BRITISH STANDARD 3892 : 1965

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SPECIFICATION FOR

PULVERIZED-FUEL ASH FOR USE IN CONCRETE

BRITISH STANDARDS INSTITUTION

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PULVERIZED-FUEL ASH FOR USE IN CONCRETE

B.S. 3892 : 1965

Price 5/- net

BRITISH STANDARDS INSTITUTION

INCORPORATED BY ROYAL CHARTER

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THIS BRITISH STANDARD, having been approved by the Aggregates, Natural Stone and Quarry Products Industry Standards Committee and endorsed by the Chairman of the Building Divisional Council, was published under the authority of the General Council on 18th May, 1965.

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 4000, fully indexed and with a note of the contents of each, will be found in the British Standards Yearbook, price 15s. The B.S. Yearbook may be consulted in many public libraries and similar institutions.

This standard makes reference to the following British Standards:

B.S. 12. Portland cement (ordinary and rapid-hardening).
B.S. 3681. Methods for the sampling and testing of lightweight aggregates for concrete.

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 editions.

The following B.S.I. references relate to the work on this standard:
Committee reference STB/8 Draft for comment D63/10771

CO-OPERATING ORGANIZATIONS

The Aggregates, Natural Stone and Quarry Products Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:

British Granite and Whinstone Federation
British Slag Federation
British Stone Federation
*D.S.I.R.—Building Research Station
English Slate Quarries Association
Federated Quarry Owners of Great Britain
*Federation of Civil Engineering Contractors
Institute of Quarrying
*Institution of Civil Engineers
Institution of Municipal Engineers
*Institution of Structural Engineers
Limestone Federation
Ministry of Housing and Local Government
Ministry of Public Building and Works
Ministry of Transport
National Federation of Building Trades Employers
*Reinforced Concrete Association
*Royal Institute of British Architects
Sand and Ballast Merchants Alliance
Sand and Gravel Association of Great Britain
Scottish Freestone Quarry Masters' Association
Society of Chemical Industry

The Government department 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:

British Coal Utilisation Research Association
British Precast Concrete Federation
British Ready Mixed Concrete Association
Cement and Concrete Association
Cement Makers' Federation
D.S.I.R.—Road Research Laboratory
Electricity Council, the Generating Board and the Area Boards in England and Wales
Marketing agents for pulverized-fuel ash
National Paving and Kerb Association
North of Scotland Hydro-Electricity Board
South of Scotland Electricity Board
Independent producer of pulverized-fuel ash

BRITISH STANDARD SPECIFICATION FOR

PULVERIZED-FUEL ASH FOR USE IN CONCRETE

FOREWORD

This standard specifies the properties of pulverized-fuel ash for use in concrete. It does not cover its use as a bulk filling material or for sintering to make lightweight aggregates.

Pulverized-fuel ash is extracted from the flue gases of boilers fired by pulverized coal. It is a fine material, the bulk of which passes a No. 200 (75 microns) fine mesh B.S. 410 test sieve. It is generally slightly basic. Some pulverized-fuel ashes may have pozzolanic properties, but there is at the present time no generally accepted method for their assessment.

It has been employed in concrete with normal Portland cement (ordinary and rapid hardening) as a fine aggregate and as a plasticizer.

It is not at present recommended for use with sulphate resisting Portland cement, Portland-blastfurnace cement, low heat slag blastfurnace Portland cement, supersulphated cement (sulphate resisting and low heat) or high alumina cement.

NOTE. Where metric equivalents are stated the figures in British units are to be regarded as the standard. The metric conversions are approximate. More accurate conversions should be based on the tables in B.S. 350, 'Conversion factors and tables'.

SPECIFICATION

SCOPE

1. This British Standard covers pulverized-fuel ash as a component material for normal Portland (ordinary and rapid hardening) cement concrete. Provision is made for two alternative maximum sulphate contents and for three standard zones of fineness, also for the supply by agreement of material within other zones distinguished by the range of specific surfaces.

NOTE. See Clause 2 which defines the type of ash covered by this specification.

