



Body of Knowledge for National Board Inspector Commission Examination

**THE
NATIONAL
BOARD
OF BOILER AND
PRESSURE VESSEL
INSPECTORS**

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*Denotes Revised Section(s)

**BODY OF KNOWLEDGE FOR
NATIONAL BOARD
INSPECTOR COMMISSION EXAMINATION**

National Board Commissioned Inspectors (Inspectors) must have knowledge *on a variety of subjects relating to inspection, repairs and alterations of boilers and pressure vessels*. The Commission Examination is designed to determine if individuals have such knowledge. The Body of Knowledge is a study guide that provides a list of specific topics in which the Inspector should be knowledgeable.

Only information covered in the categories outlined in this Body of Knowledge will be utilized for the examination questions. Not every category will be included on every examination.

The National Board Inspection Code is the primary reference document. Code calculations and other requirements may originate with the code of construction, such as Sections I, IV, VIII or B31.1 of the ASME Code. Applicants should note that the reference publications are revised on a periodic basis. Examination questions are based on requirements mandatory at the time of the examination.

Code books should be brought to the examination site and used as reference materials for the examination.

**BODY OF KNOWLEDGE FOR
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INSPECTOR COMMISSION EXAMINATION**

***PART I - CODE CALCULATIONS (ASME BASED)**

10 Questions - Total Value 10%

***PART II - WELDING PROCEDURE AND PRACTICAL KNOWLEDGE**

Welding: 10 Questions - Total Value 10%
Practical: 30 Questions – Total Value 30%

***PART III - PRACTICAL KNOWLEDGE**

50 Questions - Total Value 50%

REFERENCE PUBLICATIONS

The following reference publications are permitted at the examination site. It is unnecessary to bring those marked with a plus (+) to the examination site. Any information required from those marked with a plus (+) will be provided with the examination, when necessary.

National Board Inspection Code

ASME Boiler and Pressure Vessel Code

Section I

+Section II

Section IV

Section V

Section VIII, Division 1

Section IX

B31.1

English to foreign language (and vice versa) translation dictionary

Rules for Commissioned Inspectors, NB-263

+Recommended Boiler and Pressure Vessel Safety Legislation, NB-131

+Recommended Administrative Boiler and Pressure Vessel Safety Rules

**BODY OF KNOWLEDGE FOR
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1.0 Code Calculations

Code calculation questions will be oriented toward existing boilers and pressure vessels, not new construction. However, some calculations for existing equipment may revert to those used during new construction. Inspectors should be able to check and perform calculations relative to in-service deterioration, repairs, rerating or alterations, such as those included in the following categories:

1.1 Components Under Internal or External Pressure

The inspector should be able to use the formulas in the Code to calculate the minimum required thickness or the Maximum Allowable Working Pressure (MAWP) of such items as: tubing, piping, drums, shells, headers, heads or jackets for temperatures not exceeding those in the allowable stress tables given for the various materials.

1.2 Openings, Compensation, and Nozzle Installation

The inspector should be familiar with the rules that apply to all openings and nozzle installation in drums, shells, headers and heads and should be able to use the formulas in the Code to verify that Code requirements have been met, including:

- 1.2.1 Determination of required weld size and shape.
- 1.2.2 Size and Shape of Openings
- 1.2.3 Compensation Required for Openings in Shells, Formed Heads and Flat Heads
- 1.2.4 Flanged-In Openings in Formed Heads
- 1.2.5 Limits of Metal Available for Compensation
- 1.2.6 Strength of Compensation, including Welded Connections
- 1.2.7 Compensation for Multiple Openings
- 1.2.8 Methods of Attachment of Pipe and Nozzle Necks to Vessel Walls, including minimum requirements for attachment welds
- 1.2.9 Inspection Openings

1.3 Dished (Formed) Heads

The inspector should be able to calculate the minimum thickness or MAWP of dished heads, with or without stays and with the pressure on either the convex or concave side. The inspector should also be able to calculate the head depth for hemispherical, torispherical and standard ellipsoidal heads.

1.4 Unstayed Flat Heads and Covers

The inspector should be able to calculate the minimum thickness or MAWP of unstayed flat heads, cover plates and blind flanges.

