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Ingress Protection (IP) Testing under IEC 60529: An Applied Review of Test Methods, Uses, and Shortcomings

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***Abstract*— This paper is written to explain test methods for ingress protection testing as per IEC 60529. Its significance and how to deal with enclosure according to their IP ratings. This paper is based on detailed study of IEC 60529. The analysis of IEC 60529 suggests the prose and cones of this standard. Results obtained discuss to upgrade testing method. It approaches to build universally accepted generalize standard for all types of enclosure equipped with electrical equipment.**

Keywords: Ingress Protection, IP Code, I international Electrotechnical commission (IEC).

I. INTRODUCTION

The basic need of ingress protection is to protect against accidental contact of human. Enclosure design must comply to work under dusty and wet environmental conditions. Its design must robust that internal components are protected from outside environmental consequences. The main aim of this paper to discuss the various aspects of protection and its test methods defined in IEC 60529. In Present days, firstly, test methods are based on protection against hazardous parts. Secondly, protection against foreign objects having solid particles. Lastly, protection against water spill inside the enclosure.

However, these test methods can be modified to generate unique general standard for enclosure. Enclosure is exposed in indoor as well as outdoor applications. They undergo most severe temperature, relative humidity and air pressure conditions. IEC 60529 suggests only enclosure tested for temperature range from 15° to 35°C. Relative humidity range from 25% to 75%. Air pressure recommended is 860mbar to 1060mbar.

Test methods can be added to incorporate impact test specified in IEC 62262. Empty enclosures can also be tested in accordance with IEC 60529 by merging IEC 60068. Enclosure exposed to mechanical impact under normal working atmosphere so that can be included in IEC 60529. Worldwide temperature, relative humidity and air pressure having wide range. IEC 60529 can upgrade and specify test methods in cold, hot and moderate temperature specified in IEC 60068.

II. STRUCTURE OF THE IP CODE

An IP code is written and coded as left to right and each digit position has its own significance. “X” digit means omit protection of particular digit. For example, IP X5 enclosure is providing protection against water jets and skip protection of solid penetration. For taking example of IP 4X enclosure, it is applicable to protection against hazardous parts of one mm diameter probe and other digit of water spill is omitted.

A. First Digit of IP Code

- First digit of IP code starts from one to six digit. Each digit has its characteristics.
- It covers two types of protection in first digit. Firstly, it is protected accidental contact of technician or unskilled person. Secondly, it is protecting penetration of solid objects entering inside the enclosure.
- IP 1X: Enclosure tested with 50mm sphere refereed as back of hand applied with 50N force and it shall not penetrate inside the enclosure.
- IP 2X: Enclosure tested shown in fig 1, firstly with test finger having 12.5mm diameter with a force of 10N and then 12mm diameter sphere having force of 30N. In both case, test finger and sphere shall not enter inside the enclosure.
- IP3X: Enclosure tested with 2.5mm tool or wire with force applied is 3N. It shall be protected against hazardous as well as solid objects of 2.5mm.
- •IP 4X: Enclosure tested with 1.0mm diameter probe. The force applied is 1N from all expected openings. The wire shall not enter inside the enclosure.
- •IP 5X: Enclosure are having protection against IP 4X test and also tested in dust chamber as shown in fig. 2, Sample is tested as per Category 1 or Category 2 as per its design.
- Category 1 enclosures are those in which pressure developed inside enclosure not released in normal working condition.
- Category 2 enclosure are those in which pressure developed during working condition release by existence

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of breather or ventilation inside the enclosure.

- Acceptance criteria for IP 5X enclosure is that probe of 1.0mm shall not enter inside the enclosure and negligible amount of dust is permissible. It shall not affect to correct operation of the equipment. It is not accepted if thick continuous layer of dust is observed. It may lead to bridging between live parts inside the enclosure.
- IP 6X: Enclosure are having protection against 1.0mm probe test and also tested in dust chamber as shown in fig. 2, Sample is tested as per Category 1 only.
- Acceptance criteria for IP 6X enclosure is that probe of 1.0mm shall not enter inside the enclosure and no single particle of dust is permissible. It is not accepted if any thin or thick layer of dust is observed.

B. Second Digit of IP Code

- IP X1: Enclosures are tested with vertical rain apparatus. The water flow set is 1mm per minute and sample is mounted as per fig 3. The turntable moves and total test duration is 10 minutes. After test, sample checked visually and afterwards checked with either its functionality or high voltage test. Also, in case of Energy meter, insulation resistance test is carried out which is specified in respective product standard.
- IPX2: Enclosures are tilted 15° and mounted in vertical rain apparatus as per fig3. The water flow set is 3mm per minutes. The ample and turntable are not moving during test.

