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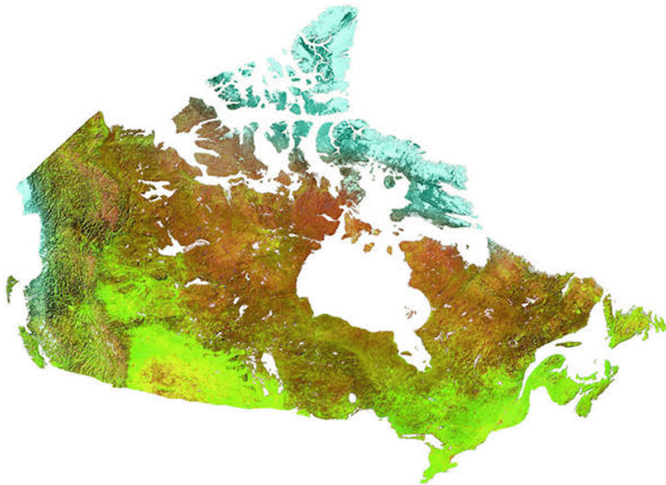
Minerals and
Metals Sector

Secteur des minéraux
et des métaux

Examination Guide for Initial Certification

Industrial Radiography

**Engineering, Materials and
Components Sector**



Canada

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Ce guide est aussi disponible en français à l'adresse suivante :

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A INTRODUCTION

Natural Resources Canada (NRCan), through the Materials Technology Laboratory (MTL) of Minerals and Metals Sector (MMS), is the NDT Certifying Agency for the Canadian Nondestructive Testing Personnel Certification Program. NRCan certifies individuals according to CAN/CGSB 48.9712 standard.

In performing this function, NRCan carries out the following tasks:

- a) examines information provided by the applicant to ensure that the applicant has the basic education, NDT training and experience required by the standard;
- b) prepares, supervises and evaluates both written and practical examinations;
- c) maintains a network of test centres across Canada for both written and practical examinations;
- d) renews certificates of candidates as specified by the standard; and,
- e) recertifies candidates as specified by the standard.

In certifying the candidate, NRCan is only attesting that the candidate has demonstrated sufficient knowledge, skill, training and experience to meet the requirements of the CAN/CGSB 48.9712 standard. NRCan cannot attest to the operators competence in any specific situation at the time of original certification or at any time thereafter.

In undertaking the administration of the program, NRCan attempts to provide the unbiased Canada-wide services required to implement a national program. An Advisory Committee composed of individuals knowledgeable about NDT in Canada advises NRCan on the operation of this program.

B **SUGGESTIONS FOR THE SUCCESSFUL COMPLETION OF
WRITTEN EXAMINATIONS FOR CERTIFICATION IN NDT**

1. Do some personal studying prior to attempting the written examinations. In general, training courses are meant to complement your personal efforts, not to substitute them. Furthermore, training courses tend to cover a lot of material over a short period of time. To assimilate the subject material covered, a great deal of personal studying is usually necessary.
Note: The marks obtained on a training course test should not be used to gauge your eventual performance on NRCan examinations. Usually, applicants find NRCan examinations more difficult.
2. Before starting a test, read all the instructions.
3. Before answering a multiple choice question read the stem and all of the options. Remember, only the best answer is correct.
4. If a question is difficult to answer, proceed by elimination. This will often result in having to choose between two possible options.
5. If you cannot answer a question, do not waste time, proceed to the next question. If you complete the test before the time limit, return to the unanswered questions.
6. To test your skills, we recommend the following sample questions that are available on the market:
 - a) Ginzler Bros. NDT Testmaker Questions Data Base
 - b) Supplements to Recommended Practice SNT-TC-1A (Question and Answer Books)

Reference Material

The textbooks identified in this guide as reference study material may be purchased from the following sources:

Canadian Institute for NDE
135 Fennell Avenue W. Port. #7
Hamilton, Ontario
L8N 3T2
Telephone: (905) 387-1640
Facsimile: (905) 574-6080

ASNT
1711 Arlingate Lane
P.O. Box 28518
Columbus, Ohio
43228 - 0518
U.S.A.
Telephone: (614) 274-6003 or 1-800-222-2768
Facsimile: (614) 274-6899

C.1 LEVEL 1 EXAMINATION SCHEME TO MEET THE CAN/CGSB - 48.9712 STANDARD

***LEVEL 1 RT WRITTEN AND PRACTICAL EXAMINATIONS IN THE
ENGINEERING MATERIALS AND COMPONENTS (EMC) SECTOR***

| EXAMINATION | PASS | CONTENT | DURATION | COMMENTS |
|------------------------------|-------------|---|-----------------|---|
| General Paper | ≥70% | 40 m.c.q. on theoretical principles of RT method | 1 hour | Need not be repeated for other sectors. |
| EMC Paper (Multi-Sector) | ≥70% | 40 m.c.q. total: -15 m.c.q. on flaws, their names, locations and appearances, detectable by RT, -25 m.c.q. on RT applications and simple techniques. | 1 hour | |
| Radiation Protection Paper | ≥70% | 25 m.c.q. applicable to radiation safety | 1 hour | Applicable to levels 1, 2 & 3. Need only be done once. |
| General Practical | ≥70% | Make the required settings and operate the test equipment properly in order to obtain satisfactory results and correctly interpret results. Includes producing an exposure chart on semi-log graph paper for a given exposure energy. | 4 hours | Need not be repeated for other sector. All tests done according to written instructions. |
| EMC Practical (Multi-Sector) | | Inspect 2 specimens, or parts thereof according to written instructions. | | Use test specimens with detailed instructions on how to inspect and record results. |

m.c.q. ⇒ multiple choice questions

Note: For Level 1 certification, a final composite grade (written and practical) must be a minimum of 80%.

C.2 REFERENCES TO PREPARE FOR THE LEVEL 1 WRITTEN EXAMINATIONS

General and EMC Papers:

1. Classroom Training Handbook Radiographic Testing (CT-6-6)
General Dynamics Convair Division
Published by ASNT
2. Radiography in Modern Industry
By Eastman Kodak Company
3. Nondestructive Testing Handbook - Volume 3
By ASNT
4. Can/CGSB 48.5-95 (48-GP-5M)
Prepared by Committee on NDT, RT Method
Published by Canadian General Standards Board
5. Nondestructive Testing, Introduction (P1-4-1)
General Dynamics

Note: Most of the subjects for the General and EMC examinations are found in the above publications. It should be noted that additional studying from other books might be useful.

Radiation Protection Paper:

1. Radiography in Modern Industry
By Eastman Kodak Company
2. Nondestructive Testing Handbook, Second Edition, Volume Three
Prepared by Lawrence E. Bryant, Paul McIntire, Robert C. McMaster
Published by American Society for Nondestructive Testing
3. Can/CGSB 48.975-95 Standard
4. Canadian Nuclear Safety Commission Act and Regulations

*References are based on the Recommended Training Course Guidelines of
Standard CAN/CGSB 48.9712 for Both General and EMC Papers*

C.3 SAMPLE QUESTIONS FOR THE LEVEL 1 WRITTEN EXAMINATIONS

Level 1 General Examination:

1. The essential parts of an atom are:
 - a) proton, positron, electron.
 - b) proton, electron, gamma ray.
 - c) photon, electron, neutron.
 - d) proton, electron, neutron.
2. Primary radiation is:
 - a) all radiation incident on a radiographic film.
 - b) radiation arising directly from a radioactive source.
 - c) radiation arising directly from the target of an x-ray tube.
 - d) b) and c) are true.
3. X-rays emitted from the focal spot on the tungsten target of an x-ray tube:
 - a) is focused downward by the angle of the tungsten target.
 - b) is deflected downward by the angle of the tungsten target.
 - c) is made up of high speed electrons which are deflected downward by the angle of the focal spot.
 - d) travels in straight lines in the form of a diverging conical beam from the focal spot.
4. Intensity of a radiographic source, measured in becquerels, plotted against time is known as a:
 - a) calibration curve.
 - b) decay curve.
 - c) exposure chart.
 - d) density gradient.
5. Alpha radiation is a form of:
 - a) gamma radiation.
 - b) electromagnetic radiation.
 - c) particulate radiation.
 - d) x-ray radiation.
6. In general, which of the following is correct for fluorescent intensifying screens:
 - a) longer exposure and poor radiographic definition.
 - b) shorter exposure and poor radiographic definition.
 - c) shorter exposure and improved radiographic definition.
 - d) shorter exposure and clear radiographic definition.
7. A material used to surround or is inserted into an object during radiography to reduce the effect of unwanted scattered radiation is known as:
 - a) collimating material.
 - b) filtering material.
 - c) refracting material.
 - d) blocking material.

8. The sharpness of the outline of the radiographic image will improve (that is less fuzzy) if:
 - a) the focal spot of x-ray tube or the physical size of the gamma source is increased.
 - b) the source-to-film distance is increased.
 - c) the film developing time is increased.
 - d) a coarse grain film is used.
9. The density difference between two adjacent areas of a radiograph is known as:
 - a) unsharpness.
 - b) radiographic contrast.
 - c) relative density of the specimen.
 - d) subject density.
10. A penetrameter (or a image quality indicator, IQI) is used in radiography to indicate:
 - a) radiographic film sensitivity.
 - b) the size of the smallest detectable defect.
 - c) radiographic film density.
 - d) radiographic film contrast.
11. Another term for real-time radiography could be:
 - a) flash radiography.
 - b) xeroradiography.
 - c) fluoroscopy.
 - d) autoradiography.
12. The selection of a suitable radiographic film to be used for the x-ray examination of a particular part depends on:
 - a) the thickness of the specimen.
 - b) the density of the specimen.
 - c) the kilovoltage range available on the x-ray machine.
 - d) all three of the above stated factors.
13. During the development stage of the radiographic film processing, it is important to observe the time-temperature relationship recommended by the manufacturers of the chemicals. However, if the time is kept constant (i.e. the same as the one recommended) and the temperature of the developing solution is reduced below the recommended figure it will result in:
 - a) overdeveloped radiographic film.
 - b) underdeveloped radiographic film.
 - c) fogging of the radiographic film.
 - d) damaging of the radiographic film due to the frilling.
14. "Inherent graininess" refers to the dispersal of the silver halide crystals in the emulsion of the unexposed radiographic film. This inherent graininess of the radiographic film will affect:
 - a) contrast.
 - b) sensitivity.
 - c) density
 - d) a), b) and c).