1.5 Stayed Surfaces

The inspector should be able to calculate the minimum thickness or MAWP for stayed surfaces, including the location, pitch, and dimensions of staybolts and welded-in stays.

1.6 Ligaments

The inspector should be familiar with the rules for ligaments and be able to use the formulas in the Code to verify that Code requirements have been met.

1.7 Static Head

The inspector should be able to calculate the pressure $AP@$ (MAWP + static head) on any vessel part. Static head calculations will be based upon a specific gravity of 1.0. The static head conversion factor is 0.433 psi/ft.

1.8 Impact Testing

The inspector should be able to evaluate the minimum design metal temperature (MDMT) and determine whether a condition is exempt from impact testing.

1.9 Attachments

The inspector should be able to determine if loading and weld sizes meet Code requirements for load bearing attachments to pressure parts. The factor for converting a fillet weld throat dimension to a leg dimension is 1.414. The factor for converting a fillet weld leg dimension to a throat dimension is 0.707.

2.0 Welding and Joining

2.1 Welding Procedure and Qualification Review. ASME Section IX

The inspector should be able to evaluate documents associated with welding. The inspector should be familiar with and understand the requirements for Weld Procedure Specifications (WPS), Procedure Qualification Records (PQR) and Welder Performance Qualification (WPQ).

- 2.1.1 For examination purposes, the weld procedure review may include SMAW, GTAW or GMAW.
- 2.1.2 It will be necessary to determine if all required essential and non-essential variables have been properly addressed.
- 2.1.3 It will be necessary to determine if the number, type, and results of mechanical tests listed on the PQR, are the proper tests, and the results are acceptable.
- 2.1.4 The base metals will be limited to P1 and P8.
- 2.1.5 Dissimilar thickness of base metals may be included.

2.2 ASME Section I, IV, VIII, IX and NBIC: General welding requirements. The inspector should be familiar with and understand the general requirements for welding, including:

- 2.2.1 Typical joints and definitions
- 2.2.2 Weld sizes
- 2.2.3 Restrictions on Joints
- 2.2.4 Maximum allowable reinforcement
- 2.2.5 Inspection requirements
- 2.2.6 Preheat and Postweld Heat Treatment
- 2.2.7 Weld material control
- 2.2.8 Standard Weld Procedures.

2.3 Heat Treatment

The inspector should be familiar with and understand the general requirements for preheating, interpass temperature control and postweld heat treatment.

3.0 Duties and Responsibilities

3.1 Jurisdictional Role, Reference NB-131, NB-132.

The inspector should be familiar with and understand:

3.1.1 The role of the jurisdiction in the adoption and enforcement of boiler and pressure vessel rules and regulations, including:

3.1.1.1 Acceptance/adoption of codes of construction

3.1.1.2 Acceptance of the NBIC for repairs and alterations

3.1.1.3 Requirements for National Board registration

3.1.1.4 Establishment of inspection requirements.

3.1.2 The reports required for inspection, repairs and alterations.

3.2 The inspector should be familiar with and understand the duties of the inspector, as defined in the Rules for Commissioned Inspectors.

3.3 The inspector should be familiar with and understand the use of the National Board Commission as defined in the Rules for Commissioned Inspectors.

4.0 Inspection & Testing Methods

4.1 Nondestructive Examination. ASME Section V

A description of each nondestructive examination method is included in the supplemental study guide. The inspector should be familiar with and understand the principles of each of the following NDE methods:

