

Australian/New Zealand Standard®

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## **Winding wires**

### **Part 1: Enamelled round copper winding wires**

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## AS/NZS 1194.1:1996

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This Joint Australian/New Zealand Standard was prepared by Joint Technical Committee EL/3, Electric Wires and Cables. It was approved on behalf of the Council of Standards Australia on 21 February 1996 and on behalf of the Council of Standards New Zealand on 15 May 1996. It was published on 5 September 1996.

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# Australian/New Zealand Standard<sup>®</sup>

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## Winding wires

### Part 1: Enamelled round copper winding wires

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## PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee EL/3 on Electric Wires and Cables to supersede, in part, AS 1194.1—1984 and NZS/AS 1194.1—1984, *Winding wires*, Part 1: *Enamelled round copper winding wires*. This Standard is part of a series, the other parts being:

AS/NZS

1194.2 Enamelled rectangular copper winding wires

1194.3 Enamelled round aluminium winding wires

1194.4 Enamelled rectangular aluminium winding wires

1194.5 Test methods

Requirements and tests are equal or superior to those specified in IEC 317, *Specifications for particular types of winding wires* and IEC 851, *Methods of test for winding wires*. Acknowledgment is made of the assistance received from these documents.

This Standard differs from the 1984 edition as follows:

- (a) Test methods have been transferred to a new Part 5.
- (b) Colour coding for labels has been deleted.
- (c) Category of tests has been deleted.
- (d) Wires  $>0.100$  and  $\leq 0.250$  mm in diameter have been transferred from Table 2.8 to 2.9 and the breakdown voltages have been adjusted.
- (e) Mandrel diameters for flexibility, adherence and heat shock tests have been brought into line with IEC tables.
- (f) Requirements have been changed to match refrigerants in current use.
- (g) Wire overall diameters and increases due to insulation have been brought into line with IEC values.
- (h) A springiness test for conductor diameters greater than 1.6 mm and a temperature index test have been added.
- (i) The resistance to refrigerants test for PVA enamelled wire and the test for completeness of cure have been deleted.

The terms 'normative' and 'informative' have been used in this Standard to define the application of the appendix to which they apply. A 'normative' appendix is an integral part of a Standard, whereas an 'informative' appendix is only for information and guidance.

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## STANDARDS AUSTRALIA/STANDARDS NEW ZEALAND

**Australian/New Zealand Standard****Winding wires****Part 1: Enamelled round copper winding wires****SECTION 1 SCOPE AND GENERAL**

**1.1 SCOPE** This Standard applies to enamelled round copper winding wires intended to be used for windings of electrical equipment.

It specifies dimensions and material requirements for the conductor and enamelled covering.

**1.2 REFERENCED DOCUMENTS** The following documents are referred to in this Standard:

AS

2737 Copper drawing stock

AS/NZS

1194 Winding wires

1194.5 Part 5: Test methods

IEC

28 International standard of resistance for copper

172 Test procedure for the determination of the temperature index of enamelled winding wires

**1.3 DEFINITIONS** For the purpose of this Standard the definitions below apply.

**1.3.1 Conductor**—the bare metal remaining after removal of all covering.

**1.3.2 Crack**—an opening in the enamel covering which exposes the conductor to view at the stated magnification.

**1.3.3 Grade of enamel**—an expression used to designate the thickness of enamel covering. It is used in the form Grade 1, Grade 2 and Grade 3, the higher grade numbers designating thicker enamels.

**1.3.4 Increase in diameter due to enamel**—the difference between the overall diameter of the wire and the measured diameter of the conductor.

**1.3.5 Increase in diameter due to enamel plus bond layer**—the difference between the overall diameter of the wire and the measured diameter of the conductor.

**1.3.6 Loss of adhesion**—the absence of bond between the enamel and the conductor as exhibited by relative movement between the two.

**1.3.7 Overall diameter of wire**—the diameter of the wire measured across the final layer of covering.

**1.3.8 Temperature index**—the number corresponding to the temperature in degrees Celsius derived from the thermal endurance graph at 20 000 h as calculated in IEC 172.