15. The amount of film darkening in radiography is given the term:
- a) transmittance
 - b) opacity
 - c) density
 - d) percent transmittance

Answers

- | | | | | | | | |
|------|------|-------|-------|-------|-------|-------|-------|
| 1. D | 2. D | 3. D | 4. B | 5. C | 6. B | 7. D | |
| 8. B | 9. B | 10. A | 11. C | 12. D | 13. B | 14. D | 15. C |

Level 1 E.M.C. Examination:

1. The duty cycle of an x-ray tube is a measure of:
 - a) the maximum kilovoltage that can be applied to the tube.
 - b) the maximum filament current that can be applied.
 - c) the amount of time the tube must rest between exposures.
 - d) the amount of time required to warm-up the tube before the first exposure of the day.
2. The normal range of steel radiographed using IR-192 is:
 - a) 5mm to 25 mm
 - b) 25mm to 75mm
 - c) 5mm to 100mm
 - d) 45mm to 200mm
3. Of the following choices, indicate the most appropriate. In order to decrease exposure time, a radiographer might:
 - a) use lead intensifying screens.
 - b) increase the focal-film-distance.
 - c) process at lower chemical temperatures.
 - d) use a copper filter at the window of the x-ray tube.
4. Primary radiation which strikes a film holder or cassette through a thin portion of the specimen will cause scattering into the shadows of the adjacent thicker portions producing an effect called:
 - a) radiation imaging.
 - b) spotting.
 - c) undercut.
 - d) unsharpness.
5. Filters placed between the source of radiation and the specimen (or object) tend to reduce scatter radiation undercutting the specimen by:
 - a) absorbing the longer wavelength components of the primary beam.
 - b) absorbing the shorter wavelength components of the primary beam.
 - c) absorbing backscatter radiation.
 - d) decreasing the intensity of the beam.

6. A general rule often employed for determining the kilovoltage to be used when x-raying a part is:
 - a) the kilovoltage should be as high as other factors will permit.
 - b) the kilovoltage should be as low as other factors will permit.
 - c) the kilovoltage is always a fixed value and cannot be changed.
 - d) the kilovoltage is not an important variable and can be changed over a wide range without affecting the radiograph.
7. The name of the defect which is most likely to occur at the junction of light and heavy sections is:
 - a) porosity
 - b) hot tear
 - c) blow hole
 - d) both a) and c)
8. Oval or circular dark spots with smooth edges appearing on weld or casting radiographs would most probably be indicative of:
 - a) burn through.
 - b) crater crack.
 - c) porosity.
 - d) lack of fusion.
9. Where on a forged piece can you find a burst?
 - a) inside the piece
 - b) always on the surface of the piece
 - c) on the surface of the piece
 - d) answers a) and c) are correct
10. Which defect results in damage to surfaces in contact, especially in a corrosive environment?
 - a) stress corrosion crack
 - b) embrittlement
 - c) fretting corrosion
 - d) intergranular corrosion

Answers

- | | | | | |
|------|------|------|------|-------|
| 1. C | 2. B | 3. A | 4. C | 5. A |
| 6. B | 7. B | 8. C | 9. D | 10. C |

Levels 1, 2 & 3 Radiation Protection Examination:

1. Geiger Mueller counters are used for radiation detection but are not recommended for industrial x-ray work because:
 - a) the high intensity of radiation causes the batteries to saturate and not work
 - b) high intensity radiation makes Geiger tubes brittle and fragile
 - c) high intensity radiation may cause the Geiger tube to saturate and give a low measure or no measure of the true exposure rate
 - d) high intensity radiation causes gas amplification by a factor of 10^{10} and this causes the Geiger tube to explode

2. An exposure rate of 5 mR/h is measured just outside the steel door to an x-ray room. The half-value layer in lead for the transmitted x-rays is 0.09 cm. What thickness of lead would have to be added to the door to reduce the exposure rate to 1 mR/h?
 - a) 0.21 cm
 - b) 0.018 cm
 - c) 2.25 cm
 - d) 0.45 cm
3. The HVL of lead to control leakage from an x-ray tube operating at 200 kV is .4 mm. What thickness of lead would be required to reduce this leakage by a factor of 16?
 - a) 0.4 mm
 - b) 0.8 mm
 - c) 1.6 mm
 - d) 4.8 mm
4. Absorbed dose, no matter what its units are given in, is a measure of:
 - a) energy deposited in a unit mass
 - b) effective biological damage
 - c) ionizations in a unit volume
 - d) the product of a and b
5. The tenth value layer of lead for 250 kVp x-rays is 2.9 mm. What thickness of lead would be needed to reduce the exposure rate for this energy of radiation by a factor of 1000?
 - a) 2,900 mm
 - b) 0.25 mm
 - c) 8.7 mm
 - d) 87 cm
6. A person who receives a whole-body dose equivalent of 5 rems in one year:
 - a) may develop radiation sickness
 - b) should not have any medical x-rays
 - c) will be unaffected
 - d) may have an increased risk of cancer
7. For an uncontrolled area next to an x-ray room, the shielding should be sufficient to ensure that the maximum exposure is:
 - a) 2.5 mR per week
 - b) 10 mR per week
 - c) 25 mR per week
 - d) 100 mR per week
8. A counter placed 18cm from an energized X-Ray tube reads 72,000 cpm (counts per minute). When measured at a new distance the reading is 44,100 cpm. What is the new distance?
 - a) 21 cm
 - b) 22 cm
 - c) 23 cm
 - d) 24 cm

9. In making an x-ray exposure, you find the dose rate at 2 meters from the x-ray tube is 1200 mR/h. What would be the dose rate at 8 meters?
- a) 75 mR/h
 - b) 100 mR/h
 - c) 200 mR/h
 - d) 300 mR/h
10. The maximum annual whole-body dose that an x-ray worker is permitted to receive is:
- a) 5 millisieverts
 - b) 50 millisieverts
 - c) 500 millisieverts
 - d) 5,000 millisieverts
11. An x-ray tube operating at 200 kVp and 4 mA is suitable for examining 1/4" thick steel pipe. What is the energy of the x-rays produced with this technique?
- a) 800 kVp
 - b) .8 kVp
 - c) up to 200 keV
 - d) 0.8 MeV
12. Given the field at 2.5 m from an IR192 source is 2 μ Gy/hr, what distance could you approach before the field rose to 25 μ Gy/hr?:
- a) 0.21 m
 - b) 0.50 m
 - c) 0.67 m
 - d) 0.71 m
13. Maximum annual dose limits for non-atomic radiation workers is:
- a) the same as ARW's
 - b) 1/2 allowed an ARW
 - c) 1/10 allowed an ARW
 - d) 1/100 allowed an ARW
14. Given the HVL for 400 kV x-rays is 7.6 mm and a field of 10 Gy/hr. How many HVL of lead are needed to reduce the field to 1 Gy/hr?:
- a) 10
 - b) 5.4
 - c) 3.3
 - d) 1.2
15. A dose equivalent of 50 millisieverts is equal to:
- a) 5 millirems
 - b) 50 millirems
 - c) 0.5 rem
 - d) 5 rem

Answers

- | | | | | | | | |
|------|------|-------|-------|-------|-------|-------|-------|
| 1. C | 2. A | 3. C | 4. A | 5. C | 6. D | 7. B | |
| 8. C | 9. A | 10. B | 11. C | 12. D | 13. C | 14. C | 15. D |

C.4 GENERAL INFORMATION FOR THE LEVEL 1 PRACTICAL EXAMINATIONS

1. The duration of the practical test is 4 hours.
2. The level 1 radiography practical examination is a closed book examination. No books or notes other than those provided will be permitted during the test. A scientific calculator may be used provided it does not contain information or established programs which provide solutions to examination problems.
3. The candidate shall be shown the operation and placement of equipment and accessories required to complete the test.
4. No surface preparations are permitted on the test specimens, they must be used as is.
5. No markings shall be placed on equipment, test pieces and reference samples.
6. The candidate is not allowed to take the paperwork nor the test specimens out of the laboratory. Thus, all reporting must be completed within the testing room or facility.
7. Candidates' questions will be answered unless the question is a test requirement. A supervisor may refuse to answer any question he considers to be part of the test.
8. Candidates will be given the opportunity to give feedback concerning the practical test. After completing the test, simply fill in and return the comment sheet provided. Hand in the comment sheet to the test supervisor or complete it at home and send directly to:

Richard Wood
NDT Certifying Agency
Natural Resources Canada
568 Booth Street, Ottawa, Ontario K1A 0G1

Tel: (613) 992-9276 Fax: (613) 943-8297

Note: There is concern about candidates who appear confused and unsure of themselves while attempting their practical test. It is the prerogative of the supervisor to discuss this situation with the candidate and, in the extreme, terminate the practical test.

C.5 TEST PROGRAM FOR THE LEVEL 1 PRACTICAL EXAMINATIONS

The candidate is required to do the following:

General Practical Test:

1. Perform one (1) calibration test according to written instructions. (Exposure curve)

EMC Practical Test:

1. Inspect a welded specimen according to written instructions.
2. Inspect a metal formed specimen according to written instructions.

C.6 HINTS FOR SUCCESSFUL LEVEL 1 PRACTICAL EXAMINATIONS

1. Do not spend too much time on one part of the test at the expense of the other parts. We suggest you devote:
 - 15 minutes to read the general information and familiarize yourself with the equipment and accessories.
 - 1.75 hours to perform the calibration test.
 - 1 hour to inspect a welded specimen.
 - 1 hour to inspect a metal formed specimen.
2. Fill in the report sheets completely, clearly and neatly
3. Do not hesitate to ask questions to the supervisor. If the supervisor cannot answer your question because it is part of the test, he or she will tell you so.

