AUTOMOBILE TRANSMISSION

INDUSTRIAL LEAK TESTING

Leak Testing Academy
Measurement Education and Studies

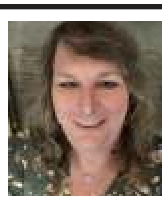
PURPOSE: Educate those who test automotive transmissions for leaks how to stop rejecting too many castings for leaks, and decrease scrap.

AIR LEAK TESTING an automobile transmission starts at the component level, and extends to the fully assembled transmission. Depending on how many speeds the transmission has, the component under test can have 10 or more cavities that require testing. A fully assembled automotive transmission requires experienced application engineers and an accurate instrument to measure the leaks.

In order to keep up with the production rate, ATEQ actually recommends a flow meter to test for leaks in this application. The flow meters should be plumbed specifically to achieve the goal of passing parts with a small external leak, while allowing a much larger leak specification for leaks between cavities. Each cavity's leak is measured individually. After the leak test, ATEQ has a test to verify that the right level of fluid was charged inside the transmission.

ABOUT THE AUTHOR

Anne-Marie Dewailly



Anne-Marie Dewailly is ATEQ's North American Technical Director responsible for carrying out feasibility studies, training customers and employees. Currently residing in Nashville Tennessee, she has 32 years of experience in industrial leak testing. Originally from France, Anne-Marie started with ATEQ in 1988 as a product development engineer acquiring extensive experience in industrial leak test applications and instrumentation. She is a listed inventor in patents in the air leak test field.
anne-marie.dewailly@atequsa.com

ATEQ is the leading global manufacturer of fast and accurate leak testing equipment. Since 1975, ATEQ has been building a leak testing knowledge portfolio filled with hundreds of renowned manufacturing companies and experience in leak testing thousands of different manufactured components.

ATEQ provides leak testing instruments to all manufacturing industries including: automotive, medical, electronics, valves, packaging, appliances, aerospace, HVAC, agricultural and batteries.

ATEQ has experienced application engineers in more than 40 countries all around the world that can provide consulting and leak testing instruments to create efficient leak or flow testing solutions. ATEQ can assist with teaching the science of leak testing, application studies, developing testing specifications, selecting the right leak tester, integrating leak testers into automated production lines, training, instrument calibrations, technical support, repairs and preventative maintenance.

INTRODUCTION

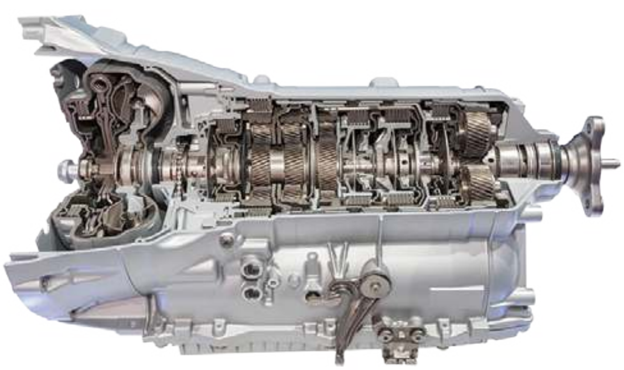
"Each component in an automobile transmission is tested for leaks at multiple levels in the manufacturing process."

WHY LEAK TESTING?

Each component in an automobile transmission is tested for leaks at multiple levels in the manufacturing process. Drivers want to avoid a leaking transmission which could cause their car to break down. Manufacturers prefer to leak test transmission components with clean dry air rather than with messy transmission fluid.

With fuel economy requirements, the number of speeds in an automatic transmission have greatly increased to make sure that the internal combustion engine is running at the optimum efficiency.

For an automobile with an automatic transmission, that means there are a lot more channels that contain pressurized fluid. These automatic transmissions are generally made with cast aluminum or light alloy to resist heat and stress.



This casting process is prone to porosity, and with all these channels, the chances of an outer leak of fluid or an internal leak increase.
The consequences of an outer leak are worse than those from an internal leak.
If there is a leak to the outside, the level of transmission fluid diminishes.

