Quality Control Managers Guide

To

On-Line Testing Equipment

Robin Enderby
BMC Controls Ltd.
Silk Mill Lane
Winchcombe, Glos
GL54 5HZ

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With the increasing pressure on companies to become more competitive, attention is being focused on automating some of the quality control tests that were traditionally performed by quality control personnel.

Although on-line leak detection is now commonplace, there are many other tests that can be performed, and it would seem inevitable that the next few years will see the introduction of much more sophisticated on-line test equipment.

This is our first technical bulletin written expressly for quality control professionals, it is not a sales document or a trouble-shooting guide. It is intended to give you a working knowledge of the operating principles and performance limitations.

This document primarily focuses on equipment designed for testing blow-moulded parts. Applications such as Medical Devices, Technical and Automotive components will be the subject of a separate document.

We would like to suggest that QC personnel get more involved with the selection of leak testing equipment as these instruments are for validating the quality of the moldings you produce.

Traditionally, leak testers are purchased by the same managers that buys blow moulding machines and other ancillaries. Their focus may be on fast cycle time, price, or even getting a ‘package deal’ from the blow machine manufacturer.

This might not be the same as your criteria for a tester that is calibrated to traceable standards, or one that will meet the next generation of ‘UN’ test regulations, or testing well within its capability, not at the extreme edge.

Many of the features incorporated in our products have evolved from customers suggestions. We welcome input from QC professionals as to how we can improve our products to meet your needs.

What follows is a draft of what we intend to be a much more comprehensive document, and again your suggestions are most welcome.

On-Line Leak Detection

Most systems in use by blow moulders work by pressurizing the moulding, and then monitoring the change in that pressure during the ‘test time’.

Although this principle seems deceptively simple, there are a variety of factors that can combine to reduce the effectiveness of this test method.

1. Container Volume
2. Container Flexibility
3. Container Temperature
4. Available test time
5. Ambient Variations
6. Test Equipment Variations

The negative effect of these factors are only troublesome when trying to detect ‘very small’ holes, but obviously holes of all sizes should concern quality conscious companies.

Let’s look more closely at these factors:

Container Volume

The bigger the container the longer you will need to find a hole compared to a small container.

Imagine two containers, a 1 Litre and 100 Litre. Both with a hole that leaks water at 1 Litre per minute.

After 1 minute all the water will have leaked out of the small bottle but the big container will still contain 99 liters. So, even with identical holes one container lost 100%, and the other only lost 1%.

If the containers were being tested with a ‘pressure decay’ leak tester you can see that the pressure drop in the small container is much more easily measured compared to the large container.

This factor alone makes the reliable detection of small holes in large containers extremely difficult.

Container Flexibility

Containers that stretch easily when pressurized are more difficult to test than rigid containers.

When you have a hole in a rigid container the pressure drops directly as a result of the leak rate multiplied by the containers volume.

The pressure in flexible containers doesn’t drop as expected because the elasticity of the container tries to make up for air loss.

An easy way of seeing this effect is to measure the pressure in an inflated balloon as air escapes from a test orifice. The pressure is maintained by the ‘gas spring’ effect, and it is not until the balloon has nearly returned to its original size does the pressure drop off rapidly.

The effects of container volume and flexibility combine directly to affect the sensitivity of the ‘pressure decay’ test principle.

Container Temperature

Back to physics class: Put some air into a hot container and you will see that the internal pressure rises because the air tries to expand but is prevented by the closed container.

This effect tends to ‘mask’ the detection of small holes because the loss of pressure due to leakage is nullified by the pressure rise due to heat.

Obviously this problem is more relevant to heavier containers like drums that can still be very hot compared to lightweight containers like dairy bottles.

Test Time

The effectiveness of the pressure decay method of leak detection is directly linked to the time available for the decay to take place.

Again the basic laws of physics apply and no amount of ‘spin’ by leak tester manufacturers can change this!

Take an extreme case: put a 1 micron hole in a 1000 liter container and measure the pressure drop the hole causes after 1 second.

There is no pressure-measuring device in the world capable of detecting the change. Only by considerably extending the test time will any measurable decay take place. Obviously the time available is linked to the blow moulding machines output rate, but extra test time can be gained by fitting the tester with multiple heads.

Ambient Variations

The quality of almost any process will be better if the conditions that the process operates in are held as constant as possible.

