1. SCOPE

1.1 This method covers apparatus, materials, and procedures for capping freshly molded concrete cylinders with neat cement and hardened cylinders and drilled concrete cores with high-strength gypsum plaster or sulfur mortar.

1.2 The values stated in English units are the preferred standard.

1.3 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific precaution statements, see Sections 4.3 and 6.2.3.1.

2. REFERENCED DOCUMENTS

2.1 AASHTO Standards:

- M 85 Portland Cement
- T 22 Compressive Strength of Cylindrical Concrete Specimens
- T 106 Compressive Strength of Hydraulic Cement Mortar (Using 2-in. (50-mm) Cube Specimens)
- M 240 Blended Hydraulic Cement

2.2 ASTM Standards:

- C 287 Specification for Chemical-Resistant Sulfur Mortar
- C 472 Physical Testing of Gypsum, Gypsum Plasters and Gypsum Concrete

2.3 ANSI Standards:

- B 46.1 Standard for Surface Texture

3. SIGNIFICANCE AND USE

3.1 This practice describes procedures for providing plane surfaces on the end surfaces of freshly molded concrete cylinders, hardened cylinders, or drilled concrete cores when the end surfaces do not conform with the planeness and perpendicularity requirements of applicable standards.

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1 This Test Method is based on AASHTO T 231-05.
4. CAPPING EQUIPMENT

4.1 *Capping Plates* — Neat cement caps and high-strength gypsum-plaster caps shall be formed against a glass plate of at least ¼ in. (6 mm) thick, a machined metal plate at least 0.45 in. (11 mm) thick (Note 1), on a polished plate of granite or diabase at least 3 in. (75 mm) thick. Sulfur mortar caps shall be formed against similar metal or stone plates. In all cases, plates shall be at least 1 in. (25 mm) greater in diameter than the test specimen and the working surfaces shall not depart from a plane by more than 0.002 in. (0.05 mm) in 6 in. (150 mm). The surface roughness of newly finished metal plates shall not exceed that set forth in Table 4 of the American National Standard for Surface Texture (ANSI B46.1) or 125 μin. (0.003 mm) for any type of surface and direction of lay. The surface when new shall be free of gouges, grooves, or indentations beyond those caused by the finishing operation. Metal plates that have been in use shall be free of gouges, grooves, or indentations greater than 0.010 in. (0.25 mm) deep or greater than 0.05 in.\(^2\) (32 mm\(^2\)) in surface area. If a recess is machined into the metal plate, the thickness of the plate beneath the recessed area shall be at least ½ in. (13 mm). In no case shall the recess in the plate be deeper than ½ in. (13 mm).

*Note 1:* In vertical capping devices, use of two-piece metal capping plates is advantageous as this facilitates refinishing of the capping surface should it become necessary to do so. In such devices, the lower section is a solid plate and the upper section has a circular hole which forms the recess. The two sections are customarily fastened together with machine screws. It is advantageous to have the upper surface of the lower plate case hardened. A Rockwell hardness of HRC 48 is suggested.

4.2 *Alignment Devices* — Suitable alignment devices such as guide bars or bull’s-eye levels shall be used in conjunction with capping plates to ensure that no single cap will depart from perpendicularity of cylindrical specimen by more than 0.5° [approximately equivalent to ¼ in. in 12 in. (3.2 mm in 305 mm)]. The same requirement is applicable to the relationship between the axis of the alignment device and the surface of a capping plate when guide bars are used. In addition, the location of each bar with respect to its plate must be such that no cap will be off-centered on a test specimen by more than 1/16 in. (1.6 mm).

4.3 *Melting Pots for Sulfur Mortars* — Pots used for melting sulfur mortars shall be equipped with automatic temperature controls and shall be made of metal or lined with a material that is nonreactive with molten sulfur.