D.1 LEVEL 2 EXAMINATION SCHEME TO MEET THE CAN/CGSB - 48.9712 STANDARD

LEVEL 2 RT WRITTEN AND PRACTICAL EXAMINATIONS IN THE ENGINEERING MATERIALS AND COMPONENTS (EMC) SECTOR

| EXAMINATION | PASS | CONTENT | DURATION | COMMENTS |
|------------------------------|------|---|-----------|--|
| General Paper | ≥70% | 40 m.c.q. on theoretical principles of RT test method | 1 hour | Need not be repeated for other sectors. |
| EMC Paper (Multi-Sector) | ≥70% | 70 m.c.q. total: -30 m.c.q. on M&P and flaws -10 m.c.q. (2 x 5) on codes -30 m.c.q. on RT applications and techniques | 2 ½ hours | |
| Radiation Protection Paper | ≥70% | 25 m.c.q. applicable to radiation safety. Same as Level 1. | 1 hour | This exam need not be repeated if successfully completed at Level 1. |
| General Practical | ≥70% | Performance/Calibration checks. Same as Level 1. | 2 days | This exam need not be done again if successfully completed at Level 1. |
| EMC Practical (Multi-Sector) | | Inspect 4 specimens: γ-ray one weld and X-ray one weld; 1 light and 1 heavy metal casting or forging. Prepare 4 technique records (instructions). Interpret 26 radiographs. | | |

m.c.q. ⇒ multiple choice questions

M&P ⇒ Materials and Processes

Note: For Level 2 certification, a final composite grade (written and practical) must be a minimum of 80%.

D.2 REFERENCES TO PREPARE FOR THE LEVEL 2 WRITTEN EXAMINATIONS

General Paper:

1. Nondestructive Testing Handbook
First and Second Editions Volumes 1 and 3, By ASNT
2. Radiography in Modern Industry, By Eastman Kodak Company
3. Can/CGSB 48.5-95 (48-GP-5M)
Prepared by Committee on NDT, RT Method
Published by Canadian General Standards Board
4. Materials and Processes for NDT Technology, By ASNT

EMC Paper:

1. Classroom Training Handbook Radiographic Testing, By General Dynamics
2. Nondestructive Testing Handbook
First and Second Editions Volume 3, By ASNT
3. Materials and Processes for NDT Technology
1981 edition, By ASNT
4. Basic Metallurgy for Nondestructive Testing, 1988 edition
5. Can/CGSB 48.5-95 (48-GP-5M)
Prepared by Committee on NDT, RT Method
Published by Canadian General Standards Board
6. Radiography in Modern Industry
By Eastman Kodak Company

At the present, five (5) codes/specifications are used for Level 2 EMC paper. These are as follows:

1. CSA Z184-M
2. ASTM E 1025-84 Hole Type Image Quality Indicators Used for Radiography
3. Military Standard Inspection Radiographic MIL-STD-453C
4. MIL-1-6865 (ASG)
5. ASTM E 94 - Standard Practice for Radiographic Testing

Note:

New codes and questions are added periodically.

It is recommended that candidates do not purchase these publications, but rather that they familiarize themselves with the general layout of codes and standards.

Note: Most of the subjects of the General and EMC written examinations are found in the above publications. It should be noted that additional studying from other books might be useful.

Radiation Protection Paper:

1. Radiography in Modern Industry
By Eastman Kodak Company
2. Nondestructive Testing Handbook, Second Edition, Volume Three
Prepared by Lawrence E. Bryant, Paul McIntire, Robert C. McMaster
Published by American Society for Nondestructive Testing
3. Can/CGSB 48.975-95 Standard
4. Canadian Nuclear Safety Commission Act and Regulations

*References are based on the Recommended Training Course Guidelines of
Standard CAN/CGSB 48.9712 for Both General and EMC Papers*

D.3 SAMPLE QUESTIONS FOR THE LEVEL 2 WRITTEN EXAMINATIONS

Level 2 General Examination:

1. A Cobalt-59 becomes a Cobalt-60 atom when it is placed in a nuclear reactor where its nucleus captures:
 - a) an electron.
 - b) a neutron.
 - c) a proton.
 - d) contamination.
2. Any action which disturbs the electrical balance of the atoms which make up matter is referred to as _____.
 - a) attenuation
 - b) ionization
 - c) absorption
 - d) decay
3. Two factors which greatly affect the suitability of the target material in an x-ray generator are:
 - a) tensile strength and yield strength.
 - b) melting point and magnetic strength.
 - c) electrical resistance and tensile strength.
 - d) atomic number and melting point.
4. The smaller the physical dimensions of a gamma-ray source:
 - a) the greater the penetrating power of the gamma-ray source.
 - b) the less the penetrating power of the gamma-ray source.
 - c) the penetrating power of the gamma-ray source does not depend upon the physical size.
 - d) none of the above are true.

5. A device that uses an electron gun, magnetic fields and a hollow circular tube (doughnut) in order to accelerate electrons in a circular path and to direct them to strike a target to give bursts of x-rays is called a:
 - a) Van de Graff Generator.
 - b) betatron.
 - c) resonance transformer.
 - d) linear accelerator.
6. The projected area of the target as viewed parallel with the centre axis of the useful emergent beam of an x-ray tube is called:
 - a) focal spot.
 - b) focus.
 - c) effective (or apparent) focal spot.
 - d) geometric unsharpness.
7. Subject contrast is affected by:
 - a) thickness differences of the specimen.
 - b) radiation quality.
 - c) scattered radiation.
 - d) all of the above.
8. The sharpness of the film image will improve if:
 - a) the focal spot or physical size of the source is made larger.
 - b) the object to film distance is increased.
 - c) the film developing time is increased.
 - d) a finer grain film is used.
9. When manually processing films, the purpose of sharply tapping hangers two or three times after the film have been lowered into the developer solution is to:
 - a) disperse unexposed silver grains on the film surface.
 - b) prevent frilling of the emulsion.
 - c) dislodge any air bubbles clinging to the emulsion.
 - d) minimize fogging.
10. As the development time increases:
 - a) the characteristic curve grows steeper and moves to the left toward the density axis.
 - b) the characteristic curve grows steeper and moves to the right toward the density axis.
 - c) the characteristic curve remains the same in shape but moves to the left toward the density axis.
 - d) there is little effect on the characteristic curve.
11. Wherever possible penetrameter placement is:
 - a) on the source side of the specimen
 - b) on the film side of the specimen
 - c) over the thickest part of the specimen
 - d) in the middle of the area of interest

12. The normal recording medium for autoradiography is the:
- a) microdensitometer
 - b) xerographic plate
 - c) radiographic film
 - d) TV screen

Answers

- | | | | | | |
|------|------|------|-------|-------|-------|
| 1. B | 2. B | 3. D | 4. C | 5. B | 6. C |
| 7. D | 8. D | 9. C | 10. A | 11. A | 12. C |

Level 2 E.M.C. Examination:

1. What is the radiation dose at 4 meters from a source when the radiation is 20 mSv at 1 metre is:
 - a) 1.25 mSv
 - b) 5 mSv
 - c) 80 mSv
 - d) 160 mSv
2. Given 100 GBq of Co-60 (half life 5.3 years), what amount of time elapses before it is only 22 GBq?
 - a) 10.2 years
 - b) 10.9 years
 - c) 11.1 years
 - d) 11.6 years
3. The penetrating ability of an x-ray beam is greatest for which of the following wavelengths:
 - a) 0.1 nm.
 - b) 9.0 nm.
 - c) 100.0 nm.
 - d) 3.0 nm.
4. A Cobalt 60 gamma-ray source has an approximate practical thickness limit in steel of:
 - a) 62 mm (2.5 in).
 - b) 100 mm (4.0 in).
 - c) 185 mm (7.0 in).
 - d) 275 mm (12.0 in).
5. If a specimen were radiographed at 40 kV and again at 50 Kv with time compensation to give the radiographs the same density, which of the following statements would be true?
 - a) The 40 kV exposure would have a lower contrast and greater latitude than the 50 kV exposure
 - b) The 40 kV exposure would have a higher contrast and greater latitude than the 50 kV exposure
 - c) The 50 kV exposure would have a lower contrast and greater latitude than the 40 kV exposure
 - d) The 50 kV exposure would have a higher contrast and greater latitude than the 40 kV exposure

6. Which is not an advantage of paper radiography?
 - a) speed of access
 - b) viewing of densities greater than film
 - c) good image quality
 - d) portability and economy
7. What must the direction of applied stress be to result in lamellar tearing?
 - a) Parallel to the rolling direction of the plate
 - b) Perpendicular to the rolling direction of the plate
 - c) 45° to the rolling direction of the plate
 - d) All of the above
8. Since rolling results in the flattening and elongation of a sheet of metal, what happens to a pocket of gas in a metal sheet as a result of hot rolling?
 - a) It is still present and is the same size.
 - b) It is still present, and it grows.
 - c) It is still present, but is larger in size.
 - d) None of the above answers.
9. Aluminum sand castings are subject to:
 - a) shrinkage cracks
 - b) surface porosity and cold shuts
 - c) microshrinkage
 - d) all of the above
10. Hot tears generally originate:
 - a) internally or at the surface
 - b) from a large pore
 - c) from internal chaplets
 - d) from flat areas
11. Underbead cracking occurs in the:
 - a) root pass of a weld
 - b) heat affected zone of a weld
 - c) second last layer of weld passes
 - d) crater at the end of a weld bead
12. In a shielded metal arc weld, entrapped gas pockets that are aligned and separated by a relatively small distance is called:
 - a) piping porosity
 - b) linear porosity
 - c) pitting
 - d) straight porosity
13. Which of the following is not a discontinuity common to forged products?
 - a) Laps
 - b) Shrinkage
 - c) Bursts
 - d) Flakes

14. Fine lines, likely to occur in groups caused by non-metallic impurities present in the original ingot and extruded lengthwise are called:
- stringers.
 - seams.
 - laminations.
 - laps.
15. Can you say that there is a difference between a corrosion fatigue crack and intergranular corrosion in terms of the grain of the metal?
- no, as these two defects are transgranular
 - no, as these two defects are intergranular
 - yes, as a corrosion fatigue crack is transgranular and intergranular corrosion is intergranular
 - yes, as a corrosion fatigue crack is intergranular and intergranular corrosion is transgranular