NOTE: The temperature index requirement based on an extrapolated life of 20 000 h relates to enamelled wires tested unvarnished and not as part of an insulation system. The temperature in degrees Celsius corresponding to the temperature index is not necessarily that at which it is recommended that the wire be operated and this will depend on many factors, including the type of equipment involved.

**1.3.9 Wire**—the conductor complete with all covering.

## SECTION 2 REQUIREMENTS

**2.1 GENERAL** The wires shall comply with the appropriate requirements specified in this Section. Tables 2.1, 2.7, 2.14, 2.16 and 2.17 specify the characteristics, test requirements and the reference test in Part 5, for the wires, as follows:

| Table | Requirements for                                                    |
|-------|---------------------------------------------------------------------|
| 2.1   | All enamelled round wires                                           |
| 2.7   | Polyvinyl acetal enamelled wire                                     |
| 2.14  | Polyesterimide enamelled wire                                       |
| 2.16  | Polyurethane enamelled wire                                         |
| 2.17  | Modified polyester, overcoated with polyamide-imide, enamelled wire |

**2.2 CONDUCTORS** Conductors shall be manufactured from electrolytic tough pitch (ETP) copper, designation 110, complying with the requirements of AS 2737.

NOTE: See Appendix A for International Standards of resistance for copper.

**2.3 ENAMEL COVERING** The properties of the enamel shall be such as will enable the wire to comply with the appropriate requirements specified herein.

NOTE: The aim is to have a conductor which is fully covered with a durable flexible enamel, having a smooth surface free from blisters and embedded particles of foreign material. It is also desirable that the outside diameter of the enamel be concentric with the outside diameter of the conductor.

**2.4 LUBRICANT** Any lubricant applied to assist in the handling of enamelled wire shall be kept to a minimum and shall have no deleterious effect on the end-use of the wire.

**2.5 TEST METHODS** The requirements tabulated in this Standard and tolerances on test parameters are subject to the procedures specified in AS/NZS 1194.5.

**TABLE 2.1**  
**REQUIREMENTS FOR ALL ENAMELLED ROUND WIRES**

| Item No. | Characteristic                                                                                                                                            | Requirements                                                                                                                                                                                                 | Reference for test method |
|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|
| 1        | Nominal conductor diameter                                                                                                                                | The preferred nominal conductor diameters shall be as specified in Table 2.2                                                                                                                                 | AS/NZS 1194.5             |
| 2        | Electrical resistance<br>(applicable to wires up to 0.063 mm nominal diameter)                                                                            | The conductor resistance, corrected to a reference temperature of 20°C, shall comply with the requirements of Table 2.3                                                                                      | AS/NZS 1194.5             |
| 3        | Dimensions of enamelled round wires:<br>(a) Minimum increase in diameter due to enamel<br><br>(b) Overall diameter                                        | The increase in diameter due to enamel shall be not less than the appropriate value specified in Table 2.2<br><br>The overall diameter of wire shall not exceed the appropriate value specified in Table 2.2 | AS/NZS 1194.5             |
| 4        | Diameter of enamelled round wires with bond layer                                                                                                         | The overall diameter of wire shall not exceed the appropriate value specified in Tables 2.4 or B2, Appendix B                                                                                                | AS/NZS 1194.5             |
| 5        | Out-of-roundness of conductor<br>(applicable to nominal conductor diameters $\geq 0.071$ mm)                                                              | The difference between the minimum and maximum diameter at any point shall not exceed the tolerance on diameter from Tables 2.2, 2.4, B1 or B2, as appropriate                                               | AS/NZS 1194.5             |
| 6        | Elongation                                                                                                                                                | The elongation shall be not less than the appropriate value specified in Table 2.5                                                                                                                           | AS/NZS 1194.5             |
| 7        | Springiness:<br>(a) applicable to nom. conductor diameter $\geq 0.050$ mm and $\leq 1.60$ mm<br><br>(b) applicable to nom. conductor diameter $> 1.60$ mm | The springback shall not exceed the appropriate value specified in Table 2.6<br><br>The wire shall not exceed a maximum springback of 5 degrees                                                              | AS/NZS 1194.5             |