*Caution:* Melting pots equipped with peripheral heating will ensure against accidents during reheating of cooled sulfur mixtures which have a crusted-over surface. When using melting pots not so equipped, a buildup of pressure under the hardened surface crust on subsequent reheating may be avoided by use of a metal rod which contacts the bottom of the pot and projects above the surface of the fluid sulfur mix as it cools. The rod should be of sufficient size to conduct enough heat to the top of reheating to melt a ring around the rod first and thus avoid the development of pressure. A large metal ladle can be substituted for the rod.
Sulfur melting pots should be used under a hood to exhaust the fumes to outdoors. Heating over an open flame is dangerous because the flash point of sulfur is approximately 440°F (227°C) and the mixture can ignite due to overheating. Should the mixture start to burn, covering will snuff out the flame. The pot should be recharged with fresh material after the flame has been extinguished.

5. CAPPING MATERIALS

5.1 The strength of the capping material and the thickness of the caps shall conform to the requirements of Table 1.

<table>
<thead>
<tr>
<th>Cylinder Compressive Strength MPa (psi)</th>
<th>Minimum Strength of Capping Material</th>
<th>Maximum Average Thickness of Cap</th>
<th>Maximum Thickness Any Part of Cap</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.5 to 50 MPa (500 to 7000 psi)</td>
<td>35 MPa (5000 psi) or cylinder strength, whichever is greater</td>
<td>6 mm (0.25 in.)</td>
<td>8 mm (0.31 in.)</td>
</tr>
<tr>
<td>greater than 50 MPa (7000 psi)</td>
<td>Compressive strength not less than cylinder strength, except as provided in Section 5.1.1</td>
<td>3 mm (0.125 in.)</td>
<td>5 mm (0.20 in.)</td>
</tr>
</tbody>
</table>

**Compressive Strength and Maximum Thickness of Capping Materials**

Table 1

5.1.1 If sulfur mortar, high strength gypsum plaster and other materials except neat cement paste are to be used to test concrete with a strength greater than 50 MPa (7000 psi), the manufacturer or the user of the material must provide documentation:

- that the average strength of 15 cylinders capped with the materials is not less than 98 percent of the average strength of 15 companion cylinders capped with neat cement paste or 15 cylinders ground plane to within 0.05 mm (0.002 in.),
- that the standard deviation of the strengths of the capped cylinders is not greater than 1.57 times that of the standard deviation of the reference cylinders,
- that the cap thickness requirements were met in the qualification tests, and
- of the hardening time of the caps used in the qualification tests.

5.1.2 Additionally, the qualification test report must include the compressive strength of 50-mm (2-in.) cubes of the material qualified and of neat cement paste cubes, if used. Capping materials conforming to these requirements are permitted to be used for cylinders with strengths up to 20 percent greater than the concrete tested in these qualification tests. The manufacturer must requalify lots of material manufactured on an annual basis or whenever there is a change in the formulation of the raw materials. The user of the material must retain a copy of the qualification results, and the dates of manufacture of material qualified and of the material currently being used. See Table 2.
Note-Manufacturer: Testing Supplies Co.

Capping Material: Super Strong AAA-Sulfur mortar

Lot: 12a45  Date Tested: 11/3/98

Signed by:___________________________________________

(Testing Agency and Responsible Official)

<table>
<thead>
<tr>
<th>Item</th>
<th>Capping Material</th>
<th>Control Cylinders</th>
<th>Ratio</th>
<th>Criteria</th>
<th>Pass/Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete Cylinder Test Data</td>
<td>Sulfur</td>
<td>Ground</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of Capping Material</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Concrete Strength, MPa (psi)</td>
<td>76.2 (11,061)</td>
<td>75.9 (11,008)</td>
<td>1.005</td>
<td>&gt;0.98 Xc</td>
<td>Pass</td>
</tr>
<tr>
<td>Standard Deviation MPa (psi)</td>
<td>2.59 (376)</td>
<td>1.72 (250)</td>
<td>1.504</td>
<td>≤1.57 C</td>
<td>Pass</td>
</tr>
<tr>
<td>Number of cylinders tested</td>
<td>15</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cap age when cylinders tested</td>
<td>7 days</td>
<td>n/a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capping Material Test Data</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average cap thickness mm (in.)</td>
<td>2.8 (0.11)</td>
<td>n/a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compressive strength of 50-mm (2-in.) cubes, MPa (psi)</td>
<td>91 (12,195)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cube age when tested</td>
<td>7 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Maximum concrete strength qualified, MPa (psi)

\[1.2 \text{ Av. Str} = 91.5 (13,273)\]

