bsi.

...making excellence a habit.™

**Please be aware that this PDF has been created from the original hardcopy document, which might not be in good condition and so the PDF might reflect this.**

BSI Group
389 Chiswick High Road
London, W4 4AL
United Kingdom

T: +44 20 845 086 9001
F: +44 20 8996 7400
cservices@bsigroup.com
bsigroup.com

British Standards Limited
Registered in England no: 07864997
Registered address: 389 Chiswick High Road
London, W4 4AL, United Kingdom

AVA Documents
INVESTORS IN PEOPLE
Document Sharing Hub

Full document details: BS 1698:1950

BRITISH STANDARD 1698:1950

# MERCURY A RECTIFIER EQUIPMENTS

BRITISH STANDARDS INSTITUTION

Full document details: BS 1698:1950

AVA Documents
Document Sharing Hub

Full document details: BS 1698:1950

BRITISH STANDARD SPECIFICATION

# MERCURY-ARC RECTIFIER EQUIPMENTS

**B.S. 1698 : 1950**

Price 5/- net, post free

BRITISH STANDARDS INSTITUTION
Incorporated by Royal Charter
24/28 VICTORIA STREET, LONDON, S.W.1
Telegrams : Standards, Sowest, London. Telephone : Abbey 3333

AVA Documents
Document Sharing Hub

THIS BRITISH STANDARD, having been approved by the Electrical Industry Standards Committee and endorsed by the Chairman of the Engineering Divisional Council, was published under the authority of the General Council on 30th December, 1950.

The Institution desires to call attention to the fact that this British Standard does not purport to include all the necessary provisions of a contract.

In order to keep abreast of progress in the industries concerned, British Standards are subject to periodical review. Suggestions for improvements will be recorded and in due course brought to the notice of the committees charged with the revision of the standards to which they refer.

A complete list of British Standards, numbering over 1700, indexed and cross-indexed for reference, together with an abstract of each standard, will be found in the Institution's Yearbook, price 5s. post free.

*British Standards are revised, when necessary, by the issue either of amendment slips or of revised editions. It is important that users of British Standards should ascertain that they are in possession of the latest amendments or edition.*

ELE/50





## CO-OPERATING ORGANIZATIONS

The Electrical Industry Standards Committee,† under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:—

Admiralty
Air Ministry
Association of Consulting Engineers Incorporated
Association of Supervising Electrical Engineers
*British Electrical and Allied Industries Research Association
*British Electrical and Allied Manufacturers' Association
British Electrical Development Association
*British Electricity Authority and Area Boards
*British Railways, The Railway Executive
Cable Makers' Association
Electric Lamp Manufacturers' Association
Electric Light Fittings Association
Electrical Contractors Association (Incorporated)
Electrical Contractors Association of Scotland
Engineering Equipment Users' Association
*General Post Office
Institution of Electrical Engineers
Ministry of Fuel and Power
Ministry of Labour and National Service (Factory Dept.)
*Ministry of Supply
Ministry of Works
National Physical Laboratory
*North of Scotland Hydro-Electric Board
Public Transport Association (Incorporated)
Radio Industry Council

The Government departments and scientific and industrial organizations marked with an asterisk in the above list, together with the following, were directly represented on the committee entrusted with the preparation of this British Standard:—

London Transport Executive
Manufacturers of rectifier equipment

† The Electrical Industry Standards Committee is the British National Committee of the International Electrotechnical Commission.