To achieve high sensitivity, leak testers are frequently set to the point of instability i.e. on the verge of rejecting good parts. This means that almost any variation will result in good mouldings being rejected, or very small holes being passed.

Changes in ambient pressure can affect the leak testers pressure sensor.

Changes in ambient temperature can affect the container stiffness and even vibration levels can have a negative effect on the leak tester's performance.

Test equipment variations

All measuring systems incorporate sensing devices that have some inherent drift.

Even though pressure transducers are 'temperature compensated' they usually exhibit a small shift in output with internal and external temperature change.

Pressure regulators and even the response speed of solenoid valves vary with temperature and other operating conditions.

A well-designed leak tester should incorporate auto-zero and auto-calibrate features to minimize the effect of component drift.

Typically the leak tester is much more stable than the product being tested, so increasing the stability of the tester will not yield any measurable improvement in the overall performance.

What Is A Hole?

As far as your customers are concerned, a hole is anything that allows the container to leak.

This can be a split weld under the handle, a hole plugged with cardboard contamination, or a poor fit between the cap and the neck.

Of these faults some can easily be detected by a leak tester and some problems are virtually impossible.

Most holes are a result of some form of contaminant and cardboard is the most common. This invariably enters the material feed system with regrind material.

Once the container is filled, the cardboard contaminant turns to a mushy pulp and washes away leaving a hole in the container.

Many companies have solved the problem of leaky containers by improving the way regrind is handled.

Weak welds can split weeks after a bottle is made, causing much head scratching about how such a bottle got through the leak tester.

There are various characteristics of a hole that can affect the testers ability to detect it, for example hole length, hole shape and internal roughness.

Whilst the following information may seem academic, it is presented to give quality control professionals an insight into the importance of using ‘calibrated’ orifices when checking leak-testing equipment.

It is the flow of air through a hole that causes the reduction in residual pressure and that is the basis of most leak testers operation.

For our purposes we can think of holes as falling into two categories: ‘sharp edged orifices’ and tubes.

A simple definition of the difference could be that a hole longer than its diameter could be called a tube.

To see the difference this makes, blow through a short length of 5 mm plastic pipe, and then blow through a long length (like the whole reel)
The difference is immediately obvious: The relevant factor here is that they are the same size hole. A leak tester however would think these are totally different holes!

Many people make a test bottle without realizing that where they put the hole will make a difference to its ‘detectability’.
This is because the wall thickness of the container at the point were the hole was made will vary from one place on the container to another, thus simulating a short or long tube.

While on the subject of how test containers are made the following should be borne in mind:

Piercing holes is bad because the ‘memory effect’ of plastic tends to close the hole down from the pierced size, often over a period of many hours. Anyone that thinks that piercing makes a specific sized hole should try it in on an even more elastic material, rubber, and see what happens.

Drilling a hole is better because some material is removed, but again, drill a hole in a piece of rubber and see if you get a hole the diameter of the drill.

Melting a hole with a hot wire appears to yield better results, partly because the ‘memory effect’ is locally destroyed in the material surrounding the hole.
The problem is that finding very small diameter wire (0.3mm) stiff enough to melt through the side of a 25 Lt. drum is quite difficult, and requires a very steady hand!

Stabbing holes with a trimming knife is probably the worst way of making a test hole because it does not represent any size hole, and is totally unrepeatable.

The only reliable method of introducing a test leak is to use properly made test orifices.

By this we do not mean carburetor jets, restrictors or home made holes drilled in a metal plate.

These calibrated orifices can be fixed in the side of the container or better still connected into the leak testers sense line.

This latter method is preferable because the test is carried out with the container at its normal production temperature.

Understanding Holes.

The formula to calculate the flow through a tube (long hole) is totally different to short holes that obey the so called ‘sharp edge’ principle. The formula also changes radically when the air flow changes from subsonic to supersonic. In small holes this happens much easier than you would think.

Actual diameter verses ‘Effective’ diameter

The flow through a small diameter orifice is highly dependent on the radius of the holes entrance. Because it is very difficult to control this radius it follows that some variability is normal due to production tolerances.

For calculation purposes it is convenient to assume that the radius of the leading edge is the same as the holes diameter. Using this figure typically makes the ‘effective’ diameter 65% of the actual diameter.

The next crucial factor is to know if the flow is ‘laminar’ (smooth) or ‘turbulent’.