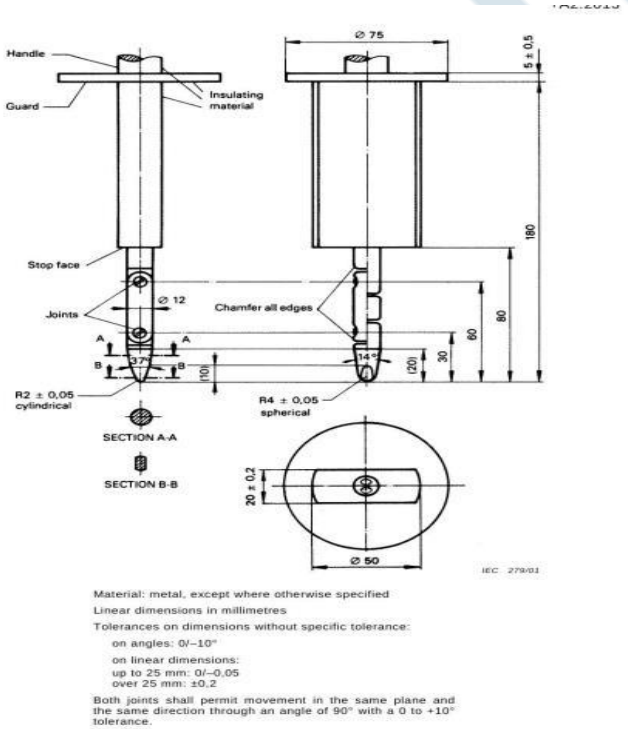


Fig. 1. IP 2X Test device [1].

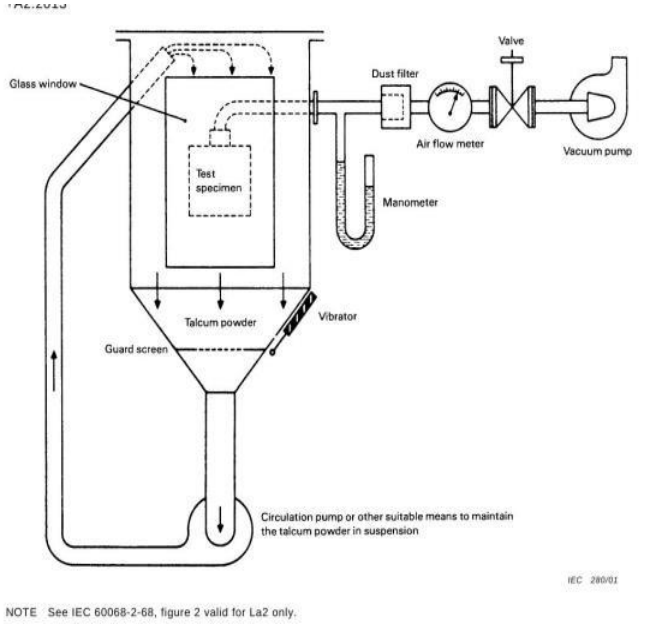


Fig. 2. Dust chamber for 5X and 6X [1].

Four positions of sample moved and each potion having test duration 2 minute and 30 seconds. Total test time is 10 minutes. After test, sample checked visually and afterwards checked with either its functionality or high voltage test. For example, Direct on-line starter.

