments and braced surfaces.**
  - d. **Safety valves and safety relief valves: size and capacity.**
  - e. **Firetube Boilers:**
    - i. **Combustion chambers and furnaces: plain circular furnaces; circular flues; Adamson ring reinforced and corrugated furnaces.**
    - ii. **Stayed surfaces: maximum spacing of stays; areas of heads to be stayed; stresses in diagonal stays.**
  
2. Industrial Administration:
  - a. **Legislation: a thorough knowledge of the Safety Standards Act and the Regulations under the Act.**
  - b. **Installations: factors and codes governing plant designs and layouts; contract specifications; working knowledge of the engineering and administration involved in plant erection; practical modifications of existing plant.**
  - c. **Management:**
    - i. **Functions and objectives of management.**
    - ii. **Personnel management: selection of staff; personnel training; motivating personnel; disciplining employees.**
    - iii. **Planning; decision making; report writing.**
    - iv. **Plant maintenance; inspection; budgeting.**
    - v. **Safety programs.**
  
3. Applied Mechanics:



**BOILER & PRESSURE VESSEL SAFETY PROGRAM  
REFERENCE SYLLABUS  
for  
SECOND CLASS  
CERTIFICATE OF QUALIFICATION  
EXAMINATION**

REVISION   1    
DATE 2006/01/01  
PAGE  13  OF  25 



- a. **Velocity and acceleration: speed; linear velocity and acceleration; angular velocity and acceleration; relative and absolute velocity.**
- b. **Mass, motion and inertia: force of gravity; weight; mass inertia; accelerating force; momentum.**
- c. **Work, power and energy: work, graphical representation; indicated and brake horsepower; potential and kinetic energy; conservation of energy; flywheel.**
- d. **Torque and angular motion: moment of inertia; radius of gyration; work done by torque.**
- e. **Motion in a circular path: centripetal acceleration; centripetal and centrifugal force; balancing of rotating masses; governors.**
- f. **Friction: coefficient of friction; frictional force; motion on horizontal and inclined planes; the screw thread; transmission of power by belt drives.**
- g. **Moments: moments of forces; couple; centroids and second moments of area.**
- h. **Stress and strain: modulus of elasticity; restricted expansion.**
- i. **Shearing forces and bending moments: sign conventions; conditions of equilibrium; simply supported beams and cantilevers; concentrated and distributed loading; mathematical and graphical solutions for shearing force and bending moment diagrams.**
- j. **Torsion: fundamental torsion equation; relationship between torque, stress and horsepower; maximum and mean torque; coupling bolts.**
- k. **Pressure of liquids: density; specific gravity; pressure at any depth; centre of pressure; displacement.**
- l. **Flow of liquids: pressure head; Bernoulli's law; Venturi meter; flow through orifices.**



**BOILER & PRESSURE VESSEL SAFETY PROGRAM  
REFERENCE SYLLABUS  
for  
SECOND CLASS  
CERTIFICATE OF QUALIFICATION  
EXAMINATION**

REVISION   1    
DATE 2006/01/01  
PAGE  14  OF  25 



**Part "A" Examination**

**Second Paper  
Afternoon Session  
3 ½ Hours**

4. Thermodynamics:
  - a. Heat and measurement of heat: temperature scales; absolute temperature; units of heat and their relationship; specific heat; water equivalent; sensible and latent heat; heat mixtures.
  - b. Expansion of solids and heat transfer: linear, surface and volumetric expansion; conduction, convection and radiation.
  - c. Work and heat: mechanical equivalent of heat; laws of thermodynamics; Boyle's and Charles Laws; general gas law; characteristic constant of a gas; specific heats of gases; thermal efficiency.
  - d. Expansion and compression of gases: Dalton's Law of partial pressures, adiabatic, isothermal and polytropic; ratios of expansion and compression; work done during expansion and compression.
  - e. Thermodynamics of steam: steam tables; saturated and superheated steam; dryness fraction; specific volume; specific heat of superheated steam; heat mixtures; throttling and separating calorimeters; internal energy of steam, enthalpy.
  - f. Entropy: entropy of water, evaporation and superheated steam; temperature-entropy diagrams and charts; computations of entropy values.
  - g. Practical Cycles:
    - i. Practical cycles: Rankine; Otto; Diesel; Brayton, thermal efficiencies; pressure-volume and temperature-entropy diagrams.
    - ii. Energy flow calculations; efficiency limits of heat engines, boiler and plant efficiencies, heat balance testing.
  