Sample Report of Qualifications of a Capping Material

### Table 2

5.1.3 The compressive strength of capping materials shall be determined by testing 50-mm (2-in.) cubes following the procedure described in Test Method T 106. Except for sulfur mortars, molding procedures shall be as in Test Method T 106 unless other procedures are required to eliminate large entrapped air voids. See test methods for alternative compaction procedures. Cure cubes in the same environment for the same length of time as the materials used to cap specimens.

5.1.4 The strength of the capping material shall be determined on receipt of a new lot and at intervals not exceeding three months. If a given lot of the capping material fails to conform to the strength requirements, it shall not be used, and strength tests of the replacement material shall be made weekly until four consecutive determinations conform to specification requirements.
5.2 Neat Hydraulic Cement Paste:

5.2.1 Make qualification test of the neat hydraulic cement paste prior to use for capping to establish the effects of water-cement ratio and age on compressive strength of 50-mm (2-in.) cubes (Note 2).

*Note 2:* The cements used generally conform to Specification M 85 Types I, II, or III; however, Specification M 240 blended cements, calcium aluminate or other hydraulic cements producing acceptable strength may be used.

5.2.2 Mix the neat cement paste to the desired consistency at a water-cement ratio equal to or less than that required to produce the required strength, generally two to four hours before the paste is to be used (Note 3). Remix as necessary to maintain acceptable consistency (Note 4). Some re-tempering of the paste is acceptable if the required water-cement ratio is not exceeded. Optimum consistency is generally produced at water-cement ratios of 0.32 to 0.36 by mass for Type I and Type II cements and 0.35 to 0.39 by mass for Type III cements.

*Note 3:* Freshly mixed pastes tend to bleed, shrink, and make unacceptable caps. The two to four hour period is generally appropriate for Portland cements.

*Note 4:* The required consistency of the paste is determined by the appearance of the cap when it is stripped. Fluid paste results in streaks in the cap. Stiff paste results in thick caps.

5.3 High-Strength Gypsum Cement Paste:

5.3.1 No fillers or extenders may be added to neat high-strength gypsum cement paste subsequent to the manufacture of the cement (Note 5). Qualification tests shall be made to determine the effects of water-cement ratio and age on the compressive strength 50-mm (2-in.) cubes. Retarders may be used to extend working time, but their effects on required water-cement ratio and strength must be determined (Note 6).

*Note 5:* Low-strength molding plaster, plaster of paris, or mixtures of plaster of paris and portland cement are unsuitable for capping.

*Note 6:* The water-gypsum cement ratio should be between 0.26 and 0.30. Use of low water-cement ratios and vigorous mixing will usually permit development of 35 MPa (5000 psi) at ages of one to two hours. Higher water-gypsum cement ratios extend working time, but reduce strength.

5.3.2 Mix the neat gypsum cement paste at the desired water-cement ratio and use it promptly since it sets rapidly.
5.4 Sulfur Mortar:

5.4.1 Proprietary or laboratory prepared sulfur mortars are permitted if allowed to harden a minimum of two hours before testing concrete with strength less than 35 MPa (5000 psi). For concrete strengths of 35 MPa (5000 psi) or greater, sulfur mortar caps must be allowed to harden at least 16 hours before testing, unless a shorter time has been shown to be suitable as specified in Section 5.1.1.