If there is a large enough internal leak, it can lead to reduced operation efficiency and unwanted gear shifting. But a small internal leak has no major consequences. That's why the part print defines different allowable air leakage for leaks to the outside than to the inside.

Since transmission fluid has a surface tension, there is always some allowable air leak rate.

To learn more about how surface tension affects air leak rates, see our Setting Leak Testing Specifications at www.leaktestacademy.com

GOING WITH THE FLOW

"Typically, ATEQ recommends a differential pressure decay leak tester on most automotive air leak test applications, but not this time."

FALSE ASSUMPTIONS

The transmission manufacturer's supplier may be convinced that it would be physically impossible to test two different leak specifications. They may also falsely assume they would have to have the same leak test specification for every internal or external leak test.

Manufacturers will not be satisfied to find that a large proportion of their rejected parts only have a minor internal leak which is actually acceptable.

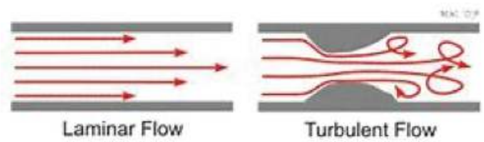
Manufacturers aim to reduce expensive scrap, so they often contact ATEQ for a solution since ATEQ is known for making fast accurate leak test instruments and superior applications engineering.

Typically, ATEQ recommends a differential pressure decay leak tester on most automotive air leak test applications, but not this time. The recommendation for leak testing was to use of a combination of differential air flow meters, and non differential air flow meters.

USING FLOW METERS

After a proof on concept using flow meters, the manufacturers are generally satisfied to see that it works, but also want to understand why and how in order to be certain that it was a valid solution.

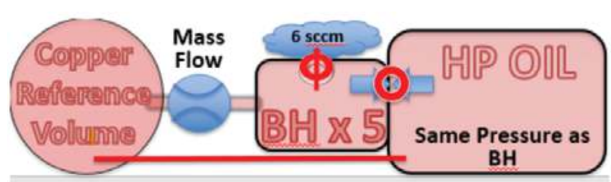
It is, in fact, a real application of the physics principle of fluid mechanics. The next question might be "will the instrument have the same reading if the leak is moved to a different location?" As long as it is in the test circuit, it should read the same. The physical leak location can be moved to a different pipe in the circuit to show that the leak reads the same anywhere.



FLUID MECHANICS

If the exact same pressure is maintained on both sides of a hole, there is no flow through the hole. So if all the chambers in the transmission are pressurized at the exact same pressure, 14.5 PSI (1 bar), at the same time, only the leaks to the outside will be visible. That's why a pressure decay test, that inherently creates a difference of pressure between cavities, was not advisable.

Although every pressure regulator regulates with a slightly different pressure and the flow meters have a pressure drop across them, creating the same pressure on both sides is achievable when the flow meters are all fed from the same tank pressure instead of each one having a pressure regulator.



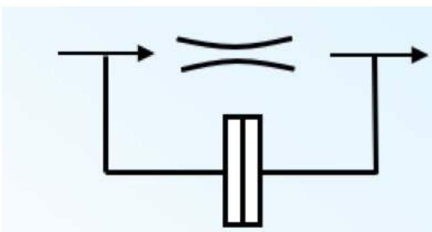
PRESSURE DROPS

"The pressure drop across the flow meter is extremely small so it does not really impact the measurement of the leaks."

DIFFERENTIAL MASS FLOW

The flow meters used were ATEQ MF differential laminar instruments with a 7 pascal pressure drop for the full scale.

This shows that there is a pressure drop across the flow meter.



$$Q = \frac{\Pi \times d^4 \times \Delta P}{128 \times L \times \eta}$$

However, the pressure drop is extremely small (7 Pa maximum compared to the test pressure 100 000 Pa). So if a leak between two cavities is 200 sccm at 1 bar (100,000 Pa), if we take a linear approximation, the same leak under 7 Pa (worse case scenario) will flow 200*7/100000=0.014 sccm.