(continued)

TABLE 2.1 (continued)

| Item No. | Characteristic                                                                  | Requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Reference for test method |
|----------|---------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|
| 8        | Continuity of covering (applicable to wires of nominal diameter $\leq 1.6$ mm)  | <p>No continuous faults shall be present in the specimen and the number of other faults recorded shall not exceed:</p> <p>(a) Nom. conductor dia <math>&lt; 0.080</math> mm:</p> <p>(i) Grade 1 enamel:<br/>30 faults per 30 m</p> <p>(ii) Grade 2 enamel:<br/>9 faults per 30 m</p> <p>(b) Nom. conductor dia. <math>\geq 0.080</math> mm but <math>\leq 0.250</math> mm:</p> <p>(i) Grade 1 enamel:<br/>20 faults per 30 m</p> <p>(ii) Grade 2 enamel:<br/>15 faults per 30 m</p> <p>(iii) Grade 3 enamel:<br/>10 faults per 30 m</p> <p>(c) Nom. conductor dia. <math>&gt; 0.250</math> mm but <math>\leq 0.450</math> mm:</p> <p>(i) Grade 1 enamel:<br/>10 faults per 30 m</p> <p>(ii) Grade 2 enamel:<br/>5 faults per 30 m</p> <p>(iii) Grade 3 enamel:<br/>3 faults per 30 m</p> <p>(d) Nom. conductor dia <math>&gt; 0.450</math> mm but <math>\leq 1.60</math>:</p> <p>(i) Grade 1 enamel:<br/>5 faults per 30 m</p> <p>(ii) Grade 2 enamel:<br/>5 faults per 30 m</p> <p>(iii) Grade 3 enamel:<br/>3 faults per 30 m</p> | AS/NZS 1194.5             |
| 9        | Resistance to solvents (applicable to nominal conductor diameters $> 0.100$ mm) | Using a pencil of hardness H, the coating shall not be removed                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | AS/NZS 1194.5             |