5.4.2 *Determination of Compressive Strength*—Prepare test specimens using a cube mold and base plate conforming to the requirements of T 106 and a metal cover plate conforming in principle to the design shown in Figure 1 (Note 7). Bring the various parts of the apparatus to a temperature of 20 to 30°C (68 to 86°F), lightly coat the surfaces that will be in contact with the sulfur mortar with mineral oil and assemble near the melting pot. Bring the temperature of the molten-sulfur mortar in the pot within a range of 129 to 143°C (265 to 290°F), stir thoroughly, and begin casting cubes. Using a ladle or other suitable pouring device, quickly fill each of the three compartments until the molten material reaches the top of the filling hole. Allow sufficient time for maximum shrinkage, due to cooling, and solidification to occur (approximately 15 minutes) and refill each hole with molten material (Note 8). After solidification is complete, remove the cubes from the mold without breaking off the knob formed by the filling hole in the cover plate. Remove oil, sharp edges, and fins from the cubes and check the planeness of the bearing surfaces in the manner described in T 106. After storage at room temperature to the desired age, but not less than two hours, test cubes in compression following the procedure described in T 106 and calculate the compressive strength in MPa (psi).
### Dimensional Equivalents

<table>
<thead>
<tr>
<th>mm</th>
<th>6.4</th>
<th>12.7</th>
<th>22.2</th>
<th>44.5</th>
<th>102</th>
<th>254</th>
</tr>
</thead>
<tbody>
<tr>
<td>in.</td>
<td>¼</td>
<td>½</td>
<td>⅛</td>
<td>1¾</td>
<td>4</td>
<td>10</td>
</tr>
</tbody>
</table>

**FIGURE 1** Sketch of Cover for 50-mm (2-in.) Cube Mold

**Notes:**
All dimensions shown in millimeters unless otherwise noted. Sketch of Cover for 50-mm (2-in.) Cube Mold

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**Figure 1**
**Note 7:** If desired, a plane phenol formaldehyde (bakelite) plate of 3 mm (0.125 in.) thickness, provided with three appropriately spaced filling holes, may be inserted between the cover plate and the mold to slow the rate of cooling of test specimens.

**Note 8:** The second filling helps to prevent the formation of a large void or shrinkage pipe in the body of a cube. However, such defects may occur no matter how much care is exercised, and it therefore is advisable to inspect the interior of tested sulfur mortar cubes for homogeneity whenever the strength values obtained are significantly lower than anticipated.

6. CAPPING PROCEDURES

6.1 *Freshly Molded Cylinders* — Use only neat Portland cement pastes (Note 9) to cap freshly molded cylinders. Make caps as thin as practicable. Do not apply the neat paste to the exposed end until the concrete has ceased settling in the molds, generally from 2 to 4 hours after molding. During the molding of the cylinder, strike off the upper end even with or slightly below the plane of the rim of the mold. Mix the neat paste to a stiff consistency 2 or 4 hour before it is to be used in order to allow the paste to go through its period of initial shrinkage. The strength of the paste will depend on the consistency, water-cement ratio, curing, brand, and type of cement. For Type I and Type II cement pastes, the optimum consistency is generally produced at a water-cement ratio of 0.32 to 0.36 by mass. For Type III cement, the water ratio should generally be between 0.35 to 0.39 by mass. The paste will stiffen during the 2 to 4 hours waiting period and the use of re-tempering water is not recommended. However, if re-tempering water is used, the amount should not increase the water-cement ratio by more than 0.05 by mass. Remove free water and laitance from the top of the specimen immediately before capping. Form the cap by placing a conical mound of paste on the specimen and then gently pressing a freshly oiled capping plate on the conical mound until the plate contacts the rim of the mold. A very slight twisting motion may be required to extrude excess paste and minimize air voids in the paste. The capping plate must not rock during this operation. Carefully cover the capping plate and mold with a double layer of damp burlap and a polyethylene sheet to prevent drying. Removal of the capping plate after hardening may be accomplished by tapping the edge with a rawhide hammer in a direction parallel to the plane of the cap.

**Note 9:** Type I neat cement caps generally require at least 6 days to develop acceptable strength and Type III neat cement caps at least 2 days. Dry concrete specimens will absorb water from freshly mixed neat cement paste and produce unsatisfactory caps. Neat cement paste caps will shrink and crack on drying and, therefore, should be used only for specimens which are to be moist-cured continuously until time of testing.
6.2  **Hardened Concrete Specimens:**

6.2.1  **General** — Caps should be about \( \frac{1}{8} \) in. (3 mm) thick, and in no instance shall any part of a cap be more than \( 5/16 \) in. (8 mm) thick. If either or both ends of a specimen have coatings or deposits of oily or waxy materials that would interfere with the bond of the cap, remove such coatings or deposits. If necessary, the ends of a specimen may be slightly roughened with a steel file or wire brush to produce proper adhesion of the cap. If desired, capping plates may be coated with a thin layer of mineral oil or grease to prevent the capping material from adhering to the surface of the plate.