So the pressure drop does not really impact the measurement of the leaks (0.9 sccm), 1.55% of the leak only.

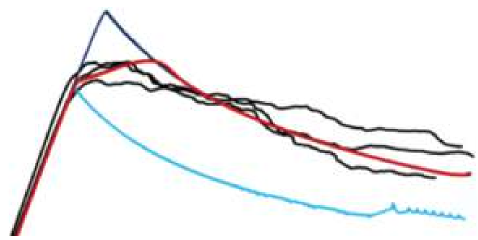
WHAT IS A PASCAL?

A Pascal (Pa) is a pressure unit named after Blaise Pascal, a French mathematician, physicist and inventor who worked on theories in pressure and vacuum and invented Pascal's mathmatical triangle, the syringe and the hydraulic press.

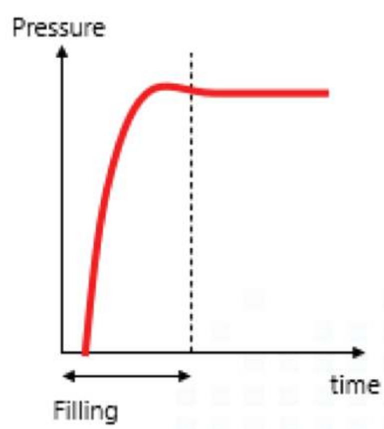
1 PSI = 6890 Pa

SYSTEM CALIBRATION

How is a system calibrated? Some manufacturers calibrate each chamber and look for separation.



Because the goal is for the pressure to be the same in each chamber, it is not recommended to "Calibrate" on the non-stabilized readings. The best option is to use the ATEQ factory ISO 17025 calibration of the flow meters since the flow meters are fast and can provide true leak readings in a reasonable test time.



The ATEQ flow meters are faster because in their proprietary design, full scale differential transducers can be adjusted to a very high accuracy of +-0,1 Pascal. This means ATEQ instruments require a much smaller maximum pressure drop to be established by the leak in the chamber under test than the maximum pressure required by competitor instruments.

Zero pressure drop across the flow meter means zero leak so no "calibration" is necessary.

PRESSURE DROP, TIME & LEAK RELATIONSHIP

"With a large enough tank, the influence of a leak reading one channel over another can be minimized."

REFERENCE TANKS

If there is a leak in one of the chambers, the pressure will drop in the common reference tank and affect the readings on the other channels.
That's true if a large enough tank is used, the influence of a leak reading one channel over another can be minimized.

How large of a common reference tank would be needed if we want a maximum of 2% impact of one channel over the other?

The pressure drops of DeltaPgen in the whole system as a result of the sum of all leaks to the outside Genleak.

To simplify, we take a 4 cavity transmission with one low pressure cavity and 3 high pressure cavities, for example.

Vref=volume of the reference tank
VLPcav=volume of the low pressure cavity
So VHPcav1 to VHPcav3=volumes of the high pressure cavities expressed in cubic centimeters.

The external leaks are respectively LeakLPcav, LeakHP1, ..., LeakHP3 expressed in sccm.

PRESSURE DROP, TIME AND LEAK

The relationship between pressure drop, time and leak is as follows:

DeltaPgen in Pa/Time=
Genleak in sccm/(0.0006*(Vref+VLPcav+ VHPcav1+VHPcav2+VHPcav3))

When the pressure drops in the system, each flow meter sees a negative flow as a consequence.

Negative flow reads:
HP1=0.0006*VHP1*DeltaPgen/time=0.0006*VHP1* GenLeak/0.0006 * (Vref+VLPcav+VHPcav1+VHPcav2+VHPcav3)
NegFlowHP1=VHP1*GenLeak/(Vref+VLPcav+VHPcav1+VHPcav2+VHPcav3)

And the same respectively for every cavity.