5. Metallurgy:
  - a. Non-ferrous metals: properties, composition and uses; copper; brasses; bronzes; aluminum; white metal.
  - b. The structure of metals: atoms; elements; crystalline structure of metals; grains and grain boundaries, metallographic examination.
  - c. Alloying elements in iron; iron-carbon equilibrium diagram; alloy steels; stainless steels and highchromium alloys; cladding steels.



**BOILER & PRESSURE VESSEL SAFETY PROGRAM  
REFERENCE SYLLABUS  
for  
SECOND CLASS  
CERTIFICATE OF QUALIFICATION  
EXAMINATION**

REVISION   1    
DATE 2006/01/01  
PAGE  15  OF  25 



- d. **Heat treatment of metals: normalizing; annealing; spheroidizing; hardening; tempering; quenching.**
  - e. **Welding symbols**
  - f. **Metallurgical applications/specifications to power plant piping and tubing**
6. **Testing of Materials:**
- a. **Procedures and interpretations affecting tensile, hardness and impact tests; forms of specimens tested.**
  - b. **Mechanical, physical and thermal properties of ferrous metals: creep resistance, corrosion resistance and fatigue tests.**
  - c. **Weldment defects: dimensional defects; structural discontinuities; defective properties.**
  - d. **Nondestructive testing: visual inspection; magnetic particle inspection; liquid penetrant testing; proof tests; leak tests, ultrasonic, radiography, acoustic emission.**



**BOILER & PRESSURE VESSEL SAFETY PROGRAM  
REFERENCE SYLLABUS  
for  
SECOND CLASS  
CERTIFICATE OF QUALIFICATION  
EXAMINATION**

REVISION   1    
DATE 2006/01/01  
PAGE  16  OF  25 



**Part "A" Examination**

**Third Paper  
Morning Session  
3 ½ Hours**

7. Boilers:
- a. Steam generator design considerations.
  - b. Methods of heat transfer; circulation; steam generator ratings.
  - c. Specialized boiler designs and applications.
  - d. Types and applications of firetube and watertube boilers/steam generators.
  - e. Boiler fittings, including safety devices, drum internals, soot blowers.
  - f. Boiler details: waterwalls; superheaters; desuperheaters; attemperators; economizers; air heaters; blow-down systems; flash tanks; steam separators.
  - g. Methods of installation and support: foundations; settings; methods of tubing; top drum erection; shop and field assembly.
  - h. Insulation: duct and baffle arrangements; boiler casings.
  - i. Operation: start up and shut down; boiling out; drying out refractory; lay-up procedure; safety precautions.
  - j. Maintenance; mechanical and chemical cleaning; inspection; upkeep and repairs; hydrostatic test; safety precautions.
  - k. Boiler Inspections: detailed procedure for complete inspection of a large boiler, including water side, fire side, and auxiliary equipment; thermal radiation techniques; inspection records and reporting procedures; liaison procedure with boiler inspector; involvement of other personnel in inspection (engineering staff, operators); inspection equipment; inspection safety.
8. Pumps:
- a. Practical Applications of pumping theory for power plants;
  - b. Installation; maintenance; operation/control.
  - c. Constructional details including: impeller types; seal selection; shaft alignment; thrust balancers; tachometers.
  - d. Boiler feed pump re-circulation control.
9. Water Treatment:
- a. Water and its impurities.



**BOILER & PRESSURE VESSEL SAFETY PROGRAM  
REFERENCE SYLLABUS  
for  
SECOND CLASS  
CERTIFICATE OF QUALIFICATION  
EXAMINATION**

REVISION   1    
DATE 2006/01/01  
PAGE  17  OF 25 



- b. Methods of feedwater treatment: subsidence; coagulation; filtration; oil removal; lime-soda softening; hot process phosphate softening; sodium and hydrogen zeolite softening; silica removal; demineralization; deaeration; evaporation; electro-dialysis and electro-deionization (ED /EDI); reverse osmosis (RO); microfiltration**
- c. Internal treatment of boiler water: control of scale, foam, embrittlement, return line corrosion; chelating agents; sludge conditioning; pH control; deaeration; carryover; blowdown; chemical feed systems; silica turbine blade deposits.**
- d. Analytical methods and equipment:**
  - i. Instruments: embrittlement detectors; steam purity; total solid meters; methods of steam sampling; measurement of pH.**
  - ii. Water analysis and interpretation of analytical results.**
- e. Cooling water treatment; slime and algae control, corrosion control.**
- f. Industrial waste treatment: effects caused by waste discharge; mechanical, chemical and biological methods of waste treatment.**
- g. Potable Water treatment and testing.**



