

Results of the Round Robin series of tests to evaluate proposed amendments to IEC 60112

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National foreword

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TECHNICAL
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TR 62062

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**Résultats de la série d'essais interlaboratoires
pour évaluer les modifications proposées
à la CEI 60112**

**Results of the Round Robin series of tests
to evaluate proposed amendments
to IEC 60112**



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**RESULTS OF THE ROUND ROBIN SERIES OF TESTS
TO EVALUATE PROPOSED AMENDMENTS TO IEC 60112**

FOREWORD

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IEC 62062, which is a technical report, has been prepared by subcommittee 15E: Methods of test, of IEC technical committee 15: Insulating materials.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
15E/128/CDV	15E/142/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until 2005.
At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

This document, which is purely informative, is not to be regarded as an International Standard.

The contents of the corrigendum of September 2002 have been included in this copy.

RESULTS OF THE ROUND ROBIN SERIES OF TESTS TO EVALUATE PROPOSED AMENDMENTS TO IEC 60112

1 Scope

This Technical Report gives details of the Round Robin organized to investigate the level of benefit to be gained by making a series of amendments to IEC 60112.

2 Reference documents

IEC 60112:1979, *Method for determining the comparative and the proof tracking indices of solid insulating materials under moist conditions*

3 Outline of the planned Round Robin

The experimental work was to be divided into two parts: the first using equipment conforming to the current standard (IEC 60112, 3rd edition), and the second using equipment that had been modified to meet the draft proposals.

A total of six different types of electrical insulating materials were selected for study with expected comparative tracking indices (CTI) ranging from 175 to >500.

Two comprehensive questionnaires were used to establish the details of the individual pieces of apparatus and procedures.

4 Details of the Round Robin

A total of 11 laboratories, labelled A to K, took part in the Round Robin but, in practice, because of economic constraints, the results were obtained using a variety of protocols: the current standard, the previous edition, the new draft and approximations to all of these.

Two laboratories (F and J) between them could afford to build four completely new pieces of apparatus to the new draft for the second part of the exercise, two laboratories (D and G) made limited changes to their existing equipment, some laboratories did not take part in the second exercise, and the remainder (A, B and C) used the same test gear that had been used for the first part of the series.

The data from laboratories A, B and C have been used to investigate repeatability.

5 Apparatus

A questionnaire was used to establish details of the equipment that was used by each laboratory. A brief summary highlighting the supposed important answers to the questionnaire for each laboratory is given below.

Laboratories A, B and C used the same make and model of equipment, which they claimed virtually conformed with the draft proposals. It used a 600 VA transformer with a (non-conforming) voltage drop of 32 V at 100 V, and 52 V at 600 V.

NOTE A maximum voltage drop requirement was included only in the latest (third) edition of the standard.

The overcurrent trip did not disconnect when the current dropped from 0,50 A to 0,49 A (no indication of the actual drop-out current was given).

A gravity loading system was used with a glass specimen table. Two series of measurements were made and because of the near conformity of the equipment these have been included in the analysis of both parts.

Laboratory D used a commercial apparatus with a 1,0 kVA transformer with an extremely small voltage drop of 1 V at 100 V and <30 V at 600 V and a gravity loading system. The over-current trip was upgraded for the second part and a glass specimen support was used.

Laboratory E used a commercial apparatus with a 1 600 VA transformer having a voltage drop of <20 V at 600 V. A gravity loading system was used with a glass specimen support. Results were only obtained for the first part of the exercise.

Laboratory F used two types of apparatus: two 1975 vintage spring-loaded units for part 1 which used 1 kVA transformers (the voltage drop of 70 V at 100 V, and 440 V at 600 V was extreme) and three units to a new design conforming with the draft proposals for part 2. The newly designed units, however, exhibited an uncommonly wide range of individual drop sizes (13 mg to 37 mg) as compared to the performance of the equipment used by the other laboratories.

