

BLOW MOULDING CONTROLS LTD

LEAK TESTING COURSE NOTES

LEAK TESTING

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SECTION 1

WHERE DO HOLES COME FROM?

Holes are produced in containers from various sources, but the number one reason is contamination. This can be from the raw material or degraded plastic inside the machine. However, the most likely explanation comes from the regrind which is blended with virgin material and masterbatch. Regrind is an inherent part of extrusion blow moulding but should be regarded as necessary evil.

When the excess flash or top and tail scrap is granulated, there is a potential opportunity for contamination to enter the recycling system. This can be bits of paper, cardboard, cloth, chipped granulator blade, pens, keys, coins, nuts and bolts, cigarettes, tools - the list is endless!

Although most blow moulders have magnets in the hopper, the non-metallic items still pass down the extruder and form part of the parison. When the blow air forms the container, the particles may manifest itself as a hole.

Ideally no regrind should be used, however this is not practical due to the polymer cost implications. Typically 20-30% flash is generated on every container, therefore 20-30% of the mix is regrind. Only companies involved in high risk products i.e. pharmaceuticals have the luxury of 100% virgin materials handling and waste management system coupled with good housekeeping.

Burnt or degraded polymer can also cause holes by periodically breaking away from the internal surface of the head or die and pin. This may form a hole when the parison is inflated. Heat sensitive materials such as PVC are particularly vulnerable to degradation.

Virgin material has also been found in the past to contain contaminants such as metal and insects. This is fairly unusual as most material suppliers take great care when producing the granules.

The other major explanation for holes is the mould or deflashing problems. If the mould closing speed is too fast a split may occur in the weld of the container, or if a mould that has sections is not rebuilt completely flush, then a pin hole leak may develop. This hole would normally be undetected by the human eye. Once the container has been blown, it may be deflashed automatically, holes can be created if the punch is not aligned correctly. Handled containers are the most likely to have this type of fault.

So now we know what causes the holes, all we have to do now is find them!

SECTION 2

METHODS OF LEAK DETECTION

There are various ways to test a container for leaks. The most common is pressure decay and is explained in some depth after a brief word on the other methods available.

Vacuum

Instead of using internal pressure, a vacuum can be applied. Although this has the slight advantage of pulling the test seal onto the bottle, most mouldings are designed to withstand internal not external pressure so container collapse is quite possible.

Tracer Gas

Various gases e.g. Helium, Freon, Ammonia etc. can easily be detected in very small concentrations by electronic sensors. By pressurising the moulding with air/tracer gas mix, small leaks can be detected with the electronic sniffer.

This method is ideal for large containers e.g. 220 litre steel drums, particularly when the likely leakage points are known, usually on the welded seam.

This technique is also good for automobile petrol tanks as 99.9% of all leaks are on the filler and fuel sender attachments.

Ultrasonic Sound

Instead of pressurising tracer gas, the ultrasonic sound method fills the container with noise. An ultrasonic sensor turned to the ultrasonic frequency - usually about 40kHz is then scanned over the outside surface. Any leak will let out the noise. This system has not been widely adopted in Europe. One problem is that the world we live in is rich in noise of all frequencies and some of these can accidentally trip the ultrasonic sensor. In particular ultrasonic welding equipment can interfere with ultrasonic leak testers at great distances.

Bubbles Under Water

Immersing a pressurised container under water is still one of the most accurate and reliable methods of finding leaks. Although virtually all modern leak testers use the pressure decay method, none can find holes as small as the bubble method. The human eye/brain combination has not been matched by any technology when it comes to spotting tiny bubbles forming. It can sometimes be very useful to see where the leak is, as in the case of steel petrol cans, as the leak can be brazed over. Unlike electronic pressure decay systems that reject the moulding regardless of where the leak is, human operators can ignore leaks caused by a poorly fitting test seal. With all these points in mind, the old fashioned bubbles under water method should not be underestimated.

Pressure Decay Method

This is by far the most popular and accepted method. Most leak testers work on the 'pressure decay' principle i.e. the moulding is pressurised usually to a very low pressure. This pressure is measured and any decay beyond a set limit causes the moulding to be rejected.

(Also see section 4)

Electrical Methods (Voltage Discharge)

The container under test is surrounded by a conductive mask. Then a special probe is lowered into the container and a high voltage pulse of over 90 thousand volts is applied. These electrons are strongly attracted to the outer conductive shield and will find their way even through micron sized holes. These are easily detected by measuring the current flow from the probe.

(Also see section 9)

SECTION 3

WHAT SIZE HOLE CAN BE DETECTED?

Leak tester manufacturers are constantly being asked "How small a hole can you find?" Because of many factors there is not a straight forward answer. The main limitations to finding very small holes is the cycle time available, the bottle capacity and the stiffness of the bottle.

There are other variables such as bottle temperature, ambient temperature and pressure, but these can be ignored for the present.

The biggest restriction to setting a leak tester to ultra sensitivity is probably the variable stiffness of the bottle.

If a series of 5 good bottles are pressurised to the same pressure e.g. 0.5 psi, after 10 seconds the pressure will have fallen to .485 .473 .464 .427 .459. Consequently the leak tester will need to be set to accept pressures higher than the lowest pressure .427 psi, otherwise this 'good bottle' will have been rejected.

It can be clearly seen that it is not practical to set the reject level at 99.9% of fill pressure otherwise all good bottles will be rejected.

As we all imagine, a perfectly set leak tester in perfect conditions with a small capacity still bottle, would yield good impressive results. Unfortunately anyone who lives in the real world will accept that their factory test conditions are less than perfect and your engineers have better things to do than play with leak tester settings all day.

Leak tester manufacturers who claim to find smaller holes than anyone else's usually end up de-sensitising their leak testers to prevent an unacceptable reject rate of good bottles.

Most good leak testers will find a 0.1mm hole reliably in a 1 litre bottle in 7 seconds.

Holes smaller than this probably only constitute 1 in 1000 holes and with good housekeeping, perhaps only 1 in 1000 bottles has any hole. Thus it is feasible to imagine only 1 bottle in a million get shipped with a hole.

Filling companies don't generally mind 1 leaker in a million. Its the bottles with 2cm holes that stop the filling line every 15 minutes that drive them crazy!

If it is essential to find very, very, small holes there are various solutions:-

- a) Test bottles when they are colder by using longer conveyors or accumulating tables before the leak tester.
- b) Hold bottles in a purpose designed nest to ensure exactly repeatable positioning.
- c) Prevent air-line fluctuations by fitting a local air receiver.
- d) Have a properly calibrated test hole fitted to a sample bottle and run it through the leak tester at least once an hour.
- e) Lock the adjustments from unskilled operatives.

On Blow Moulding Controls leak testers, the threshold or reject pressure % is factory set at 80%. This means that containers that retain less than 80% of the original pressure will be rejected.

This works very well and will detect medium and large holes. However a container with a very small hole may retain a pressure about 80% and be passed. To prevent this the unit should be fine tuned so that the reject pressure % is 2% below the lowest measured final pressure % (test result). This can be done by monitoring the final pressure % on containers passing through the unit. If the unit is set in this way, the smallest possible holes will be found. If this appears to be rejecting good containers, make sure they are good and then adjust the reject pressure % so it is 2% below the current measured final pressure %.

As already stated, the other limitation is the test time available. This has to be short enough, so that containers don't queue back into the blow moulder causing a jam up. However, the more test time available, the more credible the test., The graphs on the following pages show the correlation between container size, output rate and detectable hole size.

If the output rate of the blow moulder exceeds 1800 1 litre bottles per hour, a twin or quadruple test head must be used. A twin test head unit can cope with 2400 containers per hour and a quad 3200 per hour assuming a 1 litre bottle.

On very large containers it is necessary to have a longer test time. This is possible due to the long blowing time (2-3 minutes on a 220 litre drum). This means a 0.3mm hole can be found using the two or three minutes available.

To find holes of 30 micron or less, pressure decay can no longer be used. Blow Moulding Controls have developed the Plasma Leak Detector which eventually aims to detect holes of a few microns. The process is explained in section 9.

HOLE DIAMETER AGAINST THROUGHPUT
FOR VARIOUS BOTTLE SIZES

HOLE DIAMETER AGAINST THROUGHPUT
FOR VARIOUS MOULDING SIZES

SECTION 4

PRINCIPLES OF PRESSURE DECAY

This is by far the most popular and accepted method. Most leak testers work on this method.

i.e. The moulding is pressurised to a low pressure. This pressure is measured, any decay beyond a set limit causes the moulding to be rejects. If the moulding was rigid and leak tight and we lived in a perfect world, the pressure profile would look like figure 1 (at the end of this section). This would enable a very close limit to be set on a Pass/Fail level.

In real life many other factors come into play which reduce the repeatability of this test principle. A real life profile is shown in figure 2 (at the end of this section).

The four main contributory factors to this problem are:-

- 1) Overshoot due to switching time of pneumatic valve.
- 2) Change air heated by compression loses heat quickly and creates a small pressure drop.
- 3) A gradual decay in pressure due to the creep effect of plastic i.e. the container stretches in shape slowly with internal pressure.
- 4) Mechanical vibrations translate into pressure noise. A pressure transducer is a microphone!

Over the years, various techniques have been employed to sense the pressure decay. Initially, pressure switches are used but these have rarely been abandoned because of the poor sensitivity and drift caused by the mechanical hysteresis.

'Balanced' systems use a differential pressure transducer placed between the bottle on test and a reference container. Inevitably the reference container does not truly mimic the temperature or stiffness of the bottle under test.

BMC leak testers work by initially pressurising the container under test with air, then monitoring the pressure within the container for the remainder of the test time. The percentage of air remaining at the end of the test is used to determine the test result.

One thing all pressure decay leak testers need is clean, dry air supplied from a consistent source.

FIGURE 1

FIGURE 2

SECTION 5

TYPICAL PRESSURE DECAY TEST SEQUENCE

- 1) Bottle sensed by photoswitch.
- 2) Stopper cylinder immediately extended.
- 3) Bottle stops under test head. Test head cylinder extended. Fill valve turned on.
- 4) Separator cylinder slowly extended.
- 5) Fill valve turned off when pressurisation complete.
- 6) Initial pressure measurement recorded.
- 7) Adjustable delay period - sets overall cycle time.
- 8) Final pressure measurement recorded.
- 9) Test head cylinder retracted.
- 10) Stopper cylinder retracted. Conveyor re-starts if stopped. (Bottle moves down conveyor).
- 11) Separator cylinder retracted. (Next test can begin).
- 12) Bottle sensed by reject station photoswitch.
- 13) Reject blower turned on (if bottle failed), until rejected.

SECTION 6

USE OF TEST BOTTLE

Most companies who have leak testers use a test bottle. This is to check the test unit is finding leaks of a known size. However, relying on the same test bottle can be a recipe for disaster.

This is because eventually the test bottle passes through as a good bottle. This is due to the way the test hole was made. If a craft knife was used, the hole is a flap really, which closes together. Even a hole made with a cold pin will close up especially if oil and grease are rubbed onto the container from peoples dirty fingers.

A better way to make a test hole is to use a hot pin of a known size, this hole is less likely to close together.

The only way of creating a true test hole is by using a metal disc with a known size hole fitted in to the wall of the moulding . As long as this container is not granulated! It is the best way of using a test bottle.

SECTION 7

SETTING FAULTS

The two worst scenarios are:-

- 1) Bad containers being passed.
- 2) Good containers being failed.

Blow Moulding Controls leak testers work on the pressure decay principle. This means that the containers are pressurised with low pressure air, an initial reading taken and then following a variable test time a pressure percentage has fallen below a pre-determined level, the container will be rejected.

This variable reject can be described as the reject pressure percentage or reject threshold. Therefore if the reject percentage is set too low to detect the hold size required, the leak tester will be fooled into thinking it is OK and pass it. This is why, when a new product is set up, the reject pressure percentage should be fine tuned to ensure the smallest hole possible will be found. This is normally 2 or 3 % below the consistent measured final pressure percentage setting. Therefore all containers would be considered failures.

The other main reason is poor or intermittent sealing. This is either incorrect top load, stroke setting or unsuitable seal material. This covers point 2. (See also poor neck seal and top load setting).

Overfilling

Another common mistake is to overfill the container, which results in all mouldings being rejected. The fill rate should be set to a value equal to 1 bar per litre of container volume, upto a maximum of 4 bar. The bargraph should operate just up into the green section, if the overfill occurs the overfill LED will light. If the fill rate is too low, the test time will be unnecessarily long.

Photoswitches

The photoswitches used are diffuse reflective types with adjustable sensitivity. These work well with most bottles. However, problems are occasionally encountered with transparent shiny bottles or matt black ones. In these cases, the photoswitch sensitivity should be turned to maximum. An alternative type of photoswitch can be used if this still causes a problem.

Unstable Bottle Handling

The topper cylinder should already be extended by the time the bottle to be tested hits it. If this is not the case, move the start photoswitch up-line.

The delays between the various cylinder movements can be increased by increasing the TEST TIME. If air return cylinders (not spring return) are fitted, the speed control screws built into the valves can be used.

If the bottle tends to trip over the stop cylinder, the guide rail holding the cylinder should be moved up.

The speed control on the separator should be adjusted so that the cylinder comes in slowly enough not to knock over following bottles. For round bottles only the separator comes in between bottles. For rectangular bottles the separator pushes against the side of the bottle, trapping it against the guide rail. In this case, a short stroke (25mm) cylinder with spacer should be used.

If bottle handling continues to be a problem, the belt stop option can be used to stop the conveyor during the test.

Poor Neck Seal

The container may leak if a poor finish is evident. Dependant on quality criteria a softer pad may be used to give a good seal. If however a high quality neck finish is require, a hard pad should be used to show up neck deformation.

Top Load Setting

Rigid container in HDPE, PP and PVC normally have good top load strength. This means a fairly high pressure can be set resulting in a positive seal.

If however, flexible material or thin walled articles are in use, it may be better to set the stroke of the test head so that it just reaches the neck of the bottle on full stroke. Then a high top load pressure can be used without crushing the bottle.

Obviously crushing or deflecting the bottle will cause quality problems, it will also confuse the leak tester. The pressure % reading will increase and the fault LED will be activated on the control panel.

SECTION 8

OTHER TESTS

Weight

A high percentage of any containers cost is the amount of polymer used to make it. Therefore weight checking is of vital importance. This can be done on line either weigh every bottle or after a set amount, giving a printout of results if required.

Weight variation also affects fill levels, this may result in giving away expensive product or not being able to achieve the correct volume. On clear or translucent containers the fill level is important aesthetically so that the consumer does not feel cheated looking at the level, therefore the wall thickness and overall weight is critical.

Top Load

Top load is the amount of force exerted on the top of a container during filling or storage. The top load strength is affected by parison programming, regrind % material grade and wall thickness.

To monitor this force an LVDT can be used to measure the deflection occurring in the containers wall. The force exerted is variable so that a standard for each type of moulding can be developed. If the container fails it is rejected automatically.

Height

An LVDT is used to measure the height of the container. If flash is still attached at the top or bottom, the LVDT will record this and the container will be rejected.

Blocked Bore

This condition occurs when plastic is pushed down into the neck of the container by the blowpin. This is normally due to poor knife cut, knife timing, incorrect support air setting, or too much material in the neck section.

This can be checked by inserting a test head nozzle which detects any obstruction in the neck and rejects it. This can be performed electrically using an LVDT or mechanically so that a leak is created between the test head and the top of the container.

Missing Operation

IML (In Mould Labelling) is used on some containers to give a high quality finish not always achievable with conventional labelling. If however the label is missing or misplaced it can be detected using a photocell.

When automatic deflash is used on machines, a photocell can be used to check the handle flash has been punched out correctly.

Limitations of On-Line Testing

Due to time and costs constraint, it is difficult to test for:-

Contamination which does not create a hole.

Gas permeability.

Long term shrinkage.

Environmental stress cracking.

Colour acceptance.

SECTION 9

THE PLASMA LEAK DETECTOR

As has been stated in previous sections, most leak testers work on the pressure decay principle. This principle has some inherent weaknesses, i.e.

- 1) It relies on a clean, dry consistent air supply.
- 2) Unreliability due to the warm/hot temperature of the moulding under test.
- 3) The stretch/dimensional changes that occur when bottles are re-pressurised during testing.
- 4) Trying to locate tiny holes inside the cycle time of the blow moulder. Detecting small holes in large containers.

The disadvantages listed above are not necessarily due to poor leak testing design, but the physics of gas laws. It is also important to point out that for many applications the pressure decay methods is perfectly adequate. The concept of plasma leak detection is to pioneer fast, reliable leak detection of extremely small holes very quickly.

How does the plasma work?

The container under test (see figure 1) is surrounded by a conductive mask which can be metal or more conveniently in some applications, a conductive plastic foam.

A special probe is lowered into the container and a high voltage pulse of over 90 thousand volts is applied. This has the effect of 'spraying' the inside of the container with a 'plasma' of electrons.

These electrons are strongly attracted to the outer conductive shield and will find their way even through micron sized holes, and are easily detected by measuring the current flow from the probe.

The advantages of the PLASMA test method are:

- 1) Very Short Test Time

The leak test itself only takes a couple of milli-seconds regardless of container size. In other words, it takes no longer to detect a 10 micron hole in a 1000 litre IBC than a 10 micron hole in a 1 litre milk bottle.

- 2) High Sensitivity Without Instability

Container temperature, size and flexibility are irrelevant to this process. The addition of anti-static, U.V. inhibitors, masterbatches and post consumer regrind have no noticeable effect.

3) Immune to Ambient Conditions

Unlike pressure decay leak testers, changes in ambient pressure, temperature, sunlight and machine vibration do not affect the sensitivity or repeatability of the plasma tester.

4) Area Of Leakage Can Be Located

By separating the conductive mask into segments, we can detect the area of leakage (see figure 2). It is particularly useful to show if the problem is caused by poor neck finish handle damage or a poor base weld so that the process can be corrected to prevent the production of more containers with the same defects.

5) Variable Sensitivity

The ability to sense the location or area of leakage also gives the possibility to adjust the sensitivity for each area. For example, if neck finish is not critical because of the type of closure, sensitivity in this area can be reduced. This avoids the common problem of rejecting containers unnecessarily due to neck surface finish.

6) 'Thin Wall' Detection

Although still experimental, we have seen some positive results which indicate that the plasma tester can detect unusually thin areas of a container. This is due to the increased electron migration through such an area. More work is needed to make this feature reliable.

7) Medical and Food Application Friendly

Unlike pressure decay detection methods, the plasma leak tester does not introduce air into the container. This means it is less likely to introduce contaminants into what is otherwise a 'clean' container.

8) Excellent Repeatability

With pressure decay test methods, the difference in pressure transducer signals from a good container to one with a small hole is most indistinguishable. This is one of the main reasons why leak testers frequently reject 'good' containers. Their sensitivity is almost set up to the point of instability. Our 'plasma' method testing a 25 litre drum with a 10 micron hole gives a output signal of 10 volts. A good container about 1/2 volt. Thus the circuitry has no difficulty in detecting good containers from bad.

9) Excellent For High Speed Applications

At present, expensive rotary leak testers are usually required for applications over about 4000 bottles per hour. The new plasma technique does not require a time delay to measure pressure decay, so our process is inherently much faster.

We are constructing an 8 head in line plasma leak tester which is intended to test 5.0000 to 10,000 bottles per hour. The purpose of this development is to overcome the main disadvantages of rotary leak testers which are:

- a) Considerably more expensive than in-line testers.
- b) Can be difficult to change over with nests, star wheels, scroll screw etc.
- c) Very difficult to adjust test heads whilst rotating.
- d) Limited number of suppliers
- e) Less flexible in accepting a wide range of container shapes and sizes. For example, try running 200ml bottles on a rotary tester intended for 2 Lt angled neck bleach bottles.

10) Containers for Dangerous Chemicals

Companies who produce 'UN certified' containers may know that committee CEN227 is due to consider the subject of on-line leak testing. At present there are no set performance standards for on-line leak testers and the committee will almost certainly look at establishing test pressures and minimum size hole specifications. We would be very surprised if the 0.3mm size hole that has been the 'unofficial' pressure decay leak tester standard will be acceptable to the committee as it would be considered a 'barn door' hole to hazardous chemicals. With this in mind, the first tester we will be launching will be for 20 to 30 litre UN certified containers, and the second model for 210 litre 'L' ring style drums.

These testers will be capable of detecting micron sized holes in test times much faster than any known pressure decay method.

11) Testing Steel Drums With Plastic Liners

Theoretically, a steel drum fitted with a plastic liner is an ideal method of packaging and transporting extremely hazardous chemicals. Obviously, this is only true if the container doesn't leak!

At present it is common to leak test a blow moulded liner before fitting it into the steel container. This unfortunately will not show up any leaks caused by damage to the liner during the fitting process. "Pressure decay" leak testing the container as a complete package can be done, but holes in the liner can be masked by the liner pressing against the smooth inside of the steel drum. The steel drum would normally be completely leak tight and this also prevents the detection of leakage by pressure decay methods.

If the plastic liner leaks, chemicals can attack the lacquered coating and then the steel itself, so it is obviously important to consider testing the complete assembly. The plasma test method is ideal for this application because it measures the electron flow from the inside of the plastic container to any conductive outer surface.

Impending legislation will require drum reconditioners to carry out leak testing. The Plasma test method will detect hole and stress cracks which may be produced by the hot caustic washing often used by most reconditioning processes.

We believe that our Plasma leak testers will be the only method that will enable reconditioners to meet the requirements.

12) P.C.R. And Other Reclaimed Material

Almost by definition, any material other than new virgin stock has an increased risk of being contaminated.

This contamination can take many forms, from residues of the previous liquids, label and foil remnants and dirt. Contamination, particularly of a fibrous nature is the biggest, single cause of all leaks in plastic containers. It follows that using reclaimed material increases the need for 100% leak testing.

Leak testers operating on the 'pressure decay' principle will often not detect 'moulded in' contamination because it effectively acts as a gas seal. Unfortunately, when the container is filled, fibrous contamination will usually disintegrate and the container will leak. Although the possibility of leakage is reduced if the reclaimed material is used as a part of a multi layer extrusion, the wall strength in contaminated areas will be considerably reduced, so the likelihood of leakage is increased.

Because fibrous contaminants exhibit a very poor dielectric strength, the plasma detection principle detects fibre filled holes.

Disadvantages Of Plasma Leak Test Method

Cannot be used for steel drums, and may not be suitable for some plastic containers with moulded in metal inserts.

The container under test must be surrounded by a conductive material which does not have to be close fitting. Using conductive foam eliminates the need to shape the mask to each container.

Is Plasma Leak Testing Really New?

Yes, and patented by Blow Moulding Controls Ltd in three critical areas. It has occasionally been confused with 'spark testing' which is not new. Our patent describes in detail the differences in the two test methods.

The spark testing method has been used for years on fabricated tanks, injection moulded battery cases, and is also in use in Japan on PET preforms.

Spark testing relies on the 'brute force' of a high voltage source placed in close proximity to the container wall to actually spark through. To be effective, an electrode has to be shaped to be in close contact with the inside of the container. Obviously getting such electrodes through the neck, and in contact with recessed areas and inside handle etc. is very difficult.

Because of the wide variety of limitations we do not consider spark testing suitable for the vast majority of blow moulding applications.