DEFINITION

2. For the purposes of this British Standard the following definition applies:

Pulverized-fuel ash. Solid material extracted by electrical or mechanical means from the flue gases of boilers fired with pulverized coal. The term does not apply to ash extracted from the bottom of the furnace.

DESIGNATION OF MATERIAL FOR ORDERING PURPOSES

3. The material specified in this standard shall, for the purpose of enquiries and orders, be designated as follows:

1. B.S. 3892/Zone A or B/2½ per cent or 1½ per cent SO_3, e.g. B.S. 3892/Zone B/2½ per cent SO_3;

2. B.S. 3892/Zone C (and stating the mean specific surface to be agreed between the purchaser and the vendor)/ 2½ per cent or 1½ per cent SO_3, e.g. B.S. 3892/Zone C 5750/1½ per cent SO_3; or

3. For other zones, to be supplied by agreement between the purchaser and the vendor, B.S. 3892/ stating also the range of the specific surfaces/ and the sulphate content (see Clause 5), e.g. B.S. 3892/2000–4000/2½ per cent SO_3.

CHEMICAL COMPOSITION

4. The chemical composition of the pulverized-fuel ash as determined by the methods, where given, laid down in the Appendices shall comply with the following requirements:

	per cent
Moisture content*	1·5 maximum†
Loss-on-ignition	7·0 maximum†
Magnesia (MgO)	4 maximum
Sulphate (as SO_3)	2·5 maximum‡

* At the time of delivery.
† Unless otherwise agreed betweed purchaser and vendor.
‡ Where the weight of pulverized-fuel ash to be used in the mix is equal to or greater than the weight of cement in the mix, a limit of 1·5 per cent on the maximum sulphate content of the pulverized-fuel ash to be used shall apply.

SPECIFIC SURFACE

5. The specific surface of the pulverized-fuel ash as determined by either one of the two methods laid down in Appendix E, shall be consistently within the range appropriate to the zone as follows, except that not more than one delivery in ten of the pulverized-fuel ash shall be allowed to fall outside the respective range of the particular zone specified by an amount not to exceed 10 per cent of the limits of the range.

Zone A. 1250 and up to and including 2750 cm^2/g.

Zone B. Above 2750 and up to and including 4250 cm^2/g.

Zone C. Above 4250 cm^2/g, subject to a range not greater than 1500 cm^2/g and based on a mean to be agreed between the purchaser and the vendor.

By agreement between the purchaser and the vendor any other range of specific surfaces may be supplied.

CERTIFICATE OF COMPLIANCE

6. The vendor shall satisfy himself that the pulverized-fuel ash supplied complies with the requirements of this standard and on request shall provide a certificate to this effect to the purchaser or his accredited representative. The certificate shall state also the zone and the sulphate content limit.

SAMPLING AND TEST REQUIREMENTS

7. The samples for testing shall be taken by the method laid down in Appendix A.

No sample taken in accordance with this method shall be considered to represent more than 100 tons of pulverized-fuel ash.

If when tested in accordance with Appendices B to E the pulverized-fuel ash fails to comply with any of the requirements of Clauses 4 and 5 the test or tests in which it fails shall be repeated on each of two further portions of the same sample.

If both these further portions satisfy the requirements, the consignment shall be deemed to comply with this British Standard.

If one or both of these further portions fail to satisfy the requirements, then the consignment shall be deemed not to comply.

INDEPENDENT TESTS

8. If the purchaser or his representative requires independent tests, he shall so state in writing to the vendor when placing the order. The samples shall be tested by a mutually-agreed testing laboratory whose results shall be accepted by both the purchaser and the vendor. The samples for these independent tests shall be selected in accordance with Clause 7 either before or after the delivery of the pulverized-fuel ash at the option of the purchaser.

If the sample is taken before delivery the vendor shall afford every facility and provide all labour and materials for taking and packing the sample or samples and shall provide adequate labelling for subsequent identification of the sampled material.

Unless otherwise arranged between vendor and purchaser the cost of testing shall be borne as follows:

a. By the vendor in the event of the results indicating that the pulverized-fuel ash does not comply with the requirements of this standard.

b. By the purchaser in the event of the results indicating that the pulverized-fuel ash does so comply.