Laboratory G apparatus was made "in house". It utilized a 650 VA transformer with a near-conforming voltage drop of 10,1 V at 100 V. The drop size was marginally high and out of specification at 4,97 g for 200 drops (requirement: 3,988 g to 4,588 g). The unit was upgraded to conform with the proposed standard for the second part of the exercise.

Laboratory H used a commercial apparatus with a 600 VA transformer with a voltage drop of 13 V at 100 V. Electrode forces were marginally high (approximately 30 %) and the angle between them was only about 50°. Results were only obtained for the first part of the exercise.

Laboratory I used an in-house designed apparatus with a 1 kVA transformer with a voltage drop of 13 V at 100 V. Gravity was used to develop the electrode force. The drop size was 25 % undersize. Results were only obtained for some of the first part of the exercise.

Laboratory J used a 1975 vintage in-house designed apparatus with a 1 kVA transformer and an unspecified voltage drop for the first part of the exercise. A new in-house designed apparatus with a 1 kVA transformer with an unspecified voltage drop was used for the second series. Gravity was used in both cases to develop the electrode force.

Laboratory K used a commercial apparatus with a 1 kVA transformer with an unspecified voltage drop. Gravity was used to develop the electrode force, the specimen support table being made of metal. Results were only obtained for the first part of the exercise.

Summary of apparatus position

Laboratories A, B and C:	Identical and virtually equivalent to second-part apparatus, except for a non-conforming (high) voltage drop.
Laboratory D:	Upgraded for the second part.
Laboratory E:	Only carried out the first part.
Laboratory F:	Used two appliances for the first part, and three new/different appliances for the second part.
Laboratory G:	Upgraded for the second part.
Laboratory H:	Only carried out the first part.
Laboratory I:	Only carried out a fraction of the first part.
Laboratory J:	Used one piece of apparatus for the first part and a new/different design for the second part.
Laboratory K:	Only carried out the first part.

6 Results

Over 1 700 individual tests were made by 11 laboratories to determine the 50 drop and 100 drop points of six materials. The individual test results are given in tables A.1 to A.6 together with the three modes of failure: flaming, flaming plus tracking and tracking, although out of the 1 700 tests the specimen failed in only 327 instances. The number of failures is very dependent upon the combination of the testing strategy, i.e. start at a high voltage or a low voltage, and whether the CTI values of the materials are low or high. In this series of tests, three materials had higher CTIs than expected at the upper end of the testing range.

There were several instances where the failure mode/behaviour of the test pieces was specific to a small proportion of the pieces of apparatus:

- In eight instances out of 176, tests on unsaturated polyester in the voltage range 525 V to 600 V terminated because the electrodes penetrated the specimen: these all occurred on apparatus J₁. Conversely, although the electrodes penetrated the specimen in 21 tests out of 92 at 600 V on flame-retarded polyamide compound, none of these occurred on apparatus J₁, but with A, B, C, D and F₂.
- Failure modes for the phenolic laminate were mostly through tracking (75 instances) but apparatus C and D exhibited only flaming failure (10 instances). This behaviour was repeated with the polycarbonate test pieces, apparatus A and B were prone to give tracking failures, apparatus C and D flaming failure and yet apparatus A, B and C are of the same design.

Measured 50 drop and 100 drop points are displayed in figures 1a to 6b inclusive, with normalized numerical data shown in tables A.7 to A.14.

For the purposes of discussion, the results for each material shown in tables A.7 to A.13 have been normalized and the departure from the most commonly obtained results are discussed. The reference values ranged from 175 V to 600 V and were the same for both parts of the exercise.

In a number of instances the series of measurements on individual materials were actually made over a protracted period of time (in one case over a period of 109 days but mostly over a few days). In the analysis all results have been taken into account. This aspect raises the question whether results should be obtained over a maximum period of seven days (or whatever) to be valid.

In the first series of tests, 56 % of the 50 drop results measured by the 11 laboratories were identical and 93 % were within the range of ± 1 unit, i.e. within ± 25 V of the reference values. Out of the 69 individual results three were two units away from the reference values with outliers of one at four units and one at six units. Seven laboratories achieved 100 % of their results within ± 1 unit of the reference values.