**BOILER & PRESSURE VESSEL SAFETY PROGRAM  
REFERENCE SYLLABUS  
for  
SECOND CLASS  
CERTIFICATE OF QUALIFICATION  
EXAMINATION**

REVISION   1    
DATE 2006/01/01  
PAGE  18  OF  25 



**Part "B" Examination**

**Fourth Paper  
Afternoon Session  
3 ½ Hours**

10. Heat Engines and Prime Movers:
- a. **Steam Turbines:**
    - i. **Applications of operating principles: impulse and reaction turbines, classifications.**
    - ii. **Construction: casings; rotors; dummy pistons; blading; diaphragms; glands; seals; flexible couplings; bearings; thrusts.**
    - iii. **Details: turning gears; drains; rotor adjustment; dynamic and static balancing; critical speed; lubricating oil systems; jacking oil pump; piping; reducing gears; expansion and anchoring.**
    - iv. **Control: governors; governor systems; control valves; grid type extraction valves; casing relief valves; overspeed trips; turbine supervisory equipment.**
    - v. **Operation: starting up and shutting down; normal operation; flow diagrams; efficiencies.**
    - vi. **Maintenance: repairs; shaft alignment; bearing; thrust, blade and packing clearances; blade fouling and erosion; cleaning after erection.**
    - vii. **Theory: nozzles; velocity diagrams; angle of entry and velocity calculations; work done on blades and blade characteristics.**
    - viii. **Condensing equipment**
      - a. **Condensers: types and constructional details; backwashing and cleaning; leak testing.**
      - b. **Condenser ancillary equipment: air ejectors; cooling water systems; intakes and intake screens; cooling towers and ponds; atmospheric exhaust valves; circulating pumps; condensate pumps.**
  - b. **Internal Combustion Engines:**
    - i. **Applications: two and four stroke, oil burning, gas and dual-fuel .**
    - ii. **Fuels: classification; properties; impurities; methods of purifying and clarifying; injection systems; ignition systems; scavenging and supercharging arrangements.**
    - iii. **Operation and maintenance: causes and prevention of incomplete combustion; starting up and shutting down: prevention of crankcase**





**BOILER & PRESSURE VESSEL SAFETY PROGRAM  
REFERENCE SYLLABUS  
for  
SECOND CLASS  
CERTIFICATE OF QUALIFICATION  
EXAMINATION**

REVISION   1    
DATE 2006/01/01  
PAGE  20  OF  25 



**Part "B" Examination**

**Fifth Paper  
Morning Session  
3 ½ Hours**

14. Power Plant Systems
  - a. Feed water systems; layout and operation. regenerative feed heating cycle; closed feed systems; feed heaters; deaerators.
  - b. Steam Piping systems.
  - c. Fuel systems; layout and operation.
  - d. Steam Condensate system; layout and operation.
  - e. Cooling water systems; layout and operation.
  - f. Waste handling systems; layout and operation.
  - g. Integration of powerplant water systems
  
15. Control Instrumentation:
  - a. Electrical and Electronic Pressure measuring devices and component placement/installation.
  - b. Electrical and Electronic Temperature measuring instruments and component placement/installation.
  - c. Flow measurements with differential pressure flow meters:
    - i. Primary elements: orifice plate; flow nozzle; venturi tube; pitot tube; flow-nozzle pipes.
    - ii. Indicating mechanisms: manometer; ring balance; force balance; electric.
    - iii. Component placement/installation.
  - d. Liquid level measurement and control and component installation: ball-float; displacement-type; hydrostatic head; electric and pneumatic level transmission; electric and magnetic type level-limit devices; remote water-level indicators.
  - e. Final control elements: types and flow characteristics of control valves; construction details of control valves; power operators -solenoid, pneumatic-diaphragm, power cylinder, electric motor.
  - f. One, two and three element boiler feedwater control systems.
  - g. Superheated/reheated steam temperature control; steam pressure reducing and desuperheating control systems.