4.1.1 General Requirements

4.1.1.1 The scope of Section V

4.1.1.2 Rules for use of Section V as a reference code

4.1.1.3 Use of procedures

4.1.1.4 Calibration

4.1.1.5 Terminology

4.1.1.6 Interpretation of examination results

4.1.1.7 Record keeping requirements.

4.1.2 Radiographic Examination: The inspector should be familiar with and understand:

4.1.2.1 The scope of Section V, Article 2 and general requirements

- 4.1.2.2 The general requirements for radiography as typically applied to boilers and pressure vessels including:
 - Required Marking
 - Type, selection, number and placement of penetrameters
 - Allowable density
 - Detection and control of backscatter radiation
 - Placement of film and source.
- 4.1.2.3 Personnel qualifications
- 4.1.2.4 Records
- 4.1.3 Ultrasonic Examination: The inspector should be familiar with and understand:
 - 4.1.3.1 The scope of Section V, Article 5
 - 4.1.3.2 The general requirements for applying and using the ultrasonic method
 - 4.1.3.3 Calibration
 - 4.1.3.4 Personnel qualification
 - 4.1.3.5 Records.
- 4.1.4 Liquid Penetrant Examination: The inspector should be familiar with and understand:
 - 4.1.4.1 The scope of Section V, Article 6
 - 4.1.4.2 The general requirements for applying and using the liquid penetrant method including:
 - Contaminants
 - Techniques
 - Temperatures
 - 4.1.4.3 Personnel qualifications
 - 4.1.4.4 Records.
- 4.1.5 Magnetic Particle Examination (Yoke and Prod Techniques only): The inspector should be familiar with and understand:
 - 4.1.5.1 The scope of Section V, Article 7
 - 4.1.5.2 The general requirements for applying and using the yoke and prod techniques including:
 - Field strength verification
 - Lifting power
 - 4.1.5.3 Personnel qualifications
 - 4.1.5.4 Records.

4.1.6 ASME Sections I and VIII and NBIC:

The inspector should be familiar with and understand the type and extent of general nondestructive examination requirements.

4.2 General Applications of Inspection Methods

The inspector should have a working knowledge of the following principles:

- 4.2.1 Fit-up of weld joints
- 4.2.2 Weld defect inspection
- 4.2.3 Change in thickness transitions
- 4.2.4 Use of inspection tools and gages.

4.3 Pressure Testing

The inspector should be able to:

- 4.3.1 Evaluate a hydrotest procedure
- 4.3.2 Evaluate a pneumatic test procedure
- 4.3.3 Calculate a test pressure including compensating for temperature.

4.4 Internal Inspection

The inspector should be familiar with and understand the general requirements for internal inspection of pressure retaining items.

4.5 External Inspection

The inspector should be familiar with and understand the general requirements for external inspection of pressure retaining items.

5.0 Materials

The inspector should be familiar with and understand control of materials, including:

- 5.1 Specifications
- 5.2 Marking
- 5.3 Traceability (including documentation and transfer of markings)
- 5.4 Receiving requirements.

6.0 Boiler and Pressure Vessel Terminology

The inspector should be familiar with and understand basic boiler and pressure vessel terminology, including:

- 6.1 Generating Tubes
- 6.2 Waterwalls
- 6.3 Superheater
- 6.4 Downcomer
- 6.5 Mud and Steam Drums
- 6.6 Deareator
- 6.7 Quick Opening Closures
- 6.8 Hot Water/Steam Boilers
- 6.9 Firetube
- 6.10 Watertube

7.0 Conditions Causing Deterioration or Failures

The inspector should be familiar with and understand the effects of operations on boilers and pressure vessels, including:

7.1 Types of Corrosion and Deterioration

- 7.1.1 Corrosion by Water
- 7.1.2 Corrosion By Process Fluids
- 7.1.3 Deterioration Due to Hydrogen
- 7.1.4 Stress Corrosion Cracking
- 7.1.5 Atmospheric Corrosion and Corrosion Under Insulation
- 7.1.6 Erosion and Erosion-Corrosion
- 7.1.7 Other Types of Corrosion

7.2 Modes of Mechanical, Thermal, and High Temperature Deterioration

- 7.2.1 Mechanical and Thermal Problems
- 7.2.2 High Temperature Problems

7.3 Corrosion Rates and Inspection Intervals

The Inspector should be able to take inspection data; determine the internal and external inspection intervals and calculate metal loss, corrosion rates, remaining corrosion allowance, remaining service life and inspection intervals.

8.0 Quality System

The inspector should be familiar with and understand the elements of a quality system as described in the NBIC for the “R” stamp.