APPENDIX A

METHOD OF SAMPLING

Ensure that each sample for testing weighs at least 10 lb (4·54 kg) and that it is truly representative of the consignment or part of a consignment sampled by mixing at least 40 equal sub-samples taken from places evenly spaced throughout the consignment or part of a consignment sampled. Take sub-samples of bulk pulverized-fuel ash from the bulk container or containers during filling or emptying. For pulverized-fuel ash in bags, drums or other packages take not more than one sub-sample from any one bag, drum or other package. Where there are fewer than 40 bags, drums or other packages to be sampled, take one sub-sample from each.

Store the sample in a dry, clean airtight container until the time of testing.

APPENDIX B

PREPARATION OF SAMPLE AND MOISTURE DETERMINATION

Thoroughly remix the whole sample and reduce it by quartering and sub-quartering until approximately 25 g of the material is obtained.

Accurately weigh approximately 10 g of this, spread it in a shallow container and dry in a well-ventilated oven at 105 ± 5°C for one hour. Cool in a desiccator containing calcium chloride and reweigh. The moisture content to the nearest 0·1 per cent is expressed as a percentage of the dry weight.

APPENDIX C

DETERMINATION OF LOSS ON IGNITION

Accurately weigh approximately 1 g of the dried sample into a previously ignited and weighed shallow silica dish. Heat in a muffle furnace for ¾ hour at 900–950°C, keeping the dish covered with a suitable crucible lid for the first 10 minutes. Cool in a desiccator containing calcium chloride and reweigh. The loss in weight to the nearest 0·1 per cent expressed as a percentage of the dry weight is taken as the loss on ignition.

APPENDIX D

DETERMINATION OF SULPHATE IN PULVERIZED-FUEL ASH

Determine the sulphate content in accordance with the method given in B.S. 3681*. Use approximately 1 g of the sample prepared as described in Appendix B above and calculate the result to the nearest 0·1 per cent as a percentage of the dry weight.

APPENDIX E

DETERMINATION OF SPECIFIC SURFACE

E1. Summary. This method of test covers the procedure for determining the fineness of pulverized-fuel ash as indicated by specific surface expressed as total surface area in square centimetres per gramme.

E2. Determination of density. Determine the density of the pulverized-fuel ash in the usual manner by displacement of liquid in a 50 ml density bottle, using redistilled kerosine (paraffin oil) of known density. Transfer to the density bottle 10 grams of the sample, prepared as in Appendix B and free from lumps. Half fill the bottle with kerosine, place in a desiccator and evacuate by vacuum-pump until all the air is removed (usually about 15 minutes).

With some fine ashes complete wetting may be difficult to attain, resulting in only partial evacuation. In these cases complete removal of the air may be achieved by agitating the desiccator and its contents or, in more extreme cases, by removing the bottle and shaking. Next, fill the bottle with kerosine and maintain at a constant temperature between 15°C and 25°C ± 0·5°C throughout the determination. Carry out the determination in triplicate. The results are to be accurate to within ± 0·02 gram/millilitre of the mean value and for this purpose ensure that the kerosine used does not change by more than 0·0005 gram/millilitre when evacuated for a period of five hours.

NOTE. A suitable liquid can be prepared in the laboratory by redistilling kerosine and collecting the fraction boiling between 200°C and 240°C. Alternatively, petroleum fractions with boiling ranges of 190—250°C and with sufficiently stable density characteristics are commercially available. If any difficulty is experienced in obtaining commercial supplies, the British Standards Institution should be consulted for the names of stockists.

E3. Apparatus. The permeability cell†, plunger† and perforated plate† made to the dimensions shown in Figs. 1, 2*a*, 2*b* and 3 are used in conjunction with either

* B.S. 3681, ' Methods for the sampling and testing of lightweight aggregates for concrete'.
† It is recommended that these be made of stainless steel.

(i) the apparatus specified in that part of the appendix of B.S. 12* giving the test for fineness which describes the manometer stand and illustrates the permeability apparatus with manometer and flowmeter, or

(ii) the apparatus illustrated in Fig. 4*a* and *b*.