Again the flow calculation formulae change completely due to this effect.

At some point the velocity of the air flow will become supersonic, and this is usually taken to be when the down stream pressure is 1.8 times the upstream pressure.

Other Test Methods

Although pressure decay has become fairly standard in the blow moulding industry, there are various other methods that can give equal or better results depending on the application.

Bubbles-under-water can be particularly useful if it is important to know where the leak is. This can help in identifying which part of the production process is responsible for the leak.

It is also useful if the fault can be rectified, for example re-brazing the leak on a steel drum, water heater or other high value components. This is not generally practical for plastic bottles.

Tracer gas typically helium is one of the most sensitive test methods, and although expensive, can be justified in critical applications, for example, car fuel tanks.

Vacuum instead of pressure may have a slight advantage in some applications, but generally is not suitable for most blow-moulded containers. The good news is that the test head seal is sucked against the container neck, the bad news is that containers collapse even at very low levels of vacuum.

From a leakage rate point of view there is no difference if the pressure is +1 or –1 the flow rate is exactly the same.

Ultrasonic Noise is a well proven technique that has been used to find gas leaks in pipelines, large storage tanks, space shuttle etc. We have had excellent results testing steel drums with this method and we are experimenting with the technique for other applications.

Testing ‘UN’ certified containers

As many of our customers will know we have taken a special interest in this subject and have a separate data sheet that ‘translates’ the relevant section of the ‘CFR’

If you haven’t received a copy please contact us.

Leak Tester Calibration

Although it is very common to have most quality control instruments checked on an annual basis, leak testers can often be excluded from this requirement.

Unlike say a weigh scale that works to ‘absolute’ standards, the settings of a leak tester are frequently adjusted until a particular end result is achieved.

For example the ‘sensitivity’ is usually adjusted until a test hole is detected. The actual setting of the ‘sensitivity’ is thus irrelevant, and almost never defined in a test specification.

The pressure used to perform the leak test is usually an arbitrary value established by the leak test manufacturer as being a good compromise between finding holes and not deforming the container.

Again it is very rare that the exact test pressure is specified so ‘calibrating’ the display to accurately show the test pressure will not necessarily make the tester work any better.

One of the most useful things about a calibration visit is that the tester gets a thorough annual check which often finds a variety of small problems (worn test pad seals etc.) that may have been affecting reliability.

What Else Can Be Tested On Line?

Leaks are just one of the many defects that the blow moulding process can inflict on a plastic container. Orders have been lost for dozens of quality problems, many of which could have been avoided had the leak tester been equipped with the capability of finding more than just leaks.

Container Weight is affected by a plethora of process variables, but it is unlikely that your customer is interested in hearing why your containers are out of specification.

On-line weight measurement is available as an optional extra for some leak testers, so that every container is checked to see that it is within upper and lower weight specification.

Top Load Strength is frequently specified to ensure that the container meets the stacking strength and is strong enough to withstand the filling nozzle valve spring.

Again, this is another task that is easily accomplished with the ‘top load strength’ option on a leak tester. In essence a transducer monitors how far the test head squashes the container with a calibrated force.

Wall Thickness is not easy or cheap to measure on-line. Crude devices that shine light through the container are OK for detecting ‘push down’ on natural HDPE, but are next to useless on pigmented containers and cannot give accurate measurements.

The AGR-Topwave system is capable of measuring the wall thickness of PET and OPVC containers automatically on line, but it does not perform very well on pigmented HDPE or thick materials. The system is generally too expensive for all but the largest companies.

Flash and other unfinished trimming operations can be very easy to detect with simple photocells or in difficult situations, a vision system may be required.

Vision Systems can inspect 1000 cans of beans a minute, but get terribly confused distinguishing between, contamination, flow lines and condensation on a plastic bottle.

We have seen more time and money spent on vision systems with no useful return than any other QC device.

If you want to inspect threads on the necks of PET bottles, there are plenty of vision systems capable of doing the job, for all other applications, good luck!

Don’t be fooled by demonstrations of vision systems, which are always amazing,

On-Line Colour measurement should not be confused with ‘full blown’ laboratory tests, but it certainly is possible to measure the loss of colour saturation if the colour concentrate (masterbatch) starts to run out. The colour sensor looks just like a photocell but costs between 20 and 30 times more.

Some have a teach mode where you place a ‘reference’ bottle in front of the sensor, other systems require you to set limits on the RGB values.