**TABLE 2.2**  
**WIRE DIMENSIONS**

| 1                          | 2                        | 3                                                        | 4       | 5       | 6                              | 7       | 8       |
|----------------------------|--------------------------|----------------------------------------------------------|---------|---------|--------------------------------|---------|---------|
| Nominal conductor diameter | Conductor tolerance<br>± | Minimum increase in diameter due to the insulation<br>mm |         |         | Maximum overall diameter<br>mm |         |         |
| mm                         | mm                       | Grade 1                                                  | Grade 2 | Grade 3 | Grade 1                        | Grade 2 | Grade 3 |
| 0.020                      |                          |                                                          |         |         | 0.024                          | 0.027   |         |
| 0.025                      |                          |                                                          |         |         | 0.031                          | 0.034   |         |
| 0.032                      |                          |                                                          |         |         | 0.039                          | 0.043   |         |
| 0.040                      |                          |                                                          |         |         | 0.049                          | 0.054   |         |
| 0.050                      |                          |                                                          |         |         | 0.060                          | 0.066   |         |
| 0.063                      |                          |                                                          |         |         | 0.076                          | 0.083   |         |
| 0.071                      | 0.003                    | 0.007                                                    | 0.012   | 0.018   | 0.084                          | 0.091   | 0.097   |
| 0.080                      | 0.003                    | 0.007                                                    | 0.014   | 0.020   | 0.094                          | 0.101   | 0.108   |
| 0.090                      | 0.003                    | 0.008                                                    | 0.015   | 0.022   | 0.105                          | 0.113   | 0.120   |
| 0.100                      | 0.003                    | 0.008                                                    | 0.016   | 0.023   | 0.117                          | 0.125   | 0.132   |
| 0.112                      | 0.003                    | 0.009                                                    | 0.017   | 0.026   | 0.130                          | 0.139   | 0.147   |
| 0.125                      | 0.003                    | 0.010                                                    | 0.019   | 0.028   | 0.144                          | 0.154   | 0.163   |
| 0.140                      | 0.003                    | 0.011                                                    | 0.021   | 0.030   | 0.160                          | 0.171   | 0.181   |
| 0.160                      | 0.003                    | 0.012                                                    | 0.023   | 0.033   | 0.182                          | 0.194   | 0.205   |
| 0.180                      | 0.003                    | 0.013                                                    | 0.025   | 0.036   | 0.204                          | 0.217   | 0.229   |
| 0.200                      | 0.003                    | 0.014                                                    | 0.027   | 0.039   | 0.226                          | 0.239   | 0.252   |
| 0.224                      | 0.003                    | 0.015                                                    | 0.029   | 0.043   | 0.252                          | 0.266   | 0.280   |
| 0.250                      | 0.004                    | 0.017                                                    | 0.032   | 0.048   | 0.281                          | 0.297   | 0.312   |
| 0.280                      | 0.004                    | 0.018                                                    | 0.033   | 0.050   | 0.312                          | 0.329   | 0.345   |
| 0.315                      | 0.004                    | 0.019                                                    | 0.035   | 0.053   | 0.349                          | 0.367   | 0.384   |
| 0.355                      | 0.004                    | 0.020                                                    | 0.038   | 0.057   | 0.392                          | 0.411   | 0.428   |
| 0.400                      | 0.005                    | 0.021                                                    | 0.040   | 0.060   | 0.439                          | 0.459   | 0.478   |
| 0.450                      | 0.005                    | 0.022                                                    | 0.042   | 0.064   | 0.491                          | 0.513   | 0.533   |
| 0.500                      | 0.005                    | 0.024                                                    | 0.045   | 0.067   | 0.544                          | 0.566   | 0.587   |
| 0.560                      | 0.006                    | 0.025                                                    | 0.047   | 0.071   | 0.606                          | 0.630   | 0.653   |
| 0.630                      | 0.006                    | 0.027                                                    | 0.050   | 0.075   | 0.679                          | 0.704   | 0.728   |
| 0.710                      | 0.007                    | 0.028                                                    | 0.053   | 0.080   | 0.762                          | 0.789   | 0.814   |
| 0.750                      | 0.008                    | 0.030                                                    | 0.056   | 0.085   | 0.805                          | 0.834   | 0.861   |
| 0.800                      | 0.008                    | 0.030                                                    | 0.056   | 0.085   | 0.855                          | 0.884   | 0.911   |
| 0.850                      | 0.009                    | 0.032                                                    | 0.060   | 0.090   | 0.909                          | 0.939   | 0.968   |
| 0.900                      | 0.009                    | 0.032                                                    | 0.060   | 0.090   | 0.959                          | 0.989   | 1.018   |
| 0.950                      | 0.010                    | 0.034                                                    | 0.063   | 0.095   | 1.012                          | 1.044   | 1.074   |
| 1.000                      | 0.010                    | 0.034                                                    | 0.063   | 0.095   | 1.062                          | 1.094   | 1.124   |
| 1.060                      | 0.011                    | 0.034                                                    | 0.065   | 0.098   | 1.124                          | 1.157   | 1.188   |
| 1.120                      | 0.011                    | 0.034                                                    | 0.065   | 0.098   | 1.184                          | 1.217   | 1.248   |
| 1.180                      | 0.012                    | 0.035                                                    | 0.067   | 0.100   | 1.246                          | 1.279   | 1.311   |
| 1.250                      | 0.013                    | 0.035                                                    | 0.067   | 0.100   | 1.316                          | 1.349   | 1.381   |
| 1.320                      | 0.013                    | 0.036                                                    | 0.069   | 0.103   | 1.388                          | 1.422   | 1.455   |
| 1.400                      | 0.014                    | 0.036                                                    | 0.069   | 0.103   | 1.468                          | 1.502   | 1.535   |

(continued)