Full document details: BS 1698:1950
AVA Documents
Document Sharing Hub

## CONTENTS


### 1. SCOPE

Page

1.1. Scope 9

### 2. DEFINITIONS

2.1. DEFINITIONS

2.1.1. Rectifier equipment 9
2.1.2. Rectifier 9
2.1.3. Rating or rated output 9
2.1.4. Rated D.C. voltage 9
2.1.5. Rated current 9
2.1.6. Rated current in the middle wire of 3-wire equipments 9
2.1.7. Inherent regulation 9
2.1.8. Percentage inherent regulation 10
2.1.9. Transformer primary winding 10
2.1.10. Transformer secondary winding 10
2.1.11. Rated primary voltage 10
2.1.12. Rated primary current 10

### 3. SPECIFICATION

3.1. GENERAL

3.1.1. Rating classes and overloads 10
3.1.2. 3-wire equipments 11
3.1.3. Parallel operation 11
3.1.4. Rating plate 12
3.1.5. Service conditions 12

3.2. RECTIFIER AND ASSOCIATED AUXILIARIES

3.2.1. Limits of temperature rise for rectifiers and auxiliaries 12

3.3. MAIN AND INTERPHASE TRANSFORMERS

3.3.1. Limits of temperature rise for main and interphase transformers 13
3.3.2. Standard tappings on transformer primary windings 14
3.3.3. Rating plate 14

### 4. PERFORMANCE TESTS

4.1. GENERAL

4.1.1. Type tests and routine tests 15







4.2. RECTIFIER AND ASSOCIATED AUXILIARIES

Page

4.2.1. Performance tests 15
4.2.1.1. Type tests 15
4.2.1.2. Routine tests 16
4.2.2. Vacuum tightness tests 17

4.3. MAIN AND INTERPHASE TRANSFORMERS

4.3.1. Type tests 17
4.3.2. Routine tests 17
4.3.3. Transformer temperature rise test 18

### 5. HIGH VOLTAGE TESTS

5.1. Tests on items of combined equipment 18
5.2. Supplementary high-voltage tests 20

### 6. EFFICIENCY, POWER FACTOR AND REGULATION

6.1. Efficiency 20
6.2. Power factor (cos $\phi$) 20
6.3. Inherent regulation 20
6.4. Tolerances 20
6.4.1. Losses 20
6.4.2. Power factor (cos $\phi$) 21
6.4.3. Inherent regulation 21
6.4.4. Rated D.C. voltage 21

### APPENDICES

7. Appendix A. Service conditions 22
7.1. Service conditions 22
7.1.1. Loading 22
7.1.2. Minimum temperature 22
7.1.3. Maximum ~~ambient temperature and temperature of~~ cooling medium temperatures 22
7.1.4. Altitude 22
7.1.5. Supply voltage and frequency 22
7.2. Service conditions other than standard 22
7.2.1. Correction on rectifier load test for cooling air temperature higher than standard 22




AVA Documents
Document Sharing Hub

Page

7.2.2. Correction on rectifier load test for altitude higher than standard 23
7.2.3. Correction on limits of temperature rise of transformers and auxiliaries for ambient or coolant temperatures higher than standard 23
7.2.4. Correction on limits of temperature rise of transformers and auxiliaries for altitude higher than standard 24

8. Appendix B. Method of measurement of efficiency 25
8.1. General 25
8.2. Losses in rectifier arc 25
8.3. Losses in main transformers 26
8.4. Losses in interphase coils or apparatus for similar purpose 26
8.5. Losses in any apparatus permanently in circuit for the limitation of the no-load voltage rise 26
8.6. Loss in anode reactors 26
8.7. Loss in series D.C. smoothing reactor 26
8.8. Loss in shunt D.C. smoothing circuits 26
8.9. Loss in fan, if any, for rectifier cooling system 27
8.10. Loss in auxiliary apparatus 27
8.11. Losses in any other apparatus forming part of the rectifier equipment 27
8.12. Losses not to be included 27

9. Appendix C. Power factor of the fundamental (cos $\phi$) 29
10. Appendix D. Method of calculating inherent regulation 34
11. Appendix E. D.C. voltage wave form 35
11.1. General 35
11.2. Telephone harmonic factor 35
11.3. Values of unsmoothed voltage harmonics 36
12. Appendix F. A.C. wave form 38