Answers

- | | | | | | | | |
|------|------|-------|-------|-------|-------|-------|-------|
| 1. A | 2. D | 3. A | 4. C | 5. C | 6. B | 7. B | |
| 8. D | 9. D | 10. A | 11. B | 12. B | 13. B | 14. A | 15. C |

Levels 1, 2 & 3 Radiation Protection Examination:

- Geiger Mueller counters are used for radiation detection but are not recommended for industrial x-ray work because:
 - the high intensity of radiation causes the batteries to saturate and not work
 - high intensity radiation makes Geiger tubes brittle and fragile
 - high intensity radiation may cause the Geiger tube to saturate and give a low measure or no measure of the true exposure rate
 - high intensity radiation causes gas amplification by a factor of 10^{10} and this causes the Geiger tube to explode
- An exposure rate of 5 mR/h is measured just outside the steel door to an x-ray room. The half-value layer in lead for the transmitted x-rays is 0.09 cm. What thickness of lead would have to be added to the door to reduce the exposure rate to 1 mR/h?
 - 0.21 cm
 - 0.018 cm
 - 2.25 cm
 - 0.45 cm
- The HVL of lead to control leakage from an x-ray tube operating at 200 kV is .4 mm. What thickness of lead would be required to reduce this leakage by a factor of 16?
 - 0.4 mm
 - 0.8 mm
 - 1.6 mm
 - 4.8 mm

4. Absorbed dose, no matter what its units are given in, is a measure of:
 - a) energy deposited in a unit mass
 - b) effective biological damage
 - c) ionizations in a unit volume
 - d) the product of a and b
5. The tenth value layer of lead for 250 kVp x-rays is 2.9 mm. What thickness of lead would be needed to reduce the exposure rate for this energy of radiation by a factor of 1000?
 - a) 2,900 mm
 - b) 0.25 mm
 - c) 8.7 mm
 - d) 87 cm
6. A person who receives a whole-body dose equivalent of 5 rems in one year:
 - a) may develop radiation sickness
 - b) should not have any medical x-rays
 - c) will be unaffected
 - d) may have an increased risk of cancer
7. For an uncontrolled area next to an x-ray room, the shielding should be sufficient to ensure that the maximum exposure is:
 - a) 2.5 mR per week
 - b) 10 mR per week
 - c) 25 mR per week
 - d) 100 mR per week
8. A counter placed 18cm from an energized X-Ray tube reads 72,000 cpm (counts per minute). When measured at a new distance the reading is 44,100 cpm. What is the new distance?
 - a) 21 cm
 - b) 22 cm
 - c) 23 cm
 - d) 24 cm
9. In making an x-ray exposure, you find the dose rate at 2 meters from the x-ray tube is 1200 mR/h. What would be the dose rate at 8 meters?
 - a) 75 mR/h
 - b) 100 mR/h
 - c) 200 mR/h
 - d) 300 mR/h
10. The maximum annual whole-body dose that an x-ray worker is permitted to receive is:
 - a) 5 millisieverts
 - b) 50 millisieverts
 - c) 500 millisieverts
 - d) 5,000 millisieverts

11. An x-ray tube operating at 200 kVp and 4 mA is suitable for examining 1/4" thick steel pipe. What is the energy of the x-rays produced with this technique?
 - a) 800 kVp
 - b) .8 kVp
 - c) up to 200 keV
 - d) 0.8 MeV
12. Given the field at 2.5 m from an IR192 source is 2 μ Gy/hr, what distance could you approach before the field rose to 25 μ Gy/hr?:
 - a) 0.21 m
 - b) 0.50 m
 - c) 0.67 m
 - d) 0.71 m
13. Maximum annual dose limits for non-atomic radiation workers is:
 - a) the same as ARW's
 - b) 1/2 allowed an ARW
 - c) 1/10 allowed an ARW
 - d) 1/100 allowed an ARW
14. Given the HVL for 400 kV x-rays is 7.6 mm and a field of 10 Gy/hr. How many HVL of lead are needed to reduce the field to 1 Gy/hr?:
 - a) 10
 - b) 5.4
 - c) 3.3
 - d) 1.2
15. A dose equivalent of 50 millisieverts is equal to:
 - a) 5 millirems
 - b) 50 millirems
 - c) 0.5 rem
 - d) 5 rem

Answers

- | | | | | | | | |
|------|------|-------|-------|-------|-------|-------|-------|
| 1. C | 2. A | 3. C | 4. A | 5. C | 6. D | 7. B | |
| 8. C | 9. A | 10. B | 11. C | 12. D | 13. C | 14. C | 15. D |

D.4 GENERAL INFORMATION FOR THE LEVEL 2 PRACTICAL EXAMINATIONS

1. The level 2 Radiography practical examination is a closed book examination. **No** books or notes other than those provided will be permitted during the test. A scientific calculator may be used provided it does not contain information or established programs which provide solutions to examination problems.
The duration of the practical test is two (2) days.
2. The candidate shall be shown the operation and placement of equipment and accessories required to complete the test.
3. The candidate will be shown the accessible surfaces of the test specimens and reference samples.
4. No surface preparations are permitted on the test specimens, they must be used as is.
5. No markings shall be placed on equipment, tests pieces and reference samples.
6. The candidate is **not allowed** to take the paperwork nor the test specimens out of the laboratory. Thus, all reporting must be completed within the testing room or facility. At the end of each day all paperwork is given to the supervisor and will be returned to the candidate the following day. This process will be repeated until the time limit is reached.
7. Candidates' questions will be answered unless the question is a test requirement. A supervisor may refuse to answer any question he considers to be part of the test.
8. Candidates will be given the opportunity to give feedback concerning the practical test. After completing the test, simply fill in and return the comment sheet provided. Hand in the comment sheet to the test supervisor or complete it at home and send directly to:

Richard Wood
NDT Certifying Agency
Natural Resources Canada
568 Booth Street, Ottawa, Ontario K1A 0G1

Tel: (613) 992-9276 Fax: (613) 943-8297

Note: There is concern about candidates who appear confused and unsure of themselves while attempting their practical test. It is the prerogative of the supervisor to discuss this situation with the candidate and, in the extreme, terminate the practical test.

D.5 TEST PROGRAM FOR THE LEVEL 2 PRACTICAL EXAMINATIONS

The candidate is required to do the following:

General Practical Test {if not done at Level 1}

- A. Perform one (1) calibration test (Exposure curve)

EMC Practical Test

- B. Inspect 4 specimens and prepare 4 techniques:
one (1) heavy metal casting/forging and prepare a technique record;
one (1) light metal casting/forging and prepare a technique record;
two (2) welded specimens. One specimen is to be inspected using Gamma. A technique record will be prepared for each welded specimen

The technique for each specimen must be completed in a manner that will permit a level 1 Radiographic inspector to follow your steps and duplicate your results.

- C. Interpret 26 radiographs

A. Preparation of an Exposure Curve

There are many types of exposure curves and the candidate may choose any type with which he/she is familiar. The most popular curve is where thickness of material is plotted against exposure for specified K.V. levels on semi-log graph paper.

For exposure curves other than the ones plotted on semi-log graph paper, the candidate may be required to supply his/her own graph paper.

The candidate will be given a sloped metal wedge, semi-log graph paper and a blank data sheet.

The candidate will:

- take the exposures for the K.V. energy designated by the supervisor;
- locate and clearly mark on the resulting radiographs where the required density (2.0) has been found and record the data; and
- plot the data points as derived from the radiographs and draw the exposure curve.

Note: The plotted data points must be quite evident to the examiner.

B. Preparation and Development of Radiographic Techniques

The candidate will be provided with:

- the test samples;
- a specification which will dictate the requirements and limitations for all techniques
- the current isotope decay curve;
- film characteristic curves;
- logarithmic and anti-logarithmic tables;
- source size and effective x-ray focal spot size;
- sketches of the test specimen with the exception of the gamma test;
- exposure curves.

Cautionary Note:

After the candidate has taken his/her exposures for the curve required in Part I of the exam, the candidate will be supplied with the appropriate exposure curves for this equipment. It should be noted that, although the Test Centre supplies each candidate with exposure curves, it should not be assumed that the exposure curves are accurate for all the test specimens. This is especially true for the light alloys. Following a test shot, the candidate is expected to have the necessary wherewithal to quickly zero-in on the correct exposures.

Coverage of the Test Specimen

The test specimens are to be considered critical all over and must be radiographed 100% with the required sensitivity and unsharpness as stated in the supplied specification. The radiography of welds includes the weld only and where feasible approximately one centimetre of the adjacent parent material.

The limits of the coverage for each radiograph must be indicated on the radiograph. This may be shown by lead numbers or arrows placed on the specimen or by marking the radiograph with film-marking crayons.

Where identical cross sections of test specimens are inspected by a series of radiographs, each with identical exposure parameters, then only the first exposure of that series need be taken and submitted provided this series is properly indicated by the technique.

The area on the radiograph where pertinent film density readings are taken by the candidate must be circled in order that the examiner be able to verify the candidate's calculations.

C. Interpretation of Radiographs

Instructions are provided with the radiographs to be interpreted.

When doing the interpretation test, the following items are provided to the candidate:

- a variable high intensity viewer;
- interpretation sheets;
- a magnifying glass;
- a ruler and
- cotton gloves.

General Information

Where the candidate does not follow clearly stated guidelines (density, UG, sensitivity, etc.) the candidate's work is subject to rejection unless there are extenuating circumstances. These circumstances must be stated and supported by the invigilator.

There may be different ways to radiograph a test specimen. Grading of a technique will be according to the guidelines of coverage, radiograph density, sensitivity attained and economy of film and exposures.

Test exposures must be sent to the NDT Certifying Agency and must be separated from the final technique. A sample technique is provided for the candidates' information.

A supervisor may refuse to answer any question which he considers part of the test. Scribbled work is subject to rejection.

The candidate will use the film that is available at the centre. The candidate may be required to load and develop his/her own film. The film size should not exceed 8" X 10". It is preferred that the candidate use regular size film only.

The part should be considered a production part, therefore the cost of inspection due to the time involved and the number of films used, will be of importance.