Form the caps as described in Section 6.1 using capping plates described in Section 4.1 to achieve the alignment required in Section 4.2 (Note 10). Generally capping plates may be removed within 45 minutes with gypsum cement pastes and after 12 hours with neat cement paste, without visibly damaging the cap.

**Note 10:** A number of methods have been used to obtain the desired perpendicularity of the cap to the axis of the cylinder. A mound of paste can be placed on a capping plate and the specimen lowered into it. A bull’s-eye level on the top of the cylinder helps obtain alignment. A mound of paste can be placed on top of the cylinder and a capping plate pressed into it, again using the bull’s-eye level. A better system is to make a half-height mold with a vertical split so that it can be slipped over the hardened cylinder. A clamp is used to position the mold and to ensure the required cap thickness. The mound of paste can then be placed either on a capping plate or on top of the cylinder and pressed until the plate contacts the mold. As noted earlier, very stiff paste may require excessive force and produce thick or defective caps.

6.2.2  **End Condition** — The distance of any point on an uncapped end from a plane that passes through the highest point of the end surface and is perpendicular to the axis of the cylinder shall not exceed 3 mm (0.125 in.) (Note 11). If the end exceeds this limit, the end of the cylinder shall be cut, lapped or ground prior to capping.

**Note 11:** This provision is to control the difference between the thickest and thinnest parts of a cap. The distance may be checked using a square with one blade touching the cylinder parallel to the cylinder axis and the other blade touching the highest point on the end of the cylinder. The distance between the blade of the square and the lowest point on the end of the cylinder is measured.

6.2.3  **Capping with High-Strength Gypsum Plaster** — Mix high-strength plaster for capping, using the same percent of mixing water as was used in making the qualification test described in Section 5.2.1 (Note 12).

**Note 12:** High-strength gypsum caps soften and deteriorate on contact with water and cannot be used on freshly mixed concrete or stored in a moist room for more than very brief periods up to four hours.
6.2.4 **Capping with Sulfur Mortar** — Prepare sulfur mortar for use by heating to about 265°F (130°C), as periodically determined by an all-metal thermometer inserted near the center of the mass. Empty the pot and recharge with fresh material at frequent enough intervals to ensure that the oldest material in the pot has not been used more than five times (Note 13). Fresh sulfur mortar must be dry at the time it is placed in the pot as dampness may cause foaming. Keep water away from molten sulfur mortar for the same reason. The capping plate or device should be warmed slightly before use to slow the rate of hardening and permit the production of thin caps. Oil the capping plate lightly and stir the molten sulfur mortar immediately prior to pouring each cap. The ends of moist-cured specimens shall be dry enough at the time of capping to preclude the formation of steam or foam pockets under or in the cap larger than \( \frac{1}{4} \) in. (6 mm) in diameter. To ensure that the cap shall be bonded to the surface of the specimen, the end of the specimen shall not be oiled prior to application of the cap. When using a vertical device, pour the mortar onto the surface of the capping plate, lift the cylinder above the plate and contact the cylinder sides with the guides; slide the cylinder down the guides onto the capping plate while keeping constant contact with the alignment guides. The cylinder end should continue to rest on the capping plate with cylinder sides in positive contact with the alignment guides until the mortar has hardened. Use sufficient material to cover the cylinder end after the sulfur mortar solidifies. The sulfur mortar cap may be tapped or rubbed with a light metal implement. If a hollow sound is produced, an unsatisfactory mortar cap is indicated. See Section 25.16 of the ASTM Manual of Aggregate and Concrete Testing.

**Note 13:** Reuse of material must be restricted in order to minimize loss of strength and pourability occasioned by contamination of the mortar with oil miscellaneous debris, and loss of sulfur through volatilization.