What if we want NegFlowHP1 to be less than 2% of the reject level? Let's pretend the reject level for external leaks on HP cavity is 1 sccm and that we have the maximum acceptable leak on every other channel: 1sccm.

So Genleak=30sccm

If VLPcav=2000cc, VHpcav1=50cc and all others are the same, we are looking for Vref when Neg Flow HP1=0.02* 1= 0.02

So 0.02= 50*3/(Vref+ 2150)
Vref= (150/0.02)-2150= 5350 cc

But in fact, it's the leak reading on the largest cavity that is the most affected by VLPcav.
So using VPLcav Vref=((2000*3)/0.02)-2150= (6000/0.02)-2150=297,850 cc

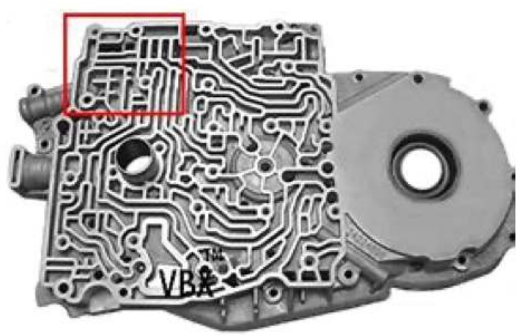
That's a very large volume, so a 10% impact would likely be acceptable.
Vref=((2000*3/0.1)-2150= 57,850cc which is more reasonable.

LEAK TYPES

"We can compensate for varying influences on different channels by combining all of the test results."

CROSS CHANNEL LEAK

Can we compensate with calculations for all these influences of one channel on another?



This can be achieved by combining all of the test results. All the formulas are known:

1) Cross channel leak influence:
Application parameters:
Range of all external leak flow meters in Sccm: Range A=Range B=10 sccm

Range of external leak flow meters in Pa: RAPaA=RAPaB=7 Pa Full scale

Test pressure for cross channel leak: TP=100,000 Pa

Variables:
Measured value in sccm of cross channel leak A-B: LeakAB

Measured value in sccm of external leak channel A: extleakA

Measured value in sccm of external leak channel B: extleakB

Corrected value external leak channel A=
extleakA+((LeakAB*((extleakB*RAPaB/RangeB) – (extleakA*RAPaA/RangeA))/TP)=extleakA+ ((extleakB-extleakA)*7/10)*leakAB/100,000)

EXTERNAL LEAKS

Corrected value external leak Channel B=
extleakB+((extleakA-extleakB)*7/10)*leakAB/100,000)

Because the ATEQ flow meter is inherently linear, these formulas cannot be used for a non linear response pressure drop to flow instrument (like a heat exchange mass flow).

For example, if cross channel leak LeakAB=50 sccm
ExtLeakA= 0.7 sccm et ExtleakB=0.3 sccm

Corrected ExtleakA= 0.7+((-0.4*7/10)*50/100000)=
0.7- 0.00014=0.69986 sccm

Corrected ExtleakB=0.3 +((0.4*7/10)*50/100000)=
0.3+0.00014=0.30014 sccm

2) External leaks in other channels influenced through a common tank:

We previously saw the impact on one channel
NegFlowHP1=
VHP1*GenLeak/(Vref+VLPcav+VHPcav1+VHPcav2+VHPcav3)

So the general formula would be with
Vtrans= VLPcav+VHP1+..+VHP3)

Corrected ExtLeakHP1=
ExtleakHP1–VHP1*Genleak/(Vref+ Vtrans)

And the same respectively for every channel.

COMPENSATIONS

"ATEQ designs pneumatic measurement systems that minimize the need for compensations of all kinds."

PNEUMATIC MEASUREMENT SYSTEMS

A computer can process the test results and generate a corrected test result with these two compensations in order to get the right readings, without negative leak readings.

ATEQ designs pneumatic measurement systems that minimize the need for compensations of all kinds because many clients prefer a large reference tank without the complexity of compensation software that requires configuration for these two formulas.