Three laboratories (A, B and C) made one set of repeated measurements on the six materials without modifying their equipment and 83 % of the results were identical, and 95 % within a range of ± 1 unit.

Four laboratories either obtained new equipment that conformed with the draft proposals, or otherwise modified their existing apparatus to achieve the same result. Their results, together with those of laboratories A, B and C are given in table A.7.

The upgraded apparatus G exhibited a marginally narrower range of results in the second series of results.

The new apparatus J₂ performed marginally better than the original (1975 vintage) J₁.

However, the upgraded apparatus D and the new versions, F₃, F₄ and F₅ performed worse than their earlier counterparts.

In the case of F₃, F₄ and F₅ it was found that the individual drop sizes were widely scattered (13 mg to 37 mg) as compared with a recommended range (new proposal) of 19 mg to 24 mg, and an achieved range (apparatus D) of 22,8 mg to 23,6 mg. Uniformity of drop size is known to be important because the action of the drop is complex: it may extinguish any scintillations as it drops and spreads before it acts as a current carrier, raising the current levels to tens/hundreds of milliamperes before it boils away. During the Round Robin, the equipment broke down and a certain amount of redesign was done. This being the case, it is not surprising that the performance was poorer than the established design of F₁ and F₂.

Although the number of tests was substantial, the number of results was only six per laboratory per part per material. This being the case, the difference between 83 % and 100 % within ± 1 unit may be only one rough result.

The first-part result for flame-retarded PBT, laboratory D was 175(150), some 25/50 V below the average; but the second-part result was inexplicably high at 325(300) V (see figures 4a and 4b).

7 Conclusions and main recommendations.

Although over 1 700 tests were made, the number of results on which to base the conclusions is small. For reasons of economy and equipment breakdown, some measurements were made over a protracted period of time which may have distorted some of the results.

Laboratory G with an upgraded equipment achieved results with a narrower distribution than any other laboratory, with laboratories B and C also achieving 100 % of results within ± 1 unit of the reference.

Laboratory J with its new design of equipment has achieved a significant narrowing of the distribution of the results over the performance of its former equipment.

- a) The results show that the proposed changes to the standard should reduce the scatter of results.
- b) There is no indication that the proposed changes would result in a shift of the mean values.
- c) The new text is more explicit with the inclusion of toleranced dimensions and also exhibits greater clarity.
- d) As materials exist which exhibit the same 50 drop and 100 drop points (in a system which differentiates at the 25 V level), they should both be determined in any future test method.
- e) The formation of a hole in the test piece during the test should not negate the result but the fact of its development shall be reported. Numerically identical results have been obtained by different laboratories where in some cases holes have been formed and in others not. Evidence is available from a material with a CTI of 600 from the Round Robin, and from other measurements for a material with a CTI of 500.
- f) Following the experience of laboratory F, it is recommended that a new requirement should be included specifying the maximum and minimum allowable mass (19 mg to 24 mg) for each and every one of a series of 20 individual drops in addition to the present limit on the mass range for 50 drops.
- g) Failure by burning: no flame persisting for more than 8 s and no flame present 25 s after any drop has fallen to ensure that flames self-extinguish and are not put out by the next drop.
- h) The overcurrent relay in the present standard is required to operate when "a current of 0,5 A has passed for 2 s". There is no mention of r.m.s. and only a hidden requirement that if the current falls below 0,5 A then the timing period shall start again. It is recommended that the draft standard should include a circuit diagram for an r.m.s. chip-based overcurrent trip.
- i) The initial test voltage for an "unknown" material should be no higher than 400 V because some materials exist where a pass can be obtained at both 400 V and 500 V with failure at some intermediate stress levels.
- j) Increases in test voltage are limited to 25 V above 400 V.
- k) The series of measurements made on one material to produce a result shall be made over a period of time not exceeding seven days to be valid and acceptable.
- l) There are indications that the scatter of results in some instances is caused by differences in the properties of the material from specimen to specimen rather than from any weakness in the test method.