When the B.S. 12* apparatus is used, a small electric air pump or similar device is required and the air is first dried by passing through a column packed with anhydrous calcium chloride or other desiccant. The apparatus shown in Fig. 4 is generally equipped with a small hand-bellows pump in order to displace the column of liquid above the top mark.

The glass U-tubes in both apparatuses are of precision bore in order to facilitate standardizing. Although the liquid used in both apparatuses is generally redistilled kerosine (paraffin oil), any liquid with a low viscosity and negligible vapour pressure is suitable.

E4. Calibration of the flowmeter. When the B.S. 12* apparatus is used, carry out the calibration according to the procedure laid down in that part of the appendix of B.S. 12* giving the test for fineness which describes the calibration of the flowmeter. The flowmeter constant C should lie within the range 2·0 to 4·0 × 10^{-6} c.g.s. units.

E5. Procedure. Fit the permeability cell with a disc of filter paper (e.g. Whatman's No. 40) having the same diameter as the perforated metal plate on which it rests. Change this disc of filter paper after every six determinations. From time to time both apparatuses should be tested for leakage by applying a small air pressure to the manometer, sealing off the air outlet and observing the meniscus. This level should not differ by more than 0·5 mm over any one minute period.

Take the ash from the sample prepared according to Appendix B and ensure that it is free from lumps.

In order to achieve uniform compaction (i.e. porosity) throughout the depth of the bed, fill the cell in four layers of approximately 2 g ash each and determine the porosity of the bed only after adding and compacting the final layer.

To effect compaction of each layer, level the loose ash by tapping the cell gently on the surface of a wooden bench and then inserting the plunger carefully and pressing on the surface of the bed. With the thumb on the cap of the plunger, tap the cell sharply 10 times on the surface of the wooden bench from a height of about 7 cm. It is important that the surface of each increment remains substantially undisturbed while withdrawing the plunger, particularly in the case of coarse ashes. This may be achieved by withdrawing the plunger slowly with a rotary motion. Make certain also that the air hole in the plunger is free from obstruction at any time before inserting into the cell.

* B.S. 12, ' Portland cement (ordinary and rapid-hardening)'.

Determine accurately to the nearest mg the weight of ash in the cell. The depth of the overall bed may be measured by vernier callipers measuring the differences to the nearest 0·1 mm in the plunger length before and after adding the ash.

When the cell has been so charged, connect it by means of rubber bungs to either of the two alternative apparatuses.

Take care to avoid any back pressure of air as this would tend to disturb the bed of ash.

Where the B.S. 12* apparatus is used, a static determination of the manometer (h_1) and flowmeter (h_2) column heights in cm is recorded. The flowmeter column height should lie within the range 15–30 cm over the complete range of fly ash finenesses likely to be encountered.

Where the Fig. 4 apparatus is used, the time in seconds for the column of liquid to travel between the etched marks ' start ' and ' A ' or ' B ' is recorded.

Make three determinations on separate ash samples.

E6. Calculations and reporting of results. Calculate the porosity of the bed (ϵ) from the formula below:

$$\epsilon = 1 - \frac{W}{A.\rho.L}$$

Where W = Weight of p.f.a. in the bed (grams)
A = Area of cross-section of the permeability cell. (This is 5·07 cm² for the 1 inch diameter cell.)
ρ = Mean density of the p.f.a. (g/ml) as determined in E2
L = Depth of the compacted bed (cm)

Calculate the specific surface (S) as follows:

a. For B.S. 12* apparatus $S = \frac{14}{\rho(1-\epsilon)} \cdot \sqrt{\frac{\epsilon^3 . A}{C . L}} \cdot \sqrt{\frac{h_1}{h_2}}$

Where ρ, ϵ, A, L are as defined above
C = The flowmeter constant
h_1 and h_2 = Readings of the manometer levels in the flowmeter.

b. For Fig. 4 apparatus

$$S = \sqrt{K_a \frac{\epsilon^3 . T . d}{(1-\epsilon)^2 . \rho^2 . L}}$$

Where d = density of the liquid (g/cc) in the U-tube.
K_a = 5·41 × 10⁶ (when timing liquid flow from ' start ' to mark ' A ') or 2·67 × 10⁶ (when timing liquid flow from ' start ' to mark ' B ')
T = Time of liquid flow (seconds) from ' start ' to either mark ' A ' or ' B '

* B.S. 12, ' Portland cement (ordinary and rapid-hardening) '.