Specific Instructions for Gamma Exposure

The candidate:

- will be supplied with a charged dosimeter and the reading will be recorded after the completion of examination;
- will develop a radiographic technique for the test specimen using the same procedure as for the x-ray technique;
- will be instructed in the safe operation of gamma camera;
- will be supplied with all safety devices and accessories for the gamma exposure;
- must follow safe working practices and ensure that individuals are never exposed to ionizing radiation beyond the permissible dose.

Demonstration Radiographic Technique

Radiographic techniques must contain all the testing parameters necessary for an individual with limited experience to duplicate your work and maintain the required level of inspection.

The following technique is intended as a guide for those candidates who wish some assistance.

It is assumed that the recipient of the technique is someone who has limited knowledge of radiography. Therefore, the transfer of information from the candidate to the recipient must be clear, concise and neat. An example of a complete and comprehensive technique is shown in Figure 1.

A comprehensive method of radiograph identification, relating each film to the technique, must be devised by the candidate.

INDUSTRIAL RADIOGRAPHY

NAME: _____

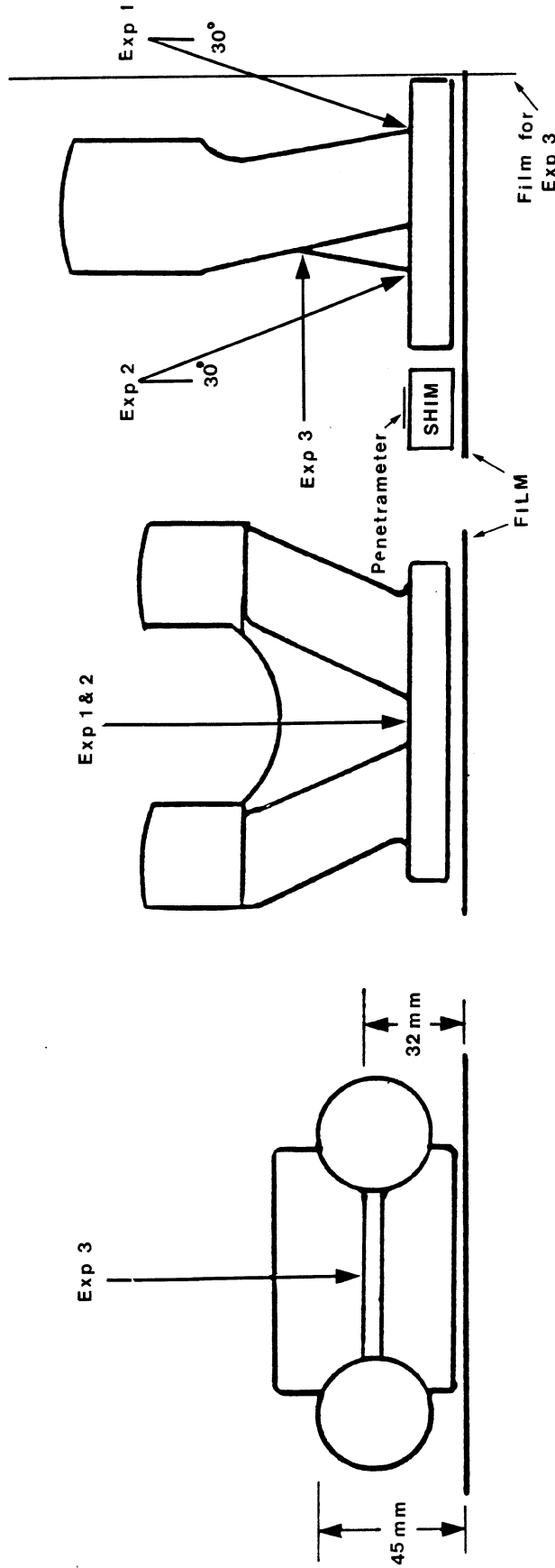
DATE: _____

SAMPLE TECHNIQUE

SOURCE SIZE
Lgth Wdth Diag

X-RAY _____ (mm)

GAMMA _____ (mm)



| EXPOSURE NUMBER | kV | HAS | THICKNESS | F.P.D. | FILM | SCREENS | FOCAL SPOT SIZE | U.G. | PEN. | ANGLE | EQUIPMENT | REMARKS |
|-----------------|----|-----|---------------|---------|---------|---------|-----------------|-------------|-----------|-------|-----------|--------------------|
| 1 | 80 | 600 | 8 mm | 1 metre | Kodak M | NIL | 2.5 mm | .02 | ASTM #6 | 30° | 160 kV | |
| 2 | 80 | 600 | 8 mm | 1 metre | Kodak M | NIL | 2.5 mm | .02 | #6 | 30° | 160 kV | Duplicate of Exp 1 |
| 3 | 60 | 800 | 4 mm 28 mm | 1 metre | Kodak M | NIL | 2.5 mm | .08 .118 | #3 #22 | 90° | 160 kV | |

FIGURE 1

D.6 HINTS FOR SUCCESSFUL LEVEL 2 PRACTICAL EXAMINATIONS

1. Budget your time. Don't spend too much time on one part of the test at the expense of the other parts. We suggest you devote:
 - 1 hour -introduction/reading instructions
 - 2.25 hour -each technique (2.25 hr x 4 = 9 hrs)
 - 2 hours -exposure curve (if required)
 - 2 hours -x-ray interpretation
 - assess the strength of the IR192 source. If low, be prepared to do this technique first as longer exposures will be required.
 - spare time, while waiting for exposures to be developed, may be used interpreting radiographs. Interpretation radiographs are not allowed to be removed from the test centre at any time.
2. Do not hesitate to ask questions to the supervisor if you encounter problems. If the supervisor cannot answer your question because it's part of the test, he or she will tell you so.

Common Errors Which Result in Failure of the Level 2 Industrial Radiography Practical Examinations:

1. Candidate not adhering to density limits as laid down in the standard supplied by the test centre.
2. Candidate unable to calculate unsharpness (UG) and develop techniques within parameters of standard supplied by the test centre.
3. Candidate unable to identify areas of interest on test samples and inspect for same.
4. Candidate unable to select/locate penetrameters properly.
5. Candidate unable to produce a legible technique with sufficient information for a Level 1 with limited experience to perform/achieve equal results.

E.1 LEVEL 3 EXAMINATION SCHEME TO MEET THE CAN/CGSB - 48.9712 STANDARD

LEVEL 3 RT WRITTEN AND PRACTICAL EXAMINATIONS IN THE ENGINEERING MATERIALS AND COMPONENTS (EMC) SECTOR

| EXAMINATION | PASS | CONTENT | TIME | COMMENTS |
|--|------------------------|--|-----------------------------------|--|
| Basic Paper | ≥70% | 140 m.c.q. ¹ total: - 10 m.c.q. on CAN/CGSB 48.9712 standard - 30 m.c.q. on M&P ² (General) - 40 m.c.q. on M&P and flaws specific to welds, castings, wrought products, etc. - 60 m.c.q. (4 x 15) on NDT methods | 3½ hours | Need not be repeated for other sectors and methods. |
| Radiation Protection Paper | ≥70% | 25 m.c.q. applicable to radiation safety | 1 hour | This exam need not be repeated if successfully completed at Levels 1 or 2. |
| General Paper | ≥70% | 30 m.c.q. on theoretical principles of RT method | ¾ hour | Need not be repeated for other sectors in RT. |
| Written Procedure ⁴ OR Written Procedure Review ⁵ | ≥70% ≥80% ³ | Writing 1 NDT procedure for certification in the <i>first</i> method and the option of Reviewing an NDT procedure for certification in each <i>additional</i> method | 4 hours OR 1 ½ hours | Need not be repeated for other sectors in RT. |
| EMC Sector –Codes and Applications Paper | ≥70% | 40 m.c.q. total: -10 m.c.q. on codes (2 x 5) -30 m.c.q. on RT applications | 1 ¾ hours | |
| Practical Test | ≥70% | Same as Level 2 | 2 ½ days | This exam need not be repeated if successfully completed at Level 2. |

¹ m.c.q. ⇒ multiple choice questions

² M&P ⇒ Materials and Processes

³ The General paper; EMC Sector Codes & Applications paper; and the Procedure Writing marks are weighted. A composite grade ≥80% is required.

⁴ Written Procedure Examination

This four hour examination **must** be completed by those seeking Level 3 certification in a **first method**.

Because writing a comprehensive NDT procedure, which meets industrial standards, would normally take many days to complete, the NDT Certifying Agency will provide the applicant, at the time of application, with a pretest package having all the information and details needed to prepare for this examination.

⁵ Written Procedure Review Examination

Candidates seeking Level 3 certification in a **second and subsequent method** have the option of completing a one and one-half hour procedure review examination.

To complete this examination, the candidate will be handed a Procedure which he/she is to assume comes from their staff for review and approval. The candidate, as the responsible Level 3 individual for the company in question, must review the Procedure and identify all that is unsatisfactory or incorrect with the document. The candidate is required to write what is unsatisfactory or incorrect directly in the Procedure, adjacent to the problem area. An example of this will be shown in the Procedure to be reviewed.

The candidate must report *at least* 10 problem areas or deficiencies with the Procedure document. Deficiencies may include any of the following: no cover sheets, no provision for approval signatures, approval signatures by unauthorized personnel, missing or incorrect information in headers, missing attachments/references, missing sections, incorrect paragraph numbering, contradicting technical data, technical data contrary to good practice, unclear statements, inconsistent formatting of the document, information placed in wrong sequence, typographical errors, etc.

E.2 REFERENCES TO PREPARE FOR THE LEVEL 3 WRITTEN EXAMINATIONS

General Paper:

1. 48-GP-4M - Study Outline
2. Can/CGSB 48.5-95 (48-GP-5M) - Manual
Prepared by Committee on Nondestructive Testing, Radiography Method
Published by Canadian General Standards Board
3. Radiography in Modern Industry, Published by Eastman Kodak Company
4. Nondestructive Testing Handbook, First and Second Editions, Volumes One and Three
Prepared by Lawrence E. Bryant, Paul McIntire, Robert C. McMaster
Published by American Society for Nondestructive Testing

EMC-Codes & Applications Paper:

At the present, five (5) codes/specifications are used for Level 3 EMC codes and applications paper:

1. CSA Z184M
2. ASTM E 1025-84 Hole Type Image Quality Indicators Used for Radiography
3. Military Standard Inspection Radiographic MIL-STD-453C
4. MIL-1-6865 (ASG)
5. ASTM E 94 - Standard Practice for Radiographic Testing

Note:

New codes and questions are added periodically. It is recommended that candidates **do not** purchase these publications, but rather that they familiarize themselves with the general layout of codes and standards.