Page

13. Appendix G. Transformer temperature tests 38
13.1. General 38
13.2. Oil-immersed transformers 38
13.3. Dry type transformers 40
13.4. Application of resistance method of temperature measurement 41
14. Appendix H. Temperature test for main and interphase transformers to Rating Class IV (see Clause 3.1.1) 41
15. Appendix J. Classification of insulating materials 42
15.1. Classification of materials 42
15.2. Insulation made up of different materials 43
16. Appendix K. Information to be given with enquiry 44
16.1. General 44
16.2. Service conditions 44
16.3. D.C. rating 44
16.4. D.C. load system 44
16.5. D.C. smoothing equipment 44
16.6. Auxiliaries and their control 45
16.7. De-gassing equipment 45
16.8. A.C. supply 45
16.9. Switchgear 45
16.10. Main transformer 45
16.11. Interconnections between main items of equipment 46

TABLES

Table 1. Limits of temperature rise, by thermometer, for anode reactors and D.C. smoothing reactors, dry type 13
Table 2. Limits of temperature rise for main and interphase transformers, with Class A insulation 14
Table 3. Applied high voltage tests on items connected to the D.C. and auxiliary circuits 19



AVA Documents
Document Sharing Hub

Page

Table 4. Reduction of limits of temperature rise for ambient or coolant temperatures higher than standard 24

Table 5. Calculation of r.m.s. currents in transformer 28

Table 6. Values of factor F 42

FIGURES

Fig. 1 (A)–1(D). Curves of power factor (cos $\phi$) for 6-phase and 12-phase equipments 30–33

Fig. 2. Weighting factors for telephone harmonic factor, (Appendix E, Clause 11.2) 36

Fig. 3. Harmonics in D.C. voltage with delay in firing, for 6-phase rectifiers (Appendix E, Clause 11.3) 37





BRITISH STANDARD SPECIFICATION FOR

# MERCURY-ARC RECTIFIER EQUIPMENTS

## 1. SCOPE

**1.1.** This British Standard applies to mercury-arc rectifier equipments comprising half-wave rectifiers of any type having mercury pool cathodes, rated at 50 kW and above, having not less than 6 phases, for D.C. voltages not exceeding 4000, and for service in non-explosive atmospheres.

Where the load duties differ from those detailed in this standard, the relevant clauses may be varied by agreement between the purchaser and the manufacturer.

## 2. DEFINITIONS

**2.1.** For the purposes of this standard the following definitions shall apply.

**2.1.1.** *Rectifier equipment.* One or more mercury-arc rectifiers together with the transformer and the auxiliary equipment necessary to meet the requirements of this standard.

**2.1.2.** *Rectifier.* The individual rectifying device.

**2.1.3.** *Rating or rated output.* The output in kW, marked on the rating plate, which the rectifier equipment can deliver under the conditions stated in this standard, within the operating limitations assigned to it by the manufacturer.

NOTE. When not otherwise specified, a rectifier equipment to work over a range of D.C. voltage shall be capable of giving its rated output at any value of the voltage from the highest specified down to the rated voltage. For voltages within the range but below the rated voltage the current shall be that corresponding to the rated voltage.

**2.1.4** *Rated D.C. voltage.* The D.C. output voltage at the rated output as marked on the rating plate.

**2.1.5.** *Rated current.* The direct current corresponding to the rated output at rated D.C. voltage.

**2.1.6.** *Rated current in the middle wire of 3-wire equipments.* That current which can be carried without injury under out-of-balance conditions, while the complete equipment is maintaining rated current in the more heavily loaded side of the system.

**2.1.7.** *Inherent regulation.* The difference between the D.C. voltages at rated load and at light load* when the equipment is supplied from a

* Light load is defined for this purpose as 5 per cent of rated load (see Note 2 below).



AVA Documents
Document Sharing Hub

system assumed to have zero reactance and supplying sinusoidal voltage of constant r.m.s. value at rated frequency.

**2.1.8.** *Percentage inherent regulation.* The inherent regulation expressed as a percentage of the rated D.C. voltage.

NOTE 1. It is pointed out that if the percentage inherent regulation is less than about 6–8 per cent, special measures may have to be adopted to enable the equipment to withstand short-circuit conditions.

NOTE 2. The most frequently used systems of transformer connections produce a steeper regulation characteristic from no load to light load than from light load to rated load: it is the latter which covers the normal working range of the rectifier equipment, and is the subject of the two regulation definitions. It is for this reason that the term 'light load' is used instead of 'no load.' In the case of such connections, the D.C. voltage may rise by 15 per cent to 20 per cent from light load to no load. In most cases it is not necessary to suppress this voltage rise; but in special cases, where the voltage rise is likely to be objectionable in service, the purchaser shall state this at the time of the enquiry, in which case apparatus for the suppression of the voltage rise shall be included in the equipment.

**2.1.9.** *Transformer primary winding.* The winding which is connected to the A.C. supply.

**2.1.10.** *Transformer secondary winding.* The winding which is connected to the rectifier and D.C. circuit.

**2.1.11.** *Rated primary voltage.* The voltage between lines of the primary circuit on which the transformer is to operate, and on which the declared performance is to be based.

**2.1.12.** *Rated primary current.* The r.m.s. current at the primary terminals of the transformer when the rectifier is delivering its rated output (assuming rectangularly-stepped wave-form of primary current).

## 3. SPECIFICATION

### 3.1. GENERAL

#### RATING CLASSES AND OVERLOADS

**3.1.1.** In fixing the overloads which a rectifier equipment is to be capable of carrying, it must be borne in mind that the overloads which would ideally fit the particular service may not necessarily fit the natural overload characteristic of the rectifier, or the natural overload characteristic of the transformer and associated apparatus.

This standard establishes five Rating Classes, which are broadly suitable for the different types of service stated below against each class. Rectifier equipments rated in accordance with this standard shall, according to their class, be capable of carrying the following loads without injury:—





*Class I* (light general or industrial service):

| | | | | | |
|---|---|---|---|---|---|
| 100 per cent of rated current continuously,* | | | | | each after 6 hours at rated current, starting at ambient temperature. |
| 125 | ,, | ,, | ,, | for 5 minutes, | |
| 200 | ,, | ,, | ,, | for 5 seconds | |

*Class II* (heavier general or industrial service, and light traction duty, e.g. most tramway and trolley-bus service):

| | | | | | |
|---|---|---|---|---|---|
| 100 per cent of rated current continuously,* | | | | | each after 6 hours at rated current, starting at ambient temperature. |
| 125 | ,, | ,, | ,, | for 2 hours, | |
| 200 | ,, | ,, | ,, | for 15 seconds | |

*Class III* (railway service):

| | | | | | |
|---|---|---|---|---|---|
| 100 per cent of rated current continuously,* | | | | | each after 3 hours at rated current, starting at ambient temperature. |
| 150 | ,, | ,, | ,, | for 2 hours, | |
| 300 | ,, | ,, | ,, | for 1 minute | |

*Class IV* (railway service in cases where Class III is not suitable):

100 per cent of rated current continuously,* and overloads as specified in the contract.

NOTE. In some cases the loading specified may require compliance with a load cycle.

*Class V* (heavy electrochemical service, etc.):

100 per cent of rated current continuously for an unlimited period, *and*

150 ,, ,, ,, for 1 minute, after continuous operation at rated current.

Class VI See 4 wat 2.

#### 3-WIRE EQUIPMENTS

**3.1.2.** Unless otherwise specified the value of the rated current in the middle wire shall be 15 per cent of the balanced rated current in the outers, and shall be subject to the same percentage overloads as are given in Clause 3.1.1 for the Rating Class specified.

Except where otherwise specified, the definitions in Clause 2.1 refer to the conditions in the outers with balanced load, and the performance particulars, e.g. efficiency, etc., refer to balanced conditions.