6.2.4.1 **Caution:** Hydrogen sulfide gas may be produced during capping when sulfur mortar is contaminated with organic materials such as paraffin or oil. The gas is colorless and has a notoriously bad odor of rotten eggs; however, the odor should not be relied upon as a warning sign, since the sensitivity to the odor disappears rapidly on exposure. High concentrations are lethal and less concentrated dosages may produce nausea, stomach ache, distress, dizziness, headache, or irritation of the eyes. For this and other reasons, it is desirable that the melting pot be located under a hood or near an exhaust fan and that the capping area be well ventilated.

6.2.4 **Daily Check** — During each day’s capping operation, planeness of the caps on at least three specimens representing the start, middle, and end of the run, shall be checked by means of a straight-edge and feeler gage, making a minimum of three measurements on different diameters to ensure that the surfaces of the caps do not depart from a plane by more than 0.05 mm (0.002 in.).
7. PROTECTION OF SPECIMENS AFTER CAPPING

7.1 Moist-cured specimens shall be maintained in a moist condition between the completion of capping and the time of testing by returning them to moist storage or wrapping them with a double layer of wet burlap. Specimens with gypsum plaster caps shall not be immersed in water and shall not be stored in a moist room for more than 4 hours. If stored in a moist room, the plaster caps shall be protected against water dripping on their surfaces.
APPENDIX
(Nonmandatory Information)

A1. COMPOSITION AND DETERMINATION OF LOSS ON IGNITION OF SULFUR MORTAR CAPPING MATERIALS

A1.1 Composition:

A1.1.1. Loss on ignition, percent 48 to 70 Residue after ignition, percent 30 to 52.

A1.2 Determination of Loss on Ignition – Obtain samples from caps on concrete cylinders or from cast specimens similar to caps in size and thickness. Divide each cap-size specimen into eight approximately equal triangular sections, and secure test samples by breaking either two or four of the triangular sections into small pieces with the fingers. Using a balance capable of determining mass to an accuracy of 0.01 g, measure out 20 to 25 g of fragmented material in a previously ignited, cooled, and tared Coors No. 3, high-form porcelain crucible. Place the crucible on a ring approximately 2 in. (50 mm) above a Terrel-type Bunsen burner and adjust the flame so that the sulfur burns slowly without spattering (Note 14). (see Section 4). When the sulfur has been completely consumed, adjust the burner for high heat and ignite the residue for 30 minutes. Cool the crucible and residue in a desiccator and determine the mass. Continue to ignite, cool, and determine the mass of the crucible until a constant mass is obtained. Calculate the percentage of loss on ignition C, as follows (Note 15):

\[ C = \frac{100}{A} \]

where:

A = original mass of sample less mass of the residue after ignition, and

B = original mass of sample.

NOTE 14– Where the filler is known or found to be composed of carbonate minerals, the ignition test shall be made at a carefully controlled temperature in the range from 600 to 650°C, to prevent calcinations of the mineral. Small amounts of plasticizer and carbon filler will be included in the reported value for loss on ignition using the simple test herein described.

NOTE 15: A referee procedure for the determination of the percent of sulfur contained in sulfur mortar may be found in ASTM C 287.
Performance Exam Checklist

Capping Cylindrical Concrete Specimens
FOP for AASHTO T 231

Participant Name __________________________ Exam Date ____________

Procedure Element
1. The tester has a copy of the current procedure on hand? ☐ ☐
2. All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present? ☐ ☐

Sulfur Only
1. Is the temperature taken and the mortar stirred at the beginning of the operation? ☐ ☐
2. Is the capping plate lightly oiled prior to use? ☐ ☐

Procedure Element (cont.)
3. Are perpendicularity guides or leveling devices used effectively? ☐ ☐
4. Are caps checked for planeness?
   a. If yes, how often? __________________________
5. Are cylinders kept moist after capping? ☐ ☐

First attempt: Pass ☐ Fail ☐ Second attempt: Pass ☐ Fail ☐

Signature of Examiner __________________________

Comments: