A Beginners Guide To
Ingress Protection Testing
Inevitability

"Everything Must Fail at Some Point, it's a Matter of Time, Material, Design and Build, External Influences and Human Intervention"

FACT

“The only way to identify weakness and prove a product is to TEST, any other method is pure THEORY”

Just like Schrodinger’s cat, you have to look inside the box to see the result, if you don’t it’s all just hypothetical

About this paper

This document is intended to provide an introduction to the subject of Ingress Protection (IP) Testing, and how it can be applied in the product research and development phase to improve product performance, prevent field failures, and reduce repair and warranty costs.

Protecting your products

Product failures in the field are a burden to any manufacturer or vendor, which not only compromise product function and create client frustration, but can result in costly failure investigations and maybe the need to redesign the product.

These factors add additional costs in time and money with reworking the product on the drawing board, adjustments in the manufacturing process, new tooling and reprogramming production line equipment and even the need for a product re-evaluation if it carries third part validations.

The cost of your recall or corrective actions will also need to be factored in – that is the logistics of collecting failed products, repairing or replacing them and re-issuing them to clients.

Disgruntled customers may also defer to alternative brands and new customers may opt not to buy from you after all. The impact of all these factors can mean the long term costs of a field failure can spiral out of control.
So what went wrong?

What is the problem?

How can it be resolved?

Are all essential questions in the circumstance of a field failure, but the real key is what you do next time to ensure that such issues are not seen in future products.

In essence most failures can be attributed to an accumulation of various stresses strains, environmental and mechanical influences. If this is the case then conventional testing may not replicate all field failure modes.

Look at your product and you will note that it is made of various materials, some of these components like alloys and silicon chips are also created by mixing various materials together in an amalgamation like an alloy or PC ABS. Each component, assembly and device has an individual tolerance to temperature, moisture, dust, friction and mechanical wear - making none of them identical. This makes the life cycle of a product very difficult to control.

Mother Nature can be the burden of every design group, manufacturer, logistics company or end user. She provides us with salty air and water, dust, grit and extremes of temperature. Add to this the manmade environmental and atmospheric conditions, and you end up with a number of elements your product will need to withstand in order to meet customer expectations for product durability, integrity and performance.

Ingress protection (stopping environmental elements getting inside your product) is a key defence element for your product to survive in the field. Lack of it is one of the main causes of equipment failure and this can be prevented.

**Nature’s gift**

The Earth provides us with natural climatic conditions such as the air we breathe. This is brought to us by the wind from plants and trees and in turn we exhale carbon dioxide that is passed back to the plants thus making us a small part of the circle of life. But this is not all that is transferred by the wind; pollen, skin cells, dust, carbon, ash, gasses, moisture and human pollution are among others.

Also, wind is not always nature’s movement; in urban environments cars, planes, trains and tubes also increase the particulate matter held within the atmosphere and these can circumnavigate the world in just four weeks, to impact other less developed environments. Indeed adverse weather events such as dust and sand storms can send contaminants over many miles and volcanic eruptions can
distribute a magma dissolved gas consisting of hot ash that is injected into the upper atmosphere, impacting people and equipment hundreds of miles away.

**Examples**

- In 1991 Mt Pinatubo erupted sending 250 megatons of gas in a single day into the upper atmosphere. Most of this gas was water vapour combined with harmful sulphur, carbon dioxide hydrogen sulphide and other gasses.

- Dust storms Simoomor, Haboos - These are frequent in arid dry areas and can release a large amount of dust into the air where it can be distributed over many miles. Wind at as low as 20mph can collect dust and sand particles elevating them as high as a mile into the air.

- In May 1990 Khartum in Sudan was affected by a large dust storm that lowered visibility to a very short distance and deposited its materials in surrounding areas or even in neighbouring countries.

However not all airborne contaminants / particles are nature made. Various production industries pump gases into the air, and when these combine with moisture, they can have adverse effects.

Vehicles can also be a major factor in propelling contaminants into the air indeed - if sand and dust can be picked up by a 20mph wind, then any moving vehicle can also place particles into the air:

- Cars, 0mph to 70mph
- Buss, coach and lorry 0 to 70mph
- Trains, 0mph to 140mph
- Tube, 0mph to 60mph

Particles are also collected within moisture vapour that creates clouds. This can be moved many thousands of miles before it converts to a liquid and falls as rain depositing the sediment or particles upon a surface (that might be your equipment!).

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Why protect against foreign objects?

In design we strive to achieve a product that can perform as expected in the users environments, but all materials we work with have a natural weakness, be it thermal, climatic, mechanical or relating the light spectrum.

One of a designers key goals is to stop external contaminates from damaging their carefully designed devices, avoiding effects such as shorting out electrical circuits or prohibiting mechanical moving parts from seizing when they become clogged with dust or grit.

Encasing the device within an enclosure assists the protection of the product, but how well this case protects the product is defined by the standard BS EN 60529, (Degrees of Protection Provided by Enclosures IP Code) for standard enclosures or BS EN 60598 for luminaires devices.

Safety is also an important issue, providing a guard or boundary that prevents contact by even the smallest finger from touching live parts, chemical compounds or mechanical moving mechanisms hazards.

We also have a responsibility to protect local wildlife. A small gap in your outer casing will allow insects, arachnids and bugs to find into an area safe from larger predators. They can short out circuits and cause irreparable damage. One insect may not be seen as a big issue, but what if the enclosure is inhabited by a swarm of bees or colony of ants.

For these reasons your choice of enclosure needs to be carefully thought over and the IP rating set accordingly. The IP standards cover ingress probe tests, dust and water ingress verification methods.

What are the test levels?

The most used ingress protection test levels are defined in the BS EN 60529, this is generally used for cases, BS EN 60598 covers Luminaries and IEC 60950 part 2 for Information Technology outdoor equipment. Although the 60598 and 60950 both reference the 60529 standard they differ in either test duration or operational requirements.

The 60529 standard will direct you to what each level represents with the first characteristic testing the ability for solid objects to penetrate the case. This starts with IP0X that shows no protection at all, IP1X ensuring nothing under 50mm can access the enclosure to IP4X where this is reduced to a 1mm test probe. Be aware that this is looking for more than just testing with a probe of a particular size but also requires consideration of a complex manner of motion for entering your device. An interpretation of this is to think of a maze, a test probe cannot enter
and exit with an obstruction, however a maze can be navigated and thus enter and exit the other side of the maze. This clause is to cover ingress of animals into the internal area.

What is the second numeral in an IPXX rating? This is for water ingress, again IPX0 is for a non protected device, IPX1 in the BS EN 60529 standard covers the unit in a 1mm per minute vertically falling water test, to IPX6 where the water is in a high flow rate of 100 litres per minute through a nest nozzle. These change from time to time so always refer to the latest standard for the procedure and test levels.

What test levels do I require?

Your selection of testing levels may already be defined by your client, however if this is not the case then you will need to select the rating that best covers the environment that your product will be used within.

For example:

**Paint pots**
Selection possible choice IP64 - Any water or dust penetrating the can would lead to a reduction in the quality of the paint. The paint pots are normally stored within a building and transported within enclosed trucks or vehicles, for this reason powerful water jets and immersion testing would be too severe for the environment it may encounter.

**Internal Transformers**
Selection possible choice IP3X - This is for an internal transformer module, protection of dust and water should be made if required from an enclosure that covers all internal modules thus eliminating the need for the transformers case to provide this protection. However it will need to prevent maintenance engineers and alike from touching live connectors or accidentally dropping tools etc. onto the PCB, causing short circuits or damaging the functionality of the unit.

**Dive watches**
Selection possible choice IPX8 - A dive watch would need to stay water proof to ensure continued functionality during submersion. The pressure and depth would be set by either your own requirements and would need to be detailed in your products documentation.

How to Protect Against Foreign Objects

Placing your product within a box sounds simple, however you may have user interface requirements such as a keypad, or touch screen. Power supply cables may also be required and interconnection ports, such as USB, RS 232 Ethernet and
other forms of cables. Various methods can be used depending on the IP level you wish to achieve but the best method is to keep it simple or ‘KIS’ for short. The more complex your design such as windows, cable entry points, keypads and doors, the more engineers tend to design complex sealing methods, and thus may introduce more opportunities for ingress.

However we don’t all want to use mono grey block construction devices, and the need to separate your product from those currently in the market place calls for radical designs, often created by folk that have little idea of the complexities of achieving the required acceptance levels set by standards or expected by the end user.

This then becomes the challenge to design engineers to keep the new innovative design and build in the necessary structures to ensure conformance to requirements and to enable manufacturing to produce the product in a cost effective and logical manner.

Think smart and don’t reinvent the wheel:

- Check your old projects / products to see if they encompass a potential direction for your latest devices design.
- Check the testing records to see how it performed and improve where possible.
- Add the data from all products for the section of interest and investigate what worked and what did not work and why.

The six sigma process may even be of use in your investigation.

This data can be saved and used in the future, thus saving time for further engineer’s investigations into corrections into correcting the same problem. Once you have determined a potential method of sealing, test it as soon as possible during the development phase, as later redesigns normally incur changes to more than a single part of the device constituting costly implications for tooling and production assembly jig fixtures etc. Pre-test the unit by the use of a hose pipe for water over areas of interest while monitoring the internals for ingress.

**Golden rules**

1. If a paper clip wire can enter the case, then so can water.

2. If water can enter the device so can dust.

3. If water gets in, let it out. (IP level dependant)
4. If water is allowed to enter create a path to the exit avoiding critical areas.

When looking at the sealing of your product don’t forget the effect of time. Rubber hardens and dries out in hot dry environments and it hardens in the cold extremes. It can even be affected by some chemicals. Ensure engineers that maintain the equipment also maintain and inspect the seals to verify integrity.

Understand that what seals now may not in a years’ time. Test the material through thermal and climatic conditions. Calculate the maintenance frequency of replacement to avoid ingress and potential damage to your encased equipment. Material life can be plotted using the bath tub analysis as shown in the next section.

**Bathtub Analysis**

The bathtub analysis is a favourite tool for showing the life cycle of your product and its material types.

![Bathtub Analysis Diagram]

This shows three distinctive areas of interest.

*Early life failures*

These depend on the context of the product in question, for example a raw material failure in this area could be a natural flaw or poor creation of the material creating a weak point. Poor protection during storage and shipment will accelerate material failures and shorten the life cycle of your component and thus also your product as the material has already started to change its state back to its natural...
form before you have even received it for use. Poor coating protection of the material will allow material to degrade at an accelerated rate.

These effects are not always immediately evident but can start to show after a short time, customers in some cases may receive a device with parts that has been slowly deteriorating while in a bonded store or on a shipment container in transport.

**Reliable Stable Life**

This area depicts the stable state of the material, product or process that needs to cover your warranty period. Some failures will still occur here due to coating damage or exposure to long term extreme atmospheric conditions, a good example is use of a material in adverse climatic conditions such as prolonged freezing fog when the product is not designed for this unnatural environment. If this failure mode rises above your threshold for your quality target then this brings forward your end of life / wear-out stage - decreasing your profit and increasing your warranty costs.

**End of Life Wear out Failures**

End of life is where the material naturally breaks down or reverts to its natural state. The aim in a product is to ensure this is past the warranty period or maintenance interval to avoid costly replacements, repairs.

Wear out can be from mechanical parts moving - causing mechanism failures, other modes may include the wear out of the protective shield (like a conformal coating) resulting in exposure of the base material to the corrosive atmosphere.

**Preparation in the design stage**

While in the research and development stage, be sure to investigate the market place you intend to sell to. You need to understand the environments and the corrosive element attributed to them. Your IP testing and test selection will help avoid ingress of not only water and dust but corrosive atmospheric metallic / conductive particles that may cause early safety failure modes resulting in not only equipment failure but personal injury.

Do not store the equipment for a long period of time to reduce the chances of early field failures.

Look at your device and design carefully, is the material constantly, intermittently or rarely handled? This will determine the level of protection required. Surfaces that are in contact with a moving part, for example door hinges may cause stress to an aging seal and may have the effect of expediting failures prematurely.
Environmental factors also increase the speed of the failures; a hot dry environment in some cases may expedite the drying out of rubber, cold and wet conditions may stiffen materials used for sealing. These may reduce the lifespan of your device.

Look at your historical data from previous models, information can be found from field failure returns, repair centres, insurance claims and even local web blogs and forums. This will not only show failure trends but the repair work sometimes can pinpoint the cause.

Testing a previous model can give you a great deal of information - this benchmark can be an acceptance criteria if the previous design was a success, or it can be the starting point if previous problems were found.

**Summary Tips**

1. Work out where your product will be used
2. Investigate what conditions will it have to survive
3. Investigate who and what needs to be protected
4. Select the IP Rating this requires
5. Design an enclosure that uses the KISS system
6. Witness the testing to ensure if a failure occurs you fully understand where the correction is required
7. Monitor your product in the field to ensure maintenance schedules for seal replacements are correct.
8. Save the field data and design from successful projects for future ones.
9. Try putting a light in your device and place it in to a dark room, any light emitting from your case indicates an opening.
10. Try to pre-test your product yourself prior to sending to the laboratory for evaluation or certification, use a hose pipe for water tests and thicker wire for probe testing.

**How Intertek can help**

- Our engineers will work with you to determine what environmental tests are relevant to your product and market.
- Our chambers routinely test products for aerospace, military, industrial, medical, life safety, lighting, domestic and IT applications and our breadth and range of experience, informs the advice we will provide.
- We can test to the IEC 60068-x-y series and MIL, DEF and RTCA standards listed below, or we can design a custom test programme to meet your needs.

MIL-STD-810G

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500.5 Low Pressure (Altitude)
501.5 High Temperature
502.5 Low Temperature
503.5 Temperature Shock
504.1 Contamination by Fluids
506.5 Rain
507.5 Humidity
509.5 Salt Fog
510.5 Sand and Dust
511.5 Explosive Atmosphere
512.5 Immersion
513.6 Acceleration
514.6 Vibration
515.6 Acoustic Noise

IEC Standards
60068-1 General and guidance
60068-2-1 Tests - Test A: Cold
60068-2-2 Tests - Test B: Dry heat
60068-2-5 Tests - Test Sa: Simulated solar radiation at ground level and guidance for solar radiation testing
60068-2-6 Tests - Test Fc: Vibration
60068-2-7 Tests - Test Ga and guidance: Acceleration, steady state
60068-2-11 Tests - Test Ka: Salt mist
60068-2-13 Tests - Test M: Low air pressure
60068-2-14 Tests - Test N: Change of temperature
60068-2-17 Tests - Test Q: Sealing
60068-2-18 Tests - Test R and guidance: Water
60068-2-27 Tests - Test Ea and guidance: Shock
60068-2-30 Tests - Test Db: Damp heat, cyclic (12 h + 12 h cycle)
60068-2-31 Tests - Test Ec: Rough handling shocks, primarily for equipment-type specimens
60068-2-38 Tests - Test Z/AD: Composite temperature/humidity cyclic test

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