9.0 Pressure Relief Devices

The inspector should be familiar with and understand set pressure and relieving capacity requirements for pressure-relieving devices, including:

- 9.1 Description of Types B General Knowledge of Application and Limitations
- 9.2 Causes of Improper Performance
- 9.3 Sizing for pressure and capacity.

10.0 General

The inspector should be familiar with and understand the general requirements for repair organizations and inspections as described in the NBIC, including:

- 10.1 Repair Program
- 10.2 Alterations
- 10.3 Inspections

SUPPLEMENTAL STUDY GUIDE

1.0 Welding

1.1 Documentation Review

The following step-by-step method may be helpful to individuals in determining if there are any errors on a WPS and PQR.

- 1.1.1 Determine if impact testing is required. (If yes, the supplementary essential variables will be required.)
 - 1.1.2 Verify the PQR and WPQ is certified by the Manufacturer.
 - 1.1.3 Verify that the WPS references the supporting PQR number.
 - 1.1.4 Verify the WPS and PQR separately to assure that:
 - 1.1.4.1 All essential variables (and supplementary essential variables if required) and nonessential variables have been addressed on the WPS; and
 - 1.1.4.2 The essential variables (and supplementary essential variables if required) are recorded on the PQR.
 - 1.1.5 Look only at the PQR. Verify that all required mechanical tests have been documented in the PQR. Verify that the test results meet the Section IX acceptance criteria.
 - 1.1.6 Place the WPS and PQR side by side and verify that the essential variables (and supplementary essential variables if required) recorded on the PQR support the essential variables (and supplementary essential variables if required) on the WPS.
 - 1.1.7 Check for mistakes; e.g., do the P-number, F-number, and A-number match their respective material specification number and AWS classification number?
- 1.2 The inspector should know that the PQR and WPQ must be signed and dated. Items considered as “editorial” and non-technical on the welding documents are excluded. This includes items such as the revision level of the WPS, company name, WPS number and date, and name of testing lab.

2.0 Nondestructive Examination

2.1 General

Section V of the ASME Code relates to the requirements and methods of nondestructive examination to the extent they are specifically referenced and required by other ASME Code sections. These nondestructive examination methods are intended to detect surface and internal discontinuities in materials, welds, and fabricated parts and components. They include radiographic examination, ultrasonic examination, liquid penetrant examination, and magnetic particle examination. The skill, experience and integrity of the personnel performing these examinations are essential to obtain meaningful results. The Inspector should review the methods and procedures to be employed to assure compliance with the requirements of the Code.

2.2 Radiography (RT)

Radiography is a volumetric method that can detect discontinuities throughout a material. This method is commonly used to examine for surface and subsurface discontinuities. The use of this method may be restricted due to the configuration of the welded joint or the limitations of the radiographic equipment. Radiography will not give an indication of the depth of discontinuity unless special procedures are used.

The method uses a source of gamma rays or x-rays as the detecting medium. The rays pass through the material and some are absorbed by the material and some pass completely through. The number of rays that pass completely through is determined by the amount of material. The more material, the less rays.

Radiography uses film to detect the number of rays which penetrate the material. The more rays, the darker the film will become, similar to exposing photographic film to sunlight.

Most discontinuities (cracks, porosity, and inclusions) reduce the amount of base material available to absorb (attenuate) x-, or gamma rays, thus allowing more of these rays to pass through the material. Most discontinuities will appear as dark shapes on the radiographic film.

The technique used for radiography depends largely on the equipment used and what experience has shown will produce the best results. It is not the function of the Inspector to indicate the procedure to be followed, provided the procedure and films satisfy all requirements of the applicable section of the ASME Code. The radiographic film provides a permanent record of the results of the examination.

2.3 Ultrasonic examination (UT)

Ultrasonic examination is a volumetric method that uses high frequency (above the audible range) sound waves to penetrate the material being examined. This method will provide indications of surface and subsurface discontinuities, the depth of which can be determined by the use of the proper technique.

One principle used for detecting discontinuities is that whenever traveling sound waves meet an interface between objects having different acoustic properties, some of the sound will be reflected back toward the source. Another principle is that sound travels through all materials at a specific velocity determined by the microstructure of the material.