Annex A lists those technical factors, included in the current standard, which the working group recommends are amended. Details of the proposed amendments are given together with the basis for the proposals.

Annex A

Notes for charts and tables

As the maximum test voltage for the method is 600 V, the highest CTI value that can be determined explicitly is a CTI of 575: 50 drop passes at 600 V indicate that the CTI value is 600 or higher, the actual figure is indeterminate because of the voltage limitation. In a similar manner 100 drop figures of 600 indicate that the actual figure is 600 or higher.

For this reason, where laboratories obtained passes at 50/100 drops at 600 V these have been marked with an asterisk (*) in the tables and an arrow (↑) in the charts.

In some cases laboratories did not complete the full statistical procedure required by the new draft particularly in the case of the second part. Where appropriate, in these instances, asterisk and arrow signs have again been used.

In this Round Robin, the results were limited to a maximum of one determination of the CTI for each of six materials for both parts by each laboratory by design because of economic considerations. In practice, the total number of results obtained was significantly less, again because of questions of cost. For this reason, the results are only displayed in chart and table form – no statistical analysis was attempted.

Table A.1 – Individual test data for unsaturated polyester

Laboratory	Part	Electrolyte ^a	Voltage	Drops to failure in order of testing	50 drops/100 drops	Remarks
A	1	395	300	>100, >100		
			400	>100		
			500	>100		
			600	4 × >100		
			600	>100		One day later
			600	5 × >50	600/600 ^c	
A	2	395	600	5 × >50		
			575	5 × >100		
			300	>50	600/575 ^c	
B	1	395/400	200	5 × >100		
			300	5 × >100		
			400	5 × >100		
			500	5 × >100		
			600	5 × >100	600/600 ^c	
B	2	395/400	600	5 × >100	600/600 ^c	
C	1	395,3	300	>100		
			400	>100		
			500	>100		
			600	5 × >100	600/600 ^c	
C	2	395,3	500	>100		
			600	2 × >100		
			600	3 × >100	600/600 ^c	
D	1	392,2	600	4 × >101, 129U	600/600 ^c	
D	2	384,6 ^b	600	5 × >101	600/600 ^c	
E	1	395	300	>51		
			400	>51		
			500	>51		
			600	>51		
			600	2 × >101		One day later
			600	3 × >101	600/600 ^c	Three days later

Notes are given at the end of the table.

Table A.1 (continued)

Laboratory	Part	Electrolyte ^a	Voltage	Drops to failure in order of testing	50 drops/100 drops	Remarks
F ₁ ^c	1	–	600	>121, >138, >107, >126, >124	600/600 ^c	
F ₂ ^c	1	–	600	135		
			600	>103, >101, >151, >102	600/600 ^c	One day later
F ₃ ^d	2	–	600	14T, >134, 20T		
			575	>104, >101, >102, >101, >103	575/575	
F ₄ ^d	2		600	>151, >158, >101, >121, >108	600/600 ^c	
F ₅ ^d	2	–	600	>146, 68T		
			600	>136, >137, >100		Two days later
			600	>100, >201	600/575(?)	Three days later
G	1	–	500	5 × >50		
			600	5 × >50		
			500	5 × >100		14 days later
			550	5 × >100		
			600	5 × >100	600/600 ^c	
G	2	395,2	625	5 × >50		
			600	5 × >100	600/600 ^{c, e}	
H	1	397	300	>50		
			400	>50		
			425	>50		
			450	>50		
			475	>50		
			500	>50		
			525	>50		
			550	>50		
			575	>50		
			600	>50, >50, 12T		
			575	>50		
			575	4 × >50		
			550	4 × >100		
			550	>100	575(550)	One days later
I	1	390	300	5 × >100U		
			400	5 × >100U		
			600	5 × >100U	600/600 ^c	

Notes are given at the end of the table.