Obviously it is important that the sensor is capable of measuring colors more accurately than the human eye, and some of the sensors we have tested did not meet this requirement.

Smell in PVC bottles, acetaldehyde in PET bottles and contaminants in post consumer regrind all present a challenge to on-line sniffer systems.

Unfortunately the systems on the market that work properly are usually very expensive. Hopefully things might be changing with the new breed of solid state sensing devices that use an array of sensors coupled with a microprocessor that learns the ‘signature’ of a smell and attempts to replicate how the human nose recognizes smell.

The reaction time and the time needed to ‘flush’ the sensor back to its neutral position will probably mean that full ‘on-line’ sensing will be impractical with these sensors in the foreseeable future.

Cyanose Inc. leaders in this field estimate that Acetaldehyde can only be detected at 100 ppm, which is not sufficient, as the human nose can easily smell 30ppm.

Refillable containers present a massive challenge to sniffer systems, as the contaminant can be virtually anything! For example the 20 Lt. spring water bottles have seen use as temporary petrol cans, urine receptacles, garden weed killer etc…

This makes it very difficult to have sensors tuned to detect specific gases when you don’t know what the gas might be.

Dimensional checks can be made of anything that a transducer can touch or scan. Container height is easy, but the I.D. of the spherical bore for the ball of a roll-on deodorant is a bit more difficult

Data logging of all measurements should be available on any modern leak tester. If your tester can’t do it, it is presumably the economy model, or slightly dated technology. The test data should be time and date stamped.

Sadly one of the main uses of archiving test results is in the event that a legal claim is made for product failure.

The archived test results are your proof that the product was properly made and met the required tests. If nothing else, it shows the judge that you take product quality seriously.

Can problems be predicted?

Monitoring process variables such as mould temperature, cycle time, and other factors can give an early warning that the conditions that produce the container may be drifting beyond acceptable limits.

There are a number of systems on the market that send machine information to the factories computer network. At this point we have to mention the name Denes Hunkar.

When he first introduced these features on his CIM systems competitors ridiculed him, "more Hunkar verbiage" one said. The fact is that many have gradually 'discovered' Denes's ideas, but copying other people's ideas and products is a popular sport these days.

Denes promoted the importance of calibration. He could see that the only way of getting truly believable data was to ensure that sensors and their signal processing circuitry was calibrated accurately to a common reference.

It is hard to see why this principle, which is so universally accepted was so derided by Hunkar's competitors.

In addition to machine monitoring systems the leak tester can also attempt to predict problems. For example if the automatic weighing system sees the container weight drifting upwards, it could signal a 'yellow alert' alarm *before* a scrap container is produced.

Automation of container handling and packing/collating/bagging equipment is frequently being integrated into leak testing equipment.

This fact may seem irrelevant to the quality control function, but it does lead to a more serious subject:

Does automation *reduce* the quality of the containers you ship?

Yes it might do!

Packing containers by hand has the most useful spin-off of human visual inspection.

The eye-brain combination still has the ability to spot defects that would be difficult or expensive to automate.

The decision has to be based on profit verses quality.

We live in a competitive world, and the increasing cost of labour may mean that in some instances automated packing is the only way to stay in business. It follows that the need for properly designed on-line test equipment is crucial whenever automation is introduced.

Summary

The Future of on-line container testing will be PC based hardware.

The days of equipment manufacturers producing their own little cards has to be numbered.

Windows and other operating systems are becoming stable enough for industrial applications and hardware prices continue to drop. Graphical User Interfaces are inherently user friendly, and as the general engineering population becomes totally comfortable with Windows® the last hurdles to this transition will be overcome

This is the first document we have written specifically for Quality Control personnel, and we hope you find it useful.

Leak testing equipment is essentially an ‘Automatic Quality Control System” and as such should be seen as a tool in the quality control managers armory in the battle to maintain quality.

We feel that the selection, operation and calibration of this equipment should involve QC personnel, which is certainly not the case in many companies.

Generally the same departments that select ancillaries like hopper loaders and granulators specify test equipment.

Quality Control in blow moulding is never going to be easy. The task of trying to ship quality containers from a production process that is affected by a plethora of variables sometimes seems like a form of Russian roulette.

We’re all in this together; lets try and make it as easy as possible. There must be more to life than making plastic bottles. Work Smarter, Play Harder!