TABLE 2.2 (continued)

| 1                                | 2                              | 3                                                        | 4       | 5       | 6                              | 7       | 8       |
|----------------------------------|--------------------------------|----------------------------------------------------------|---------|---------|--------------------------------|---------|---------|
| Nominal conductor diameter<br>mm | Conductor tolerance<br>±<br>mm | Minimum increase in diameter due to the insulation<br>mm |         |         | Maximum overall diameter<br>mm |         |         |
|                                  |                                | Grade 1                                                  | Grade 2 | Grade 3 | Grade 1                        | Grade 2 | Grade 3 |
| 1.500                            | 0.015                          | 0.038                                                    | 0.071   | 0.107   | 1.570                          | 1.606   | 1.640   |
| 1.600                            | 0.016                          | 0.038                                                    | 0.071   | 0.107   | 1.670                          | 1.706   | 1.740   |
| 1.700                            | 0.017                          | 0.039                                                    | 0.073   | 0.110   | 1.772                          | 1.809   | 1.844   |
| 1.800                            | 0.018                          | 0.039                                                    | 0.073   | 0.110   | 1.872                          | 1.909   | 1.944   |
| 1.900                            | 0.019                          | 0.040                                                    | 0.075   | 0.113   | 1.974                          | 2.012   | 2.048   |
| 2.000                            | 0.020                          | 0.040                                                    | 0.075   | 0.113   | 2.074                          | 2.112   | 2.148   |
| 2.120                            | 0.021                          | 0.041                                                    | 0.077   | 0.116   | 2.196                          | 2.235   | 2.272   |
| 2.240                            | 0.022                          | 0.041                                                    | 0.077   | 0.116   | 2.316                          | 2.355   | 2.392   |
| 2.360                            | 0.024                          | 0.042                                                    | 0.079   | 0.119   | 2.438                          | 2.478   | 2.516   |
| 2.500                            | 0.025                          | 0.042                                                    | 0.079   | 0.119   | 2.578                          | 2.618   | 2.656   |
| 2.650                            | 0.027                          | 0.043                                                    | 0.081   | 0.123   | 2.730                          | 2.772   | 2.811   |
| 2.800                            | 0.028                          | 0.043                                                    | 0.081   | 0.123   | 2.880                          | 2.922   | 2.961   |
| 3.000                            | 0.030                          | 0.045                                                    | 0.084   | 0.127   | 3.083                          | 3.126   | 3.166   |
| 3.150                            | 0.032                          | 0.045                                                    | 0.084   | 0.127   | 3.233                          | 3.276   | 3.316   |
| 3.350                            | 0.034                          | 0.046                                                    | 0.086   | 0.130   | 3.435                          | 3.479   | 3.521   |
| 3.550                            | 0.036                          | 0.046                                                    | 0.086   | 0.130   | 3.635                          | 3.679   | 3.721   |
| 3.750                            | 0.038                          | 0.047                                                    | 0.089   | 0.134   | 3.838                          | 3.883   | 3.926   |
| 4.000                            | 0.040                          | 0.047                                                    | 0.089   | 0.134   | 4.088                          | 4.133   | 4.176   |
| 4.250                            | 0.043                          | 0.049                                                    | 0.092   | 0.138   | 4.341                          | 4.387   | 4.431   |
| 4.500                            | 0.045                          | 0.049                                                    | 0.092   | 0.138   | 4.591                          | 4.637   | 4.681   |
| 4.750                            | 0.048                          | 0.050                                                    | 0.094   | 0.142   | 4.843                          | 4.891   | 4.936   |
| 5.000                            | 0.050                          | 0.050                                                    | 0.094   | 0.142   | 5.093                          | 5.141   | 5.186   |

NOTE: The conductor sizes given in Table 2.2 are preferred sizes and should be selected whenever practicable in the interest of rationalization.

Where, for technical reasons, intermediate conductor diameters are required, the recommended diameters are specified in Appendix B.