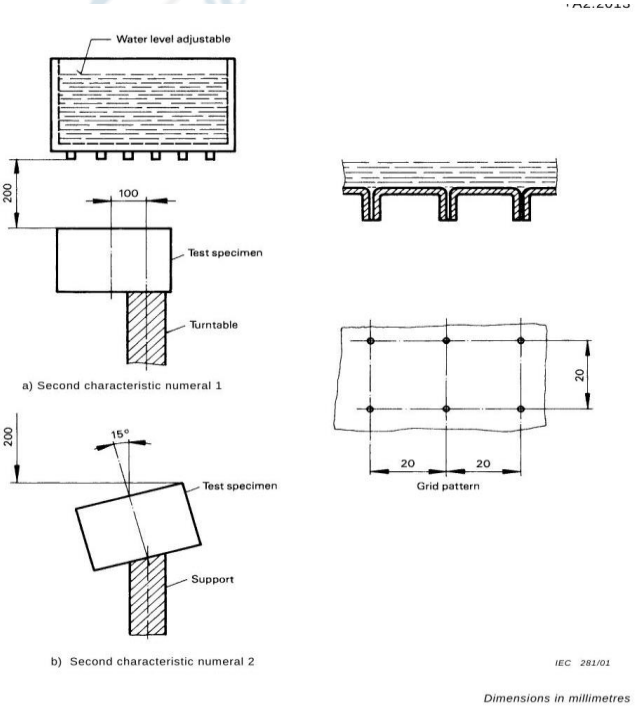


Fig3. Vertical rain apparatus

- IPX3: Enclosures are protected against spraying water test. Testing cane be performed by using either oscillating tube or Spray nozzle.
- Oscillating tube method: Water sprayed from 60° vertical hole of 0.4mm having water flow as per number of holes,

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maximum distance 200mm and as per fig 4. The minimum test time of 10 minutes applicable for small size enclosure.

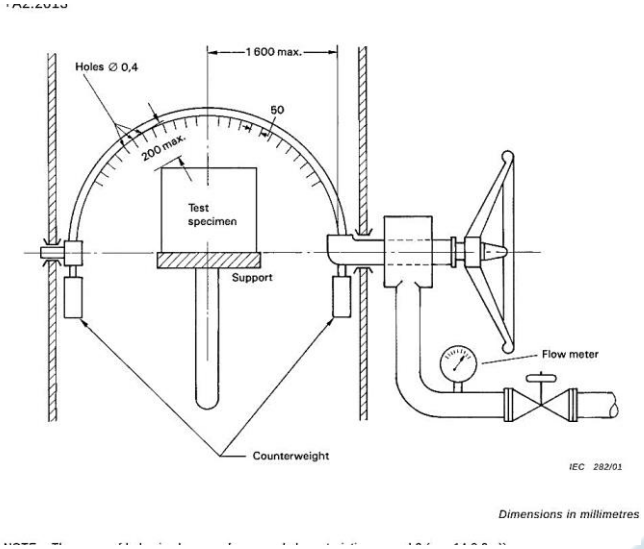


Fig. 4. Oscillating-tube device for IP X3 and IP X4 [1].

- Spray Nozzle method: Water sprayed hole of having 0.5mm from 60° vertical having water flow 10liter per minute. Distance between sample of spray nozzle is between 300mm to 500mm as per fig 5. The minimum test time of 5 minutes for small version of enclosure. For big enclosures, Calculated application time for one minute per meter square area.
- IPX4: Enclosures are protected against splashing water test. Testing cane be performed by using either oscillating tube or Spray nozzle.
- Oscillating tube method: Holes of 0.4mm and water splashed from all practicable directions and water flow as per number of holes, maximum distance 200mm and as per fig 4. The minimum test time of 10 minutes applicable for small size enclosure.
- Spray Nozzle method: Water splashed from any practicable directions having 0.5mm hole and water flow 10 liter per minute. Distance between sample of spray nozzle is between 300mm to 500mm as per fig 5. The minimum test time of 5 minutes for small version of enclosure. For big enclosures, Calculated application time for one minute per meter square area.

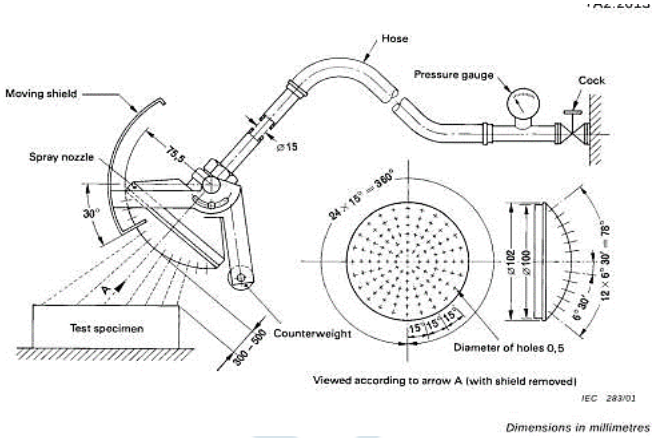


Fig. 5. Manually operated Nozzle device for IPX3 and IPX4 [1].

- IPX5: Enclosures are protected against water jets. Testing with jet nozzle having 6.3mm diameter as per fig 6. Water flow set is 12.5 liter per minute and distance from jet nozzle to sample is 3 meters. Water jet is applied as per 1 minute per meter square area.
- IPX6: Enclosures are protected against powerful water jets. Testing with jet nozzle having 12.5mm diameter as per fig 6. Water flow set is 100 liter per minute and distance from jet nozzle to sample is 3 meters. Water jet is applied as per 1 minute per meter square area.