Calculate the results of each of the three determinations and take the average to the nearest 10 cm²/g.

If any determination varies from the average by more than ± 5 per cent, repeat on a further separate sample. Calculate the average of the four results and reject the result differing most from the average. Recalculate the average of the remaining three results. Repeat this procedure with succeeding samples if necessary until three results are obtained none of which varies from the average by more than ± 5 per cent. Report the average to the nearest 10 cm²/g as the specific surface of the ash.

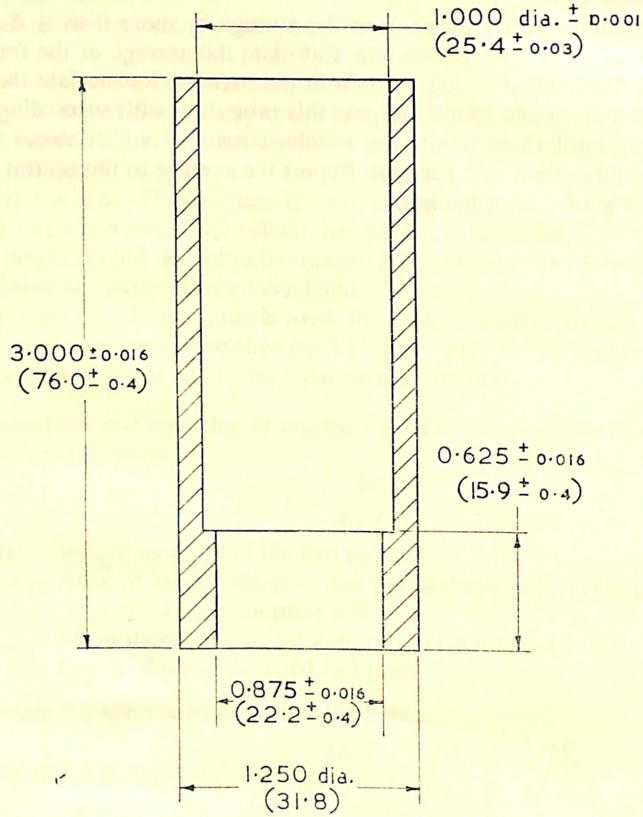

Fig. 1. Permeability cell