TABLE 2.3  
CONDUCTOR RESISTANCE AT 20°C

| Nominal conductor diameter<br>mm | Conductor resistance<br>Ω/m |       |
|----------------------------------|-----------------------------|-------|
|                                  | min.                        | max.  |
| 0.020                            | 48.97                       | 59.85 |
| 0.025                            | 31.34                       | 38.31 |
| 0.032                            | 19.13                       | 23.38 |
| 0.040                            | 12.28                       | 14.92 |
| 0.050                            | 7.922                       | 9.489 |
| 0.063                            | 5.045                       | 5.922 |

NOTE: The maximum and minimum resistance values above are based on the calculations in Appendix C. The nominal resistance values for larger conductors are given for information only in Appendix D.

**TABLE 2.4**  
**OVERALL DIMENSIONS OF ENAMELLED**  
**WIRES WITH BONDING LAYER**

| Nominal<br>conductor<br>diameter | Conductor<br>tolerance<br>± | Maximum overall<br>diameter |         |
|----------------------------------|-----------------------------|-----------------------------|---------|
|                                  |                             | mm                          |         |
| mm                               | mm                          | Grade 1                     | Grade 2 |
| 0.020                            |                             | 0.026                       | 0.029   |
| 0.025                            |                             | 0.034                       | 0.037   |
| 0.032                            |                             | 0.044                       | 0.048   |
| 0.040                            |                             | 0.055                       | 0.060   |
| 0.050                            |                             | 0.068                       | 0.074   |
| 0.063                            |                             | 0.085                       | 0.092   |
| 0.071                            | 0.003                       | 0.094                       | 0.101   |
| 0.080                            | 0.003                       | 0.105                       | 0.112   |
| 0.090                            | 0.003                       | 0.117                       | 0.125   |
| 0.100                            | 0.003                       | 0.129                       | 0.137   |
| 0.112                            | 0.003                       | 0.143                       | 0.152   |
| 0.125                            | 0.003                       | 0.158                       | 0.168   |
| 0.140                            | 0.003                       | 0.175                       | 0.186   |
| 0.160                            | 0.003                       | 0.197                       | 0.209   |
| 0.180                            | 0.003                       | 0.220                       | 0.233   |
| 0.200                            | 0.003                       | 0.243                       | 0.256   |
| 0.224                            | 0.003                       | 0.270                       | 0.284   |
| 0.250                            | 0.004                       | 0.300                       | 0.316   |
| 0.280                            | 0.004                       | 0.331                       | 0.348   |
| 0.315                            | 0.004                       | 0.369                       | 0.387   |
| 0.355                            | 0.004                       | 0.413                       | 0.432   |
| 0.400                            | 0.005                       | 0.461                       | 0.481   |
| 0.450                            | 0.005                       | 0.514                       | 0.536   |
| 0.500                            | 0.005                       | 0.568                       | 0.590   |
| 0.560                            | 0.006                       | 0.630                       | 0.654   |
| 0.630                            | 0.006                       | 0.704                       | 0.729   |
| 0.710                            | 0.007                       | 0.788                       | 0.815   |
| 0.750                            | 0.008                       | 0.832                       | 0.861   |
| 0.800                            | 0.008                       | 0.882                       | 0.911   |
| 0.850                            | 0.009                       | 0.937                       | 0.967   |
| 0.900                            | 0.009                       | 0.987                       | 1.017   |
| 0.950                            | 0.010                       | 1.041                       | 1.073   |
| 1.000                            | 0.010                       | 1.091                       | 1.123   |
| 1.060                            | 0.011                       | 1.154                       | 1.187   |
| 1.120                            | 0.011                       | 1.214                       | 1.247   |
| 1.180                            | 0.012                       | 1.276                       | 1.309   |
| 1.250                            | 0.013                       | 1.346                       | 1.379   |
| 1.320                            | 0.013                       | 1.419                       | 1.453   |
| 1.400                            | 0.014                       | 1.499                       | 1.533   |
| 1.500                            | 0.015                       | 1.602                       | 1.638   |
| 1.600                            | 0.016                       | 1.702                       | 1.738   |
| 1.700                            | 0.017                       | 1.805                       | 1.842   |

(continued)