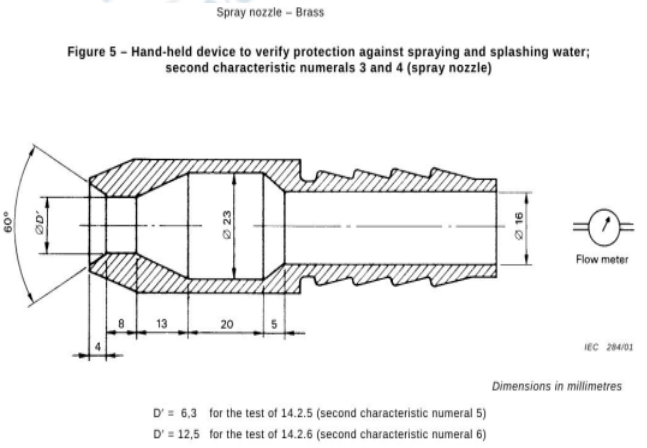


Fig. 6. Jet nozzle for IPX5 and IPX6 [1].

- IP X7: Enclosures are protected against temporary immersion. Sample under test is immersed in water tank for 30minutes. For enclosure having height less than 850mm are immersed 1000mm below lowest point of enclosure. For enclosures having height more than 850mm are immersed 150mm above highest point of enclosure.
- IPX8: Enclosures are protected against continuous immersion. Sample under test are immersed in water as per agreement between manufacturer and testing laboratory. The primary condition of IP X8 is such that severity more than specified for IP X7 test. It means

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immersion depth and testing duration shall be more severe.

- IPX9: Enclosures are tested with high temperature and high-Pressure using high-Temperature Jet Test Testing was added in Amendment 2. For increasing severity point, A fan-jet nozzle hits the enclosure from four angles — 0°, 30°, 60°, 90° — while it rotates on a turntable as shown in fig. 7. Water temperature arrives at 80 °C, water flow rate is 14–16 L/min, Air pressure 8,000–10,000 kPa, maintained for each angle for at least 30 seconds from 100–150 mm distance away.

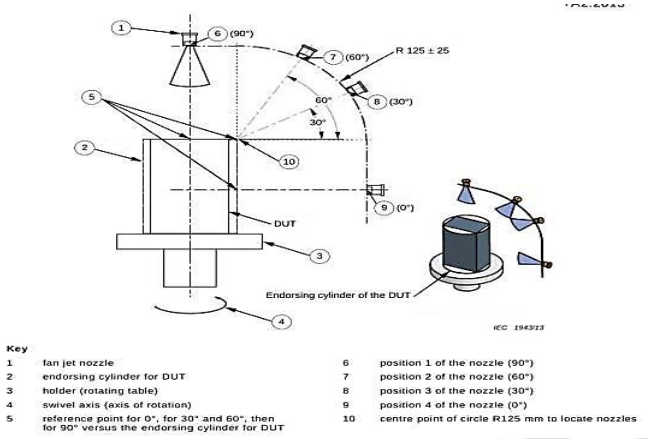


Fig. 7. Test device for IPX9 [1].

- Acceptance criteria for IP X1 to X9 are same. After the test, if water entered inside the enclosure, it shall not be in quantity to affect correct operating method of enclosure. Water shall not reach to live parts of enclosure which are not required to operate in wet condition. It shall not deposit on insulation parts it may decay with its life cycle. Either dielectric test or performance test as carried out after visual examination. If it is complying one of the tests, we can conclude that enclosure conformity in particular code.

Table I. First Digit: Protection Against Accidental Contacts

Digit	Description	Verification
0	No protection	—
1	Back-of-hand contact	50 mm sphere probe must not reach hazardous parts
2	Finger contact	12 mm jointed test finger must not reach hazardous parts
3	Tool contact	2.5 mm probe must not penetrate
4	Wire contact	1.0 mm probe must not penetrate
5	Wire contact	1.0 mm probe must not penetrate
6	Wire contact	1.0 mm probe must not penetrate

Table II. The First Digit: Protection Against Foreign Material

Digit	Description	Verification
0	No protection	—
1	≥50 mm objects	50 mm sphere must not fully penetrate
2	≥12.5 mm objects	12.5 mm sphere must not fully penetrate
3	≥2.5 mm objects	2.5 mm probe must not penetrate at all
4	≥1.0 mm objects	1.0 mm probe must not penetrate at all
5	Dust-protected	Some dust ingress tolerated, provided it doesn't impair operation or safety
6	Dust-tight	No dust ingress permitted