#### PARALLEL OPERATION

**3.1.3.** In the case of parallel operation of several units, where the term units means either complete rectifier equipments or individual rectifier tanks or

* These Rating Classes are not recommended for continuous process work operating at full rated load for unlimited periods, e.g. heavy electrochemical service, etc.



AVA Documents
Document Sharing Hub

bulbs, the current of each unit when operating under similar conditions shall not differ from its correct share of the total current, at any load between one-half rated load and rated load, by more than the following amounts:

*a.* Duplicate units, supplied on the same contract, ± 10 per cent of the rated current of the unit.

*b.* Dissimilar units, or units not supplied on the same contract, ± 15 per cent of the rated current of the unit.

RATING PLATE

**3.1.4.** Each rectifier and each main item of the rectifier auxiliaries shall be marked with the manufacturer's name or trade mark and serial number.

In addition each rectifier equipment shall have a rating plate giving the following particulars:—

Manufacturer's name.
Rated output in kW.
Rated D.C. voltage.
Rated current.
Primary phases } of main transformer
Rated frequency } of main transformer
Rated primary voltage } of main transformer
The number of this British Standard, i.e. B.S. . . . .
Rating Class.

NOTE. For Rating Class IV, if the rated output has not been specified the rated output to be marked on the rating plate shall be the equivalent continuous rating as determined in accordance with Appendix H.

For rectifier equipments arranged for 3-wire working on the D.C. side the following additional information shall be given:—

Rated current in middle wire.

SERVICE CONDITIONS

**3.1.5.** The equipment shall be capable of operating under the service conditions set out in Appendix A.

## 3.2. RECTIFIER AND ASSOCIATED AUXILIARIES

LIMITS OF TEMPERATURE RISE FOR RECTIFIERS AND AUXILIARIES

**3.2.1.** Since the safe temperature limit of the rectifier is not dependent on the safe temperature limits of the materials employed, no limits are specified for the temperature rise of the external parts of the rectifier.

For auxiliary transformers, motors, contactors, resistors and similar





accessories, the limits of temperature rise shall comply with the requirements of the appropriate British Standards.

For shunt D.C. smoothing reactors, and for anode reactors and series D.C. smoothing reactors, all of dry type, the limits of temperature rise shall be as given in Table 1.

For oil-immersed anode reactors and series D.C. smoothing reactors, the limits of temperature rise shall comply with Clause 3.3.1.

If the ambient temperature or altitude exceeds the normal values given in Appendix A, Clauses 7.1.3 and 7.1.4, the limits given in Table 1 are to be reduced in accordance with Appendix A, Clauses 7.2.3 and 7.2.4.

TABLE 1

LIMITS OF TEMPERATURE RISE, BY THERMOMETER, FOR ANODE REACTORS AND D.C. SMOOTHING REACTORS, DRY TYPE

| Rating Class (see Clause 3.1.1) | When measured | Anode reactors and series D.C. smoothing reactors | | Shunt D.C. smoothing reactors | |
|---|---|---|---|---|---|
| | | Class A* insulation | Class B* insulation | Class A* insulation | Class B* insulation |
| | | °C | °C | °C | °C |
| I | After application of rated current for 3 hours | 50 | 70 | 40 | 55 |
| II | ,, ,, | 40 | 55 | 40 | 55 |
| III | ,, ,, | 30 | 40 | 40 | 55 |
| IV | When max. temperature is reached after any specified overload, or during specified load cycle | 55 | 75 | 40 | 55 |
| V | After application of rated current until steady | 50 | 70 | 40 | 55 |

## 3.3. MAIN AND INTERPHASE TRANSFORMERS

LIMITS OF TEMPERATURE RISE FOR MAIN AND INTERPHASE TRANSFORMERS

**3.3.1.** The limits of temperature rise for transformers having windings with Class A insulation * shall be as given in Table 2. For type AB transformers with Class B insulation,* the limits in Table 2 shall be increased by 15 degree °C.

* For definitions of Class A and B insulation, see ~~Appendix J.~~ BS 2757



AVA Documents
Document Sharing Hub