Basic Paper:

1. Materials and Processes for NDT Technology
By ASNT
2. Basic Metallurgy for Nondestructive Testing
By British Institute of NDT
3. Why Metals Fail, chapter 2
By R.D. Barer and B.F. Peters
4. Qualification and Certification of Nondestructive Testing Personnel CAN/CGSB - 48.9712
5. Manufacturing Processes
By Vernon L. Stokes

Note:

A general familiarity with capabilities and limitations of other NDT methods is required for the Basic paper.

Radiation Protection Paper:

1. Radiography in Modern Industry
By Eastman Kodak Company
2. Nondestructive Testing Handbook, Second Edition, Volume Three
Prepared by Lawrence E. Bryant, Paul McIntire, Robert C. McMaster
Published by American Society for Nondestructive Testing
3. Can/CGSB 48.975-95 Standard
4. Canadian Nuclear Safety Commission Act and Regulations

Written Procedure Examination

As indicated in E.1, notes 4 and 5, the NDT candidate will be provided with, at the time of application, a pretest package having all the information and details needed.

*References are based on the Recommended Training Course Guidelines of
Standard CAN/CGSB 48.9712 for the General and EMC Papers*

E.3 SAMPLE QUESTIONS FOR THE LEVEL 3 WRITTEN EXAMINATIONS

Level 3 General Examination:

1. Radium:
 - a) is a daughter product of radon.
 - b) has a very short half-life.
 - c) is an artificially made isotope.
 - d) a metallic element.
2. High-energy photons of 1.02 MeV or greater typically interact with matter by which one of the following:
 - a) photoelectric process.
 - b) Compton scattering process.
 - c) pair production process.
 - d) photodisintegration process.

3. An anode in which the target is located at the bottom of an opening or a "pocket" is frequently used in industrial x-ray tubes for improving the distribution of the high voltage field. This type of anode is referred to as a:
 - a) rotating anode.
 - b) hot anode.
 - c) hooded anode.
 - d) line-focus anode.
4. Cobalt 59:
 - a) is an element different than that of Cobalt 60.
 - b) transforms to Cobalt 60 after capturing a neutron.
 - c) emits gamma radiation which is of different energies than Cobalt 60.
 - d) both a) and b) are correct.
5. Which is not an advantage of a linear accelerator for producing x-rays?
 - a) low cost
 - b) high radiation output
 - c) small focal spot dimensions
 - d) light weight
6. Fluoroscopic screens of zinc cadmium sulfide find occasional use in industrial applications. These screens normally are not subject to wear or deterioration from exposure to long term x-rays. Which one of the following will severely degrade this type of screen?
 - a) Cleaning of the screen with grain alcohol
 - b) Prolonged storage in a low-humidity environment will cause the crystal to hydrolyze
 - c) Exposure to ultraviolet radiation sources
 - d) Contamination with nickel, as little as one part per million will create severe afterglow problems
7. The intensity of a monoenergetic radiation after passing through a material may be calculated by the formula $I = I_0 e^{-\mu t}$. This formula does not take into account:
 - a) linear absorption.
 - b) scattered radiation.
 - c) half-value layer thickness.
 - d) attenuation.
8. Radiographic image magnification by placing the film at a distance from the object is practical when using linatrons and betatrons because:
 - a) natural magnification occurs with high energy x-rays
 - b) of their large beam spread
 - c) of the small focal spot size
 - d) high energy x-rays have such short wavelengths
9. Radiographic image quality may be adversely affected by poor subject contrast; this may be caused by:
 - a) insufficient absorption differences in the specimen.
 - b) excessive radiation energy for the application.
 - c) unwanted and excessive scatter.
 - d) all of the above.

10. The primary reason(s) why sight (under safelight conditions) development of radiographs should be avoided is:
- a) it is difficult to discern the image with the light output provided by a safelight.
 - b) the appearance of a developed but unfixed radiograph will be different when compared with properly finished film.
 - c) removal of the film from the developer will affect the development time.
 - d) film speed changes when exposed to a safelight.
11. Wire penetrameters are most commonly used in _____ codes.
- a) AFNOR
 - b) ASME
 - c) ASTM
 - d) DIN
12. Generally, the sensitivity and accuracy of thickness gauging of homogeneous materials by reflection methods is:
- a) superior to transmission gauging.
 - b) superior to fluorescence methods.
 - c) inferior to transmission gauging.
 - d) approximately the same as with transmission gauging.

Answers

- | | | | | | |
|------|------|------|-------|-------|-------|
| 1. D | 2. C | 3. C | 4. B | 5. A | 6. C |
| 7. B | 8. C | 9. D | 10. B | 11. D | 12. C |

Level 3 E.M.C. -Codes & Applications Examination:

1. Using geometric enlargement principles, determine the image size, if the object is 8 cm in diameter, the source-to-film distance is 1 meter and the object-film-distance is 3 cm.
- a) 86.95 mm
 - b) 46.13 mm
 - c) 89.88 mm
 - d) 49.88 mm
2. A source of iridium-192, whose half-life is 75 days, today provides an optimum exposure of a given test object in a period of 3.2 minutes. Five months from now, what exposure time would be required for the same radiographic density, under similar exposure conditions?
- a) 4.6 minutes
 - b) 1.6 minutes
 - c) 6.4 minutes
 - d) 12.8 minutes
3. Cobalt-60 has a half life of 5.4 years. After 3 years, what would be the strength of a source which was initially 1850 gigabecquerels?
- a) 3330 gigabecquerels
 - b) 1036 gigabecquerels
 - c) 1027 gigabecquerels
 - d) 1258 gigabecquerels

4. The absorption of radiation by a material varies:
 - a) directly with the square of the distance from the source.
 - b) directly with the thickness of the material.
 - c) inversely with the amount of scattering in the material.
 - d) in an approximately exponential manner with the thickness of the material.
5. Images of discontinuities close to the source side of the specimen become less clearly defined as:
 - a) source-to-object distance increases.
 - b) the thickness of the specimen increases.
 - c) the size of the focal spot decreases.
 - d) the thickness of the specimen decreases.
6. A wetting agent is added to an extra tank after final rinse in manual processing to:
 - a) stabilize hardener
 - b) eliminate dichroic stain
 - c) eliminate brown stain
 - d) eliminate water droplets
7. The radiographic appearance of diffraction patterns is mottled and may be confused with which one of the following sets of discontinuity indications?
 - a) Porosity or segregation
 - b) Oxidation or burn through
 - c) Porosity or burst
 - d) Misruns or porosity
8. When radiographing a specimen with a radiographic source, it is found that it is desirable to lengthen the source-to-film distance. With the source at the new location, the amount of radiation reaching the film will:
 - a) vary inversely with the square of the distance.
 - b) vary equally with the square of the distance.
 - c) will not change.
 - d) vary inversely with the distance.
9. Tungsten is the preferred target material for X-ray tubes used in industrial x-ray tubes because it provides a double advantage. One of the advantages is its:
 - a) efficiency in the production of x-rays is proportional to its atomic number.
 - b) low melting point.
 - c) efficiency in the production of x-rays is inversely proportional to its atomic number.
 - d) high curie point.
10. The principal gamma ray energies emitted by iridium-192 are:
 - a) 0.66, 0.84, 0.91 MeV
 - b) 0.31, 0.47, 0.60 MeV
 - c) 0.05, 0.05, 0.66 MeV
 - d) 0.15, 1.12, 0.18 MeV

Answers

- | | | | | |
|------|------|------|------|-------|
| 1. C | 2. D | 3. D | 4. D | 5. B |
| 6. D | 7. A | 8. A | 9. A | 10. B |

Level 3 Basic Examination:

1. The Canadian standard for the certification of nondestructive testing personnel is developed and maintained by:
 - a) the Canadian General Standards Board (CGSB).
 - b) standard committee composed of representatives from industry working under the auspice of CGSB.
 - c) Natural Resources Canada under the auspice of the Canadian General Standards Board.
 - d) a cooperative effort between various Canadian regulatory bodies and Natural Resources Canada.
2. The levels of certification covered by the CGSB standard on NDT personnel certification are:
 - a) trainee, Level 1, Level 2, Level 3.
 - b) apprentice, trainee, Level 1, Level 2, Level 3.
 - c) Level 1, Level 2, Level 3.
 - d) none of the above.
3. The pickling time will be least for:
 - a) low carbon steel.
 - b) high carbon steel.
 - c) alloy steels.
 - d) pickling time is the same for all three materials.
4. Which of the following may be considered an advantage of powder metallurgy as a manufacturing method?
 - a) Production of parts of closer tolerances
 - b) Mass production of hard-to-shape parts
 - c) Produce parts with a high strength to weight ratio
 - d) All of the above
5. Which of the following heat treatments usually follows a hardening treatment in order to make the steel more ductile?
 - a) Annealing
 - b) Tempering
 - c) Spheroidizing
 - d) Normalizing
6. Which of the following statements is correct?
 - a) Alkaline solutions are never used to clean aluminum alloys.
 - b) Acid solutions are never used to clean aluminum alloys.
 - c) Acid solutions are usually used to clean aluminum alloys.
 - d) Alkaline solutions are usually used to clean aluminum alloys.
7. Suitable combinations of two different materials each with specific properties may result in a composite that:
 - a) is better in terms of resistance to heat than either of the two components alone.
 - b) is stronger in tension per unit weight than either of the two components alone.
 - c) is stiffer per unit weight than either of the two components alone.
 - d) any of the above.

8. The practical length standards used by industry for gauging are:
 - a) angle slip gauges.
 - b) sine bars.
 - c) wavelengths of light emitted by different elements.
 - d) gauge blocks.
9. Thermal conductivity of a metal is an important factor to consider in making quality weldments because:
 - a) some metals, such as aluminum, have a low conductivity which results in weld defects due to localized heat build up.
 - b) some metals, such as stainless steel, have a high conductivity which results in lack of fusion defects as the heat is quickly removed from the weld zone.
 - c) in some metals, such as aluminum, very high temperature gradients are produced, causing stresses during cooling.
 - d) none of the above.
10. Fracture is a type of material failure. Of the following, which is another type of material failure?
 - a) Fracture mechanics
 - b) Low frequency dynamic loading
 - c) Permanent deformation
 - d) Elongation within the elastic range
11. To remove iron from the ore in a blast furnace, the following materials are added to the furnace to generate the desired chemical reactions:
 - a) coke, ore and oxygen.
 - b) bauxite, ore and air.
 - c) coke, ore, limestone and air.
 - d) coke, ore, limestone and bauxite.
12. The reason for putting ingots in a soaking pit is:
 - a) to control the direction of crystallization.
 - b) to homogenize the structure and composition of the ingots.
 - c) to permit slow cooling of the ingots.
 - d) to bring them to the temperature required for rolling.
13. An advantage of using green sand molds over dry sand molds is:
 - a) green sand molds are stronger than dry sand molds and thus are less susceptible to damage in handling.
 - b) surface finish of large castings are better when using green sand molds.
 - c) over-all dimensional accuracy of the mold is better with green sand.
 - d) there is less danger of hot tearing of castings when using green sand molds.
14. Shielded metal-arc welding is a process of joining metals which is:
 - a) fully automated.
 - b) semi-automated.
 - c) carried out manually.
 - d) all of the above.

15. In the resistance spot welding of low-carbon steel the heat generated is:
 - a) concentrated between the positive electrode and the work.
 - b) concentrated at the interface of the two plates to be welded.
 - c) concentrated between the negative electrode and the work.
 - d) evenly distributed in the work between the electrodes.
16. Which of the following is not a brazing process?
 - a) Furnace brazing
 - b) Induction brazing
 - c) Infrared brazing
 - d) Electron beam brazing
17. Completely recrystallized hot rolled steel products have:
 - a) exactly the same mechanical properties in the longitudinal and transverse directions.
 - b) superior mechanical properties in the direction of rolling.
 - c) superior mechanical properties in the transverse direction.
 - d) inferior mechanical properties than the original cast structure.
18. Care must be taken not to splash steel on the walls of the mold when pouring to prevent formation of surface defects like:
 - a) inclusions.
 - b) seams.
 - c) cold shots.
 - d) bursts.
19. Bursts are caused by:
 - a) casting at too low a temperature.
 - b) forging metal which is either too hot or too cold.
 - c) insufficient reduction in size is attempted in one forging operation.
 - d) none of the above.
20. Slag inclusions in welds are caused by:
 - a) wide weaving.
 - b) incomplete deslagging of a previous pass.
 - c) moisture entrapped in the joint.
 - d) both a) and b).
21. Cobalt-60 is reported to have a half life of 5.3 years. By how much should exposure time be increased (over that used initially to produce excellent radiographs when the cobalt-60 source was new) when the source is two years old?
 - a) no change in exposure time is needed.
 - b) exposure time should be about 11% longer.
 - c) exposure time should be about 37% longer.
 - d) exposure time should be from 62 to 100% longer.
22. In ultrasonics, increasing the length of the pulse to activate the search unit will:
 - a) decrease the resolving power of the instrument.
 - b) increase the resolving power of the instrument.
 - c) have no effect on the test.
 - d) will decrease the penetration of the sound wave.

23. Optimum magnetic particle inspection of a 50 mm inside diameter gear containing a keyway would require:
- circular method with magnetic field parallel to keyway.
 - circular method with magnetic field perpendicular to keyway.
 - using central conductor.
 - all of the above.
24. Which of the following physical properties, more than any other, determines what makes a material a good penetrant?
- viscosity.
 - surface tension.
 - wetting ability.
 - no one single property determines if a material will or will not be a good penetrant.
25. Direct current saturation coils would most likely be used when testing _____ by the eddy current method.
- steel
 - aluminum
 - copper
 - brass

Answers

- | | | | | | |
|-------|-------|-------|-------|-------|-------|
| 1. B | 2. C | 3. C | 4. D | 5. B | 6. D |
| 7. D | 8. D | 9. D | 10. C | 11. C | 12. D |
| 13. D | 14. C | 15. B | 16. C | 17. B | 18. C |
| 19. B | 20. D | 21. C | 22. A | 23. D | 24. D |
| | | | | | 25. A |

Levels 1, 2 & 3 Radiation Protection Examination:

- Geiger Mueller counters are used for radiation detection but are not recommended for industrial x-ray work because:
 - the high intensity of radiation causes the batteries to saturate and not work
 - high intensity radiation makes Geiger tubes brittle and fragile
 - high intensity radiation may cause the Geiger tube to saturate and give a low measure or no measure of the true exposure rate
 - high intensity radiation causes gas amplification by a factor of 10^{10} and this causes the Geiger tube to explode
- An exposure rate of 5 mR/h is measured just outside the steel door to an x-ray room. The half-value layer in lead for the transmitted x-rays is 0.09 cm. What thickness of lead would have to be added to the door to reduce the exposure rate to 1 mR/h?
 - 0.21 cm
 - 0.018 cm
 - 2.25 cm
 - 0.45 cm

3. The HVL of lead to control leakage from an x-ray tube operating at 200 kV is .4 mm. What thickness of lead would be required to reduce this leakage by a factor of 16?
 - a) 0.4 mm
 - b) 0.8 mm
 - c) 1.6 mm
 - d) 4.8 mm
4. Absorbed dose, no matter what its units are given in, is a measure of:
 - a) energy deposited in a unit mass
 - b) effective biological damage
 - c) ionizations in a unit volume
 - d) the product of a and b
5. The tenth value layer of lead for 250 kVp x-rays is 2.9 mm. What thickness of lead would be needed to reduce the exposure rate for this energy of radiation by a factor of 1000?
 - a) 2,900 mm
 - b) 0.25 mm
 - c) 8.7 mm
 - d) 87 cm
6. A person who receives a whole-body dose equivalent of 5 rems in one year:
 - a) may develop radiation sickness
 - b) should not have any medical x-rays
 - c) will be unaffected
 - d) may have an increased risk of cancer
7. For an uncontrolled area next to an x-ray room, the shielding should be sufficient to ensure that the maximum exposure is:
 - a) 2.5 mR per week
 - b) 10 mR per week
 - c) 25 mR per week
 - d) 100 mR per week
8. A counter placed 18cm from an energized X-Ray tube reads 72,000 cpm (counts per minute). When measured at a new distance the reading is 44,100 cpm. What is the new distance?
 - a) 21 cm
 - b) 22 cm
 - c) 23 cm
 - d) 24 cm
9. In making an x-ray exposure, you find the dose rate at 2 meters from the x-ray tube is 1200 mR/h. What would be the dose rate at 8 meters?
 - a) 75 mR/h
 - b) 100 mR/h
 - c) 200 mR/h
 - d) 300 mR/h

10. The maximum annual whole-body dose that an x-ray worker is permitted to receive is:
 - a) 5 millisieverts
 - b) 50 millisieverts
 - c) 500 millisieverts
 - d) 5,000 millisieverts
11. An x-ray tube operating at 200 kVp and 4 mA is suitable for examining 1/4" thick steel pipe. What is the energy of the x-rays produced with this technique?
 - a) 800 kVp
 - b) .8 kVp
 - c) up to 200 keV
 - d) 0.8 MeV
12. Given the field at 2.5 m from an IR192 source is 2 μ Gy/hr, what distance could you approach before the field rose to 25 μ Gy/hr?:
 - a) 0.21 m
 - b) 0.50 m
 - c) 0.67 m
 - d) 0.71 m
13. Maximum annual dose limits for non-atomic radiation workers is:
 - a) the same as ARW's
 - b) 1/2 allowed an ARW
 - c) 1/10 allowed an ARW
 - d) 1/100 allowed an ARW
14. Given the HVL for 400 kV x-rays is 7.6 mm and a field of 10 Gy/hr. How many HVL of lead are needed to reduce the field to 1 Gy/hr?:
 - a) 10
 - b) 5.4
 - c) 3.3
 - d) 1.2
15. A dose equivalent of 50 millisieverts is equal to:
 - a) 5 millirems
 - b) 50 millirems
 - c) 0.5 rem
 - d) 5 rems

Answers

- | | | | | | | | |
|------|------|-------|-------|-------|-------|-------|-------|
| 1. C | 2. A | 3. C | 4. A | 5. C | 6. D | 7. B | |
| 8. C | 9. A | 10. B | 11. C | 12. D | 13. C | 14. C | 15. D |

E.4 GENERAL INFORMATION FOR THE LEVEL 2 PRACTICAL EXAMINATIONS

1. The level 2 Radiography practical examination is a closed book examination. **No** books or notes other than those provided will be permitted during the test. A scientific calculator may be used provided it does not contain information or established programs which provide solutions to examination problems.
The duration of the practical test is two (2) days.
2. The candidate shall be shown the operation and placement of equipment and accessories required to complete the test.
3. The candidate will be shown the accessible surfaces of the test specimens and reference samples.
4. No surface preparations are permitted on the test specimens, they must be used as is.
5. No markings shall be placed on equipment, tests pieces and reference samples.
6. The candidate is **not allowed** to take the paperwork nor the test specimens out of the laboratory. Thus, all reporting must be completed within the testing room or facility. At the end of each day all paperwork is given to the supervisor and will be returned to the candidate the following day. This process will be repeated until the time limit is reached.
7. Candidates' questions will be answered unless the question is a test requirement. A supervisor may refuse to answer any question he considers to be part of the test.
8. Candidates will be given the opportunity to give feedback concerning the practical test. After completing the test, simply fill in and return the comment sheet provided. Hand in the comment sheet to the test supervisor or complete it at home and send directly to:

Richard Wood
NDT Certifying Agency
Natural Resources Canada
568 Booth Street, Ottawa, Ontario K1A 0G1

Tel: (613) 992-9276 Fax: (613) 943-8297

Note: There is concern about candidates who appear confused and unsure of themselves while attempting their practical test. It is the prerogative of the supervisor to discuss this situation with the candidate and, in the extreme, terminate the practical test.

E.5 TEST PROGRAM FOR THE LEVEL 2 PRACTICAL EXAMINATIONS

The candidate is required to do the following:

General Practical Test {if not done at Level I}

- A. Perform one (1) calibration test (Exposure curve)

EMC Practical Test

B. Inspect 4 specimens and prepare 4 techniques:

- one (1) heavy metal casting/forging and prepare a technique record;
- one (1) light metal casting/forging and prepare a technique record;
- two (2) welded specimens. One specimen is to be inspected using Gamma. A technique record will be prepared for each welded specimen

The technique for each specimen must be completed in a manner that will permit a level 1 Radiographic inspector to follow your steps and duplicate your results.

C. Interpret 26 radiographs

A. Preparation of an Exposure Curve

There are many types of exposure curves and the candidate may choose any type with which he/she is familiar. The most popular curve is where thickness of material is plotted against exposure for specified K.V. levels on semi-log graph paper.

For exposure curves other than the ones plotted on semi-log graph paper, the candidate may be required to supply his/her own graph paper.

The candidate will be given a sloped metal wedge, semi-log graph paper and a blank data sheet.

The candidate will:

- take the exposures for the K.V. energy designated by the supervisor;
- locate and clearly mark on the resulting radiographs where the required density (2.0) has been found and record the data; and
- plot the data points as derived from the radiographs and draw the exposure curve.

Note: The plotted data points must be quite evident to the examiner.

B. Preparation and Development of Radiographic Techniques

The candidate will be provided with:

- the test samples;
- a specification which will dictate the requirements and limitations for all techniques
- the current isotope decay curve;
- film characteristic curves;
- logarithmic and anti-logarithmic tables;
- source size and effective x-ray focal spot size;
- sketches of the test specimen with the exception of the gamma test;
- exposure curves.

Cautionary Note:

After the candidate has taken his/her exposures for the curve required in Part I of the exam, the candidate will be supplied with the appropriate exposure curves for this equipment. It should be noted that, although the Test Centre supplies each candidate with exposure curves, it should not be assumed that the exposure curves are accurate for all the test specimens. This is especially true for the light alloys. Following a test shot, the candidate is expected to have the necessary wherewithal to quickly zero-in on the correct exposures.

Coverage of the Test Specimen

The test specimens are to be considered critical all over and must be radiographed 100% with the required sensitivity and unsharpness as stated in the supplied specification. The radiography of welds includes the weld only and where feasible approximately one centimetre of the adjacent parent material.

The limits of the coverage for each radiograph must be indicated on the radiograph. This may be shown by lead numbers or arrows placed on the specimen or by marking the radiograph with film-marking crayons.

Where identical cross sections of test specimens are inspected by a series of radiographs, each with identical exposure parameters, then only the first exposure of that series need be taken and submitted provided this series is properly indicated by the technique.

The area on the radiograph where pertinent film density readings are taken by the candidate must be circled in order that the examiner be able to verify the candidate's calculations.

C. Interpretation of Radiographs

Instructions are provided with the radiographs to be interpreted.

When doing the interpretation test, the following items are provided to the candidate:

- a variable high intensity viewer;
- interpretation sheets;
- a magnifying glass;
- a ruler and
- cotton gloves.

General Information

Where the candidate does not follow clearly stated guidelines (density, UG, sensitivity, etc.) the candidate's work is subject to rejection unless there are extenuating circumstances. These circumstances must be stated and supported by the invigilator.

There may be different ways to radiograph a test specimen. Grading of a technique will be according to the guidelines of coverage, radiograph density, sensitivity attained and economy of film and exposures.

Test exposures must be sent to the NDT Certifying Agency and must be separated from the final technique. A sample technique is provided for the candidates' information.

A supervisor may refuse to answer any question which he considers part of the test. Scribbled work is subject to rejection.

The candidate will use the film that is available at the centre. The candidate may be required to load and develop his/her own film. The film size should not exceed 8" X 10". It is preferred that the candidate use regular size film only.

The part should be considered a production part, therefore the cost of inspection due to the time involved and the number of films used, will be of importance.

Specific Instructions for Gamma Exposure

The candidate:

- will be supplied with a charged dosimeter and the reading will be recorded after the completion of examination;
- will develop a radiographic technique for the test specimen using the same procedure as for the x-ray technique;
- will be instructed in the safe operation of gamma camera;
- will be supplied with all safety devices and accessories for the gamma exposure;
- must follow safe working practices and ensure that individuals are never exposed to ionizing radiation beyond the permissible dose.

Demonstration Radiographic Technique

Radiographic techniques must contain all the testing parameters necessary for an individual with limited experience to duplicate your work and maintain the required level of inspection.

The following technique is intended as a guide for those candidates who wish some assistance.

It is assumed that the recipient of the technique is someone who has limited knowledge of radiography. Therefore, the transfer of information from the candidate to the recipient must be clear, concise and neat. An example of a complete and comprehensive technique is shown in Figure 1.

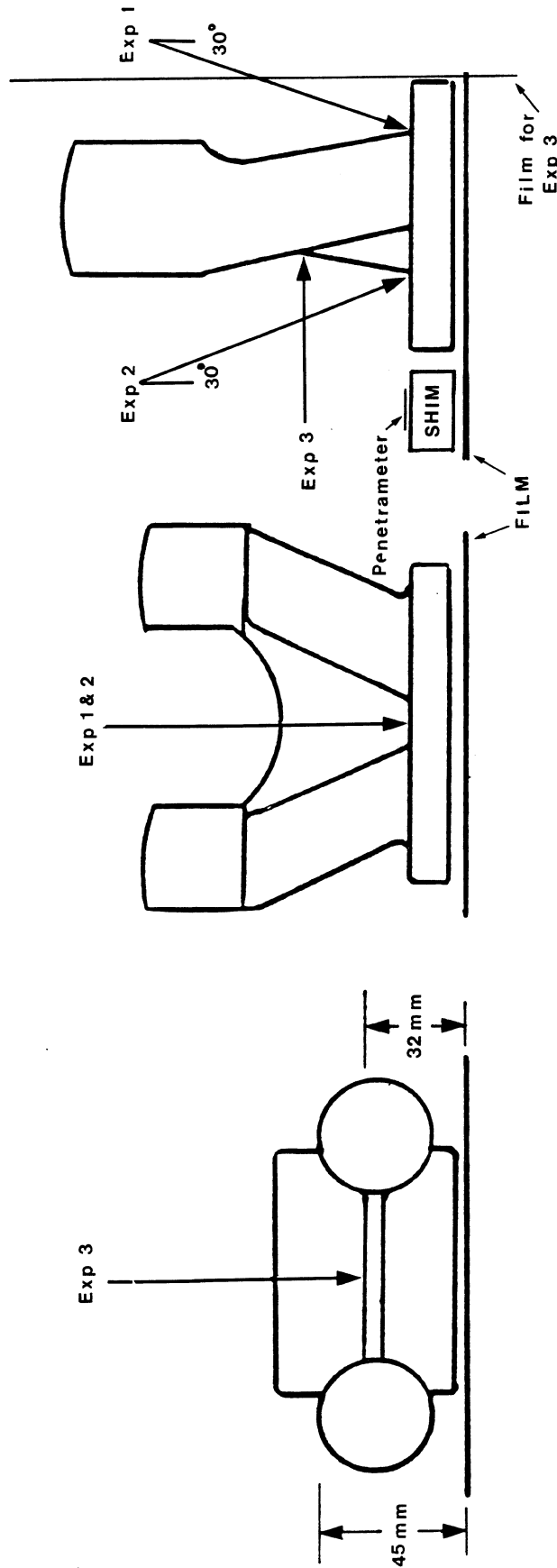
A comprehensive method of radiograph identification, relating each film to the technique, must be devised by the candidate.

INDUSTRIAL RADIOGRAPHY

NAME: _____
DATE: _____

SAMPLE TECHNIQUE

SOURCE SIZE
Lgth Wdth Diag
(mm) (mm) (mm)
X-RAY _____
GAMMA _____



| EXPOSURE NUMBER | kV | MAS | THICKNESS | F.P.D. | FILM | SCREENS | FOCAL SPOT SIZE | U.G. | PEN. | ANGLE | EQUIPMENT | REMARKS |
|-----------------|----|-----|---------------|---------|---------|---------|-----------------|-------------|-----------|-------|-----------|--------------------|
| 1 | 80 | 600 | 8 mm | 1 metre | Kodak M | NIL | 2.5 mm | .02 | ASTM #6 | 30° | 160 kV | |
| 2 | 80 | 600 | 8 mm | 1 metre | Kodak M | NIL | 2.5 mm | .02 | #6 | 30° | 160 kV | Duplicate of Exp 1 |
| 3 | 60 | 800 | 4 mm 28 mm | 1 metre | Kodak M | NIL | 2.5 mm | .08 .118 | #3 #22 | 90° | 160 kV | |

FIGURE 1

E.6 HINTS FOR SUCCESSFUL LEVEL 2 PRACTICAL EXAMINATIONS

1. Budget your time. Don't spend too much time on one part of the test at the expense of the other parts. We suggest you devote:
 - 1 hour -introduction/reading instructions
 - 2.25 hour -each technique ($2.25 \text{ hr} \times 4 = 9 \text{ hrs}$)
 - 2 hours -exposure curve (if required)
 - 2 hours -x-ray interpretation
 - assess the strength of the IR192 source. If low, be prepared to do this technique first as longer exposures will be required.
 - spare time, while waiting for exposures to be developed, may be used interpreting radiographs. Interpretation radiographs are not allowed to be removed from the test centre at any time.
2. Do not hesitate to ask questions to the supervisor if you encounter problems. If the supervisor cannot answer your question because it's part of the test, he or she will tell you so.

Common Errors Which Result in Failure of the Level 2 Industrial Radiography Practical Examinations:

1. Candidate not adhering to density limits as laid down in the standard supplied by the test centre.
2. Candidate unable to calculate unsharpness (UG) and develop techniques within parameters of standard supplied by the test centre.
3. Candidate unable to identify areas of interest on test samples and inspect for same.
4. Candidate unable to select/locate penetrameters properly.
5. Candidate unable to produce a legible technique with sufficient information for a Level 1 with limited experience to perform/achieve equal results.