During examination, sound is introduced into the material, usually on a surface that is readily accessible. The sound will travel through the material, at a specific velocity until it encounters an interface. If there are no discontinuities, this interface will be the far side of the material. When the sound encounters this interface some will pass through and some will be reflected back to the sound source. Since sound travels at a constant velocity determined by the material in which it is traveling, the amount of time it takes for the sound to travel to the interface (discontinuity) and back to its source can be measured. The distance from the entrance interface to the discontinuity interface can then be computed by the ultrasonic examination instrument.

Since normally there is no record of the results other than electronic indicators on a screen, the skill, experience and integrity of the personnel performing the test are of prime importance.

Ultrasonic examination for thickness determination uses the same principles as used for detecting discontinuities.

2.4 Liquid Penetrant examination (PT)

The liquid penetrant examination method is used to detect discontinuities which are open to the surface of the material being examined. This method may be used on both ferrous and nonferrous materials. Liquid penetrant examination may be used for the detection of surface discontinuities such as cracks, seams, laps, cold shuts, laminations and porosity.

Liquid penetrant examination works by applying a colored liquid (penetrant) to the object to be examined. Time is allowed for the liquid to fill any voids that are open to the surface. Excess penetrant is then removed and a "developer" is applied in a uniform, thin coating. The developer acts as a blotter and draws the penetrant out of the discontinuity. The developer is usually of a contrasting color

to the penetrant. The penetrant indications will appear as colored figures on a background of the developer.

Liquid penetrant examination is portable, fast, and requires minimal operator training.

2.5 Magnetic Particle examination (MT)

The magnetic particle examination method can be used only on ferromagnetic materials to reveal surface discontinuities and to a limited degree, those located below the surface. It uses the principle that magnetic lines of force will attract magnetizable material. The sensitivity of this method decreases rapidly with depth below the surface being examined and, therefore, it is used primarily to examine for surface discontinuities.

In order to use MT, a magnetic field has to be established within the material to be examined. This can be done directly by bringing a strong magnetic field into close proximity of the item being examined, or by inducing a magnetic field in the object by passing electric current through the object.

If there is a discontinuity at or near the surface, it will deflect the magnetic lines of force out of the object, thus creating a north pole (magnetic lines leave the north pole of a magnet). The magnetic lines of force will reenter the test object on the other side of the discontinuity, thereby creating a south pole (magnetic lines enter the south pole of a magnet). Since a north and a south pole have been created, they will attract magnetizable objects. Iron powder is placed on the discontinuity is held in place by the lines of force and will be visible on the surface of the test object.

3.0 Heat Treatment

The inspector should know the purpose of various heat treatments associated with welding.

Preheat: As the name implies, preheat is the application of heat to a weld joint prior to welding. Its purpose is to reduce the temperature gradient between the molten weld metal and the solid base material. On certain materials, having a higher temperature gradient can result in a heat affected zone (the area of base metal adjacent to the weld, that is affected by the heat from welding) that is unacceptably hard and brittle.

Interpass Temperature: The interpass temperature is the maximum temperature permitted between successive welding passes. The purpose of controlling the interpass temperature is to limit the heat input into a base material to a specified range. On certain materials, excessive heat input can change their mechanical properties.

Postweld Heat Treatment: Postweld heat treatment is the application of heat to a weld area following welding. Depending upon the material, it is commonly performed at minimum temperatures ranging from 1100F to 1250F. The primary purposes of postweld heat treatment are to reduce the residual stresses resulting from welding and to improve the properties of the base material heat affected zone.

4.0 Internal and External Inspection

The inspector should know the proper steps to follow when faced with a potential life threatening situation. For example, if a boiler pressure gage shows 200 psig and the safety valves are set at 145 psig, the inspector should have a pre-developed plan of action acceptable to the inspector's employer. In this situation, the boiler should probably be shut down to determine the cause of the overpressure condition. Each inspector's employer will have a different process for getting the boiler offline and, the inspector needs to understand that process.

The inspector must also be aware of the conditions around the inspection site. Potential hazards need to be recognized and the accepted method to deal with the condition known. The inspector needs to know the accepted process both by the site and the inspector's employer. Lock out, tag out, confined space entry are most important.