All dimensions in inches, millimetre equivalents in parentheses

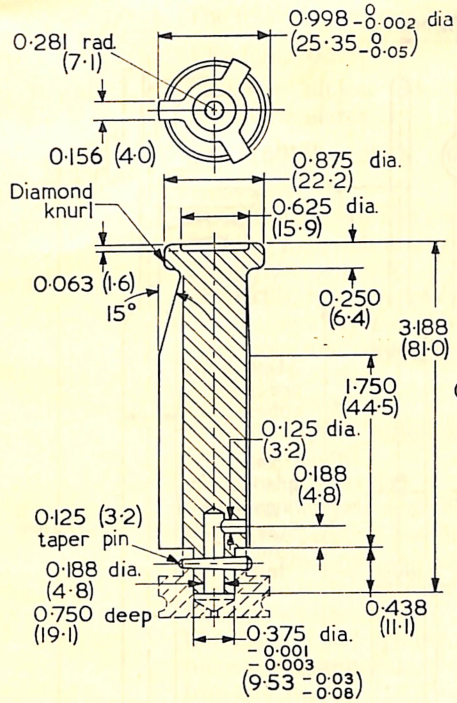

Fig. 2*a*. Plunger

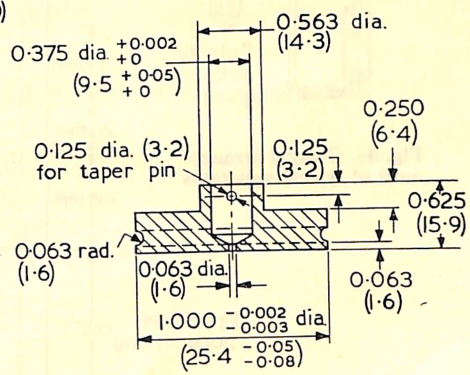

Fig. 2*b*. Detail of plunger base

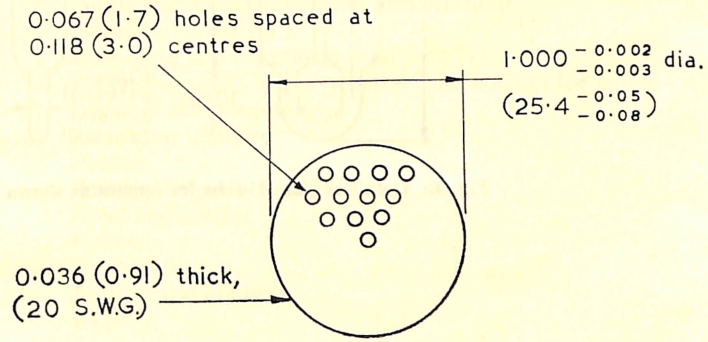

Fig. 3. Perforated plate

All dimensions in inches, millimetre equivalents in parentheses

DETERMINATION OF SPECIFIC SURFACE

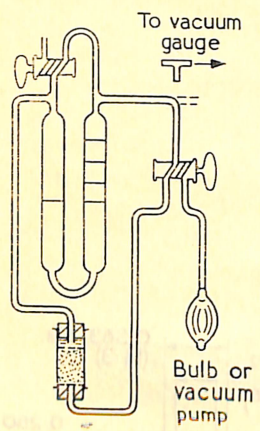

Fig. 4*a*. General arrangement of typical apparatus

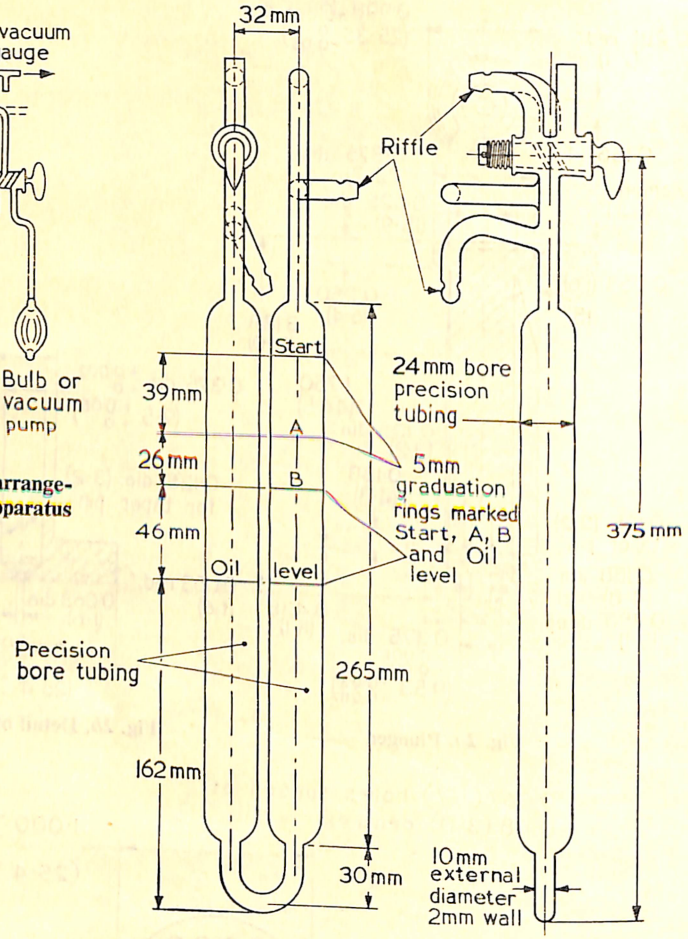

Fig. 4*b*. Detail of glass U-tube for apparatus shown in Fig. 4*a*

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BRITISH STANDARDS INSTITUTION

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