Table III. Second Digit: Protection Against Water Spill

Digit	Description	Verification
0	No protection	—
1	Vertical drips	No harmful effect from vertically falling drops
2	Drips, tilted 15°	No harmful effect with enclosure tilted up to 15° either side
3	Spray	No harmful effect from water sprayed up to 60° off vertical
4	Splashing	No harmful effect from splashing water, any direction
5	Water jets	No harmful effect from jets, any direction
6	Powerful jets	No harmful effect from powerful jets, any direction
7	Temporary immersion	No harmful ingress under standardized pressure/time immersion
8	Continuous immersion	No harmful ingress under conditions agreed between maker and user, stricter than numeral 7

III. WHERE THE STANDARD FALLS SHORT

Although IEC 60529 [1] is the mother standard for enclosure having ingress protection, but it does not define whole parameters of enclosure which are mentioned in standards like UL 50E [4] or NEMA 4X [3] makes the big gaps visible by comparing it.

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Table IV. Supplementary digit of IP Code

Letter	Significance
H	High-voltage apparatus
M	Tested for harmful effects due to the ingress of water when the movable parts of the equipment (for example, the rotor of a rotating machine) are in motion
S	Tested for harmful effects due to the ingress of water when the movable parts of the equipment (for example, the rotor of a rotating machine) are stationary
W	Suitable for use under specified weather conditions and provided with additional protective features or processes

Table V. Additional digit of IP Code

Additional letter	Degree of protection		Test conditions, see
	Brief description	Definition	
A	Protected against access with the back of the hand	The access probe, sphere of 50 mm Ø, shall have adequate clearance from hazardous parts	15.2
B	Protected against access with a finger	The jointed test finger of 12 mm Ø, 80 mm length, shall have adequate clearance form hazardous parts	15.2
C	Protected against access with a tool	The access probe of 2,5 mm Ø, 100 mm length, shall have adequate clearance from hazardous parts	15.2
D	Protected against access with a wire	The access probe of 1,0 mm Ø, 100 mm length, shall have adequate clearance from hazardous parts	15.2

A. Narrow Scope and Test Method:

The standard covers protection against solids and water only. It says nothing about corrosion resistant, long-term weathering decay, UV degradation, or freeze–thaw cycling — all factors that UL 50E [4] and the NEMA framework [3] openly address.

B. Measurement Method:

It is based on visual examination. Test results obtained after test required more precision.

C. Durability Issue:

The sample tested according to IEC 60529 does not specify deign validation and guarantee about its consistent operation. There is no specified self-life of enclosures tested. IEC 60529 is not specifying material, gasket, locks, hardware etc. of enclosures for ingress protection.

D. Provision of Sealant:

IEC 60529 does not suggest use of silicon sealant. Also, not promoting use of sealant via sealing material like Ana bond, M-seal and any other types. Probability of tempering enclosure with sealant used always meet ingress protection.

IV. WHERE THE STANDARD UPGRADE IN FUTURE

A. Addition of Other Test Method:

IEC 60529 can expand its scope by adding test methods of enclosures for another standard like UL 50E [4], NEMA 4X [3], IEC 62262 and IEC 60068-2. Finally, it can become universally unique standard for enclosure testing with all parameters covered.

B. Ageing Aspect Declaration:

IEC60529 does not specify self-life of enclosures testing. Its gasket, sealant, hardware etc. decay after some time of operation. Sample can be pre-conditioned in field (indoor/outdoor) before submission for test and after testing perform its working operation for specified days.

C. Sealant Banned:

IEC 60529 should specify that sealant must not applied for enclosure under test. It is recommended to use only clear and sealant free sample. If sealant sample is tested, it means we are covering by umbrella to enclosure during testing time. In actual field, it will no work for longer time. Temperature, humidity and air pressure start degrade its gasket, sealant and other parameters.

D. Digital Based Result:

Presently, visual examination is used for result declaration. Digital scanner and other computation technique can add to declare results. It could be more accurate and precise rather than humanize inspection. Instead of physical testing, automated system can save testing time.

V. CONCLUSION

As IEC 60529 is general standard for enclosure testing, it defines very simple way coding system and its significance. It is required to test enclosure under different temperature, relative humidity and air pressure so that useful worldwide. If it expands scope by adding corrosion, mechanical impact, environment test etc. led to become universally accepted standard. With those parallel standards into the core framework, single standard for IP rating carries a completer picture of real-world enclosure performance.

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