**BOILER & PRESSURE VESSEL SAFETY PROGRAM  
REFERENCE SYLLABUS  
for  
SECOND CLASS  
CERTIFICATE OF QUALIFICATION  
EXAMINATION**

REVISION   1    
DATE 2006/01/01  
PAGE 22 OF 25



- iv. flue gas chemical conditioning
- v. baghouses and precipitators
- c. Significance of measured parameters:
  - i. Air quality particulates, stack opacity, SO<sub>2</sub> and NO<sub>x</sub> concentration and mass flow, mercury, O<sub>2</sub>, CO<sub>2</sub>, hydrocarbons
  - ii. Wastewater - iron, phosphorous, biological oxygen demand, chemical oxygen demand, hydrocarbons, temperature, flow, pH, nitrogen



**BOILER & PRESSURE VESSEL SAFETY PROGRAM  
REFERENCE SYLLABUS  
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SECOND CLASS  
CERTIFICATE OF QUALIFICATION  
EXAMINATION**

REVISION   1    
DATE 2006/01/01  
PAGE  23  OF  25 



**Part "B" Examination**

**Sixth Paper  
Afternoon Session  
3 ½ Hours**

18. Electrotechnology:
- a. **A.C. Theory:**
    - i. **The sine wave: generation of an alternating electromotive force; root mean square values; vector representation of sinusoidal quantities, peak, peak to peak.**
    - ii. **Resistance, inductance and capacitance in single-phase A.C. circuits; inductive reactance; capacitive reactance, impedance, resonance.**
    - iii. **Power in A.C. circuits; true and apparent power; practical importance of power factor; power factor correction.**
    - iv. **Three-phase circuits: delta and star connected alternators and loads, current and voltage relationships; three-phase power.**
  - b. **D.C. Machines:**
    - i. **Generators: principle of operation; construction; commutation; armature reaction; interpoles; compensating windings; lap and wave wound armatures; generator types and characteristics; parallel operation; voltage regulation; theory of self-excitation; efficiency and power losses; selection of generators and applications; parallel operation; ratings.**
    - ii. **Motors: principle of motor action; torque development; Fleming's left-hand rule; back electromotive force: voltage, current and speed computation; motor types and characteristics; starting arrangements; dynamic and regenerative braking; speed control; efficiency and power losses.**
  - c. **A. C. Machines:**
    - i. **Alternators: types; construction of stators, rotors and excitors; stator windings; relationship between speed, frequency and number of pole pairs; cooling systems; shaft sealing systems; voltage regulators; synchronizing; parallel operation; power factor control, voltage drops in armatures; rating, efficiency and power losses.**
    - ii. **Single-phase motors: universal, shaded pole and split-phase types; repulsion-start and reluctance-start types; capacitance starting method.**



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SECOND CLASS  
CERTIFICATE OF QUALIFICATION  
EXAMINATION**

REVISION   1    
DATE 2006/01/01  
PAGE  24  OF  25 



- iii. **Polyphase induction motors; principle of operation; rotating magnetic field; slip and rotor speed; stator and rotor construction; starting methods.**
  - iv. **Synchronous motors: general facts concerning synchronous motors; stator and rotor construction, starting methods.**
  - v. **Transformers: principle of transformer action; ratings; efficiency and losses; short and open circuit tests; types of construction; methods of cooling; connections; paralleling; instrument transformers.**
  - vi. **Protection of electrical systems: alternator stator and rotor protection devices; motor protection devices; transformer safety fittings.**
  - vii. **Circuit-protective equipment; interrupting capacity; fuses; switches; circuit-breakers; relays.**
19. Principles of Air and Gas Compression:
- a. **Applications of air and gas compression: effects of altitude, temperature, humidity.**
  - b. **Reciprocating, axial, centrifugal and rotary compressors: operation, applications; construction; regulation and control; drive selection criteria and preventive maintenance.**
  - c. **Ancillary equipment: valves; coolers; receivers; oil and water separators; filters; unloaders; safety/relief valves; instruments; piping layouts, dryers.**
20. Industrial/Commercial Refrigeration:
- a. **Applications of refrigeration: compression and absorption systems; thermoelectric refrigeration; hermetic cycles; cascade systems; heat pump systems.**
  - b. **Refrigerating plants: types; layouts; installation details.**
  - c. **Plant equipment: compressors; condensers; evaporators; liquid receivers; oil separators; absorbers; generators; heat exchangers; rectifiers; driers; scale traps; piping and fittings; cold room construction.**
  - d. **Operation of refrigerating plants: starting up and shutting down; charging; hand and automatic purging; automatic expansion valves; compressor lubrication; brine solutions; leak testing; trouble shooting.**



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EXAMINATION**

REVISION   1    
DATE 2006/01/01  
PAGE  25  OF 25 



- e. **Safety and control: Code requirements; safety fittings; compressor and system instrumentation and controls; cooling water system controls.**
- f. **Computations of capacities and performances of refrigerating plants; ideal and practical refrigerant cycles; theoretical piston displacement; heat pump effect; theoretical power; pressure-enthalpy charts.**