IMPREGNATION

Now that a test that works and reduces unnecessary scrap has been achieved, is it possible to save more time by impregnating all the castings that leak below a certain level, like 40 sccm?

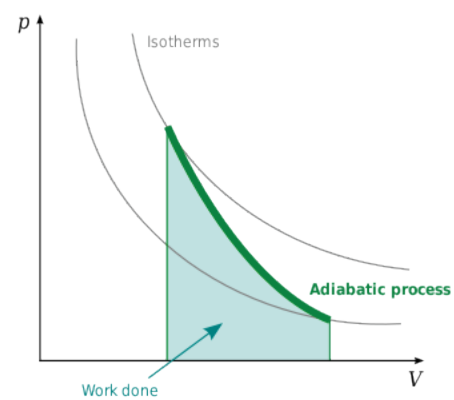
Impregnation is a manufacturing process that enables sealing of small leaks in castings with a liquid solution or polymer.

Note: It is not able to seal major defects.

ADIABATIC DECOMPRESSION

In order to be able to measure leaks in that range, the differential flow meters' ranges would need to be increased. The flow meters can measure both 0.9 sccm and 40 sccm accurately on the same factory calibration since the measurement principle is inherently linear.

An extra tank and pressure regulator on the pressure supply is needed for the source of air leak test, known as adiabatic decompression, which simply means that the air cools down when it is decompressed.



This tank stores the optimum pressure and exchanges heat to minimize adiabatic effects when the largest cavity in a transmission is filled with air from the line pressure.

For more information on ideal adiabatic pressure, review our article on engine leak testing. www.leaktestacademy.com

TESTING TIPS

"To decrease test time, the test sequence can be reanalyzed to understand which was the most critical test."

TANK MATERIAL CHOICE

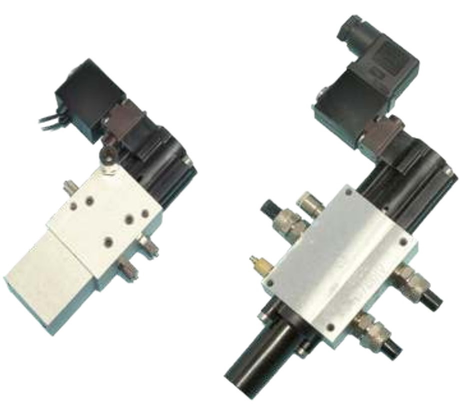
The tank needs to be made of a material that exchanges heat easily, like copper, aluminum or gold, since the function of the tank is to stabilize quickly when repressurized after a large leak.

Since the copper is exposed to clean, dry filtered air, there is little risk of condensation or corrosion on the inside.

It is advisable that the whole test circuit is insulated on the outside to prevent heat exchange with the environment during the test. Inside, it is supposed to exchange heat quickly with the compressed air.

Y VALVES

The testing is not affected by all the valves in the test circuit if ATEQ Y valves are used because they are pneumatically operated and pressurized. The ATEQ Y valves were designed specifically for air leak testing and they don't heat up. The seals (O-rings) do not move during the test because of the valve pressurization that maintains the test pressure on both sides of the seal. In a clean environment, they can last millions of cycles without leaking.



FULLY ASSEMBLED TRANSMISSION TEST

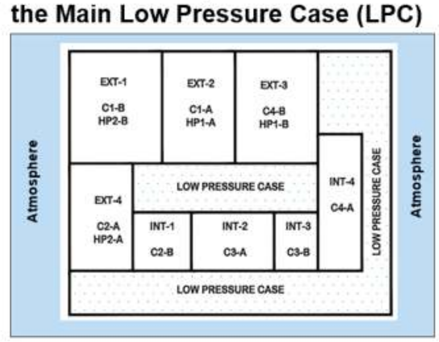
Cross-channel leaks on a fully assembled transmission can not be tested because the test on a fully assembled transmission is limited to an external leak test since there is no access to the internal channels.

SAVING TIME

We can, however, save more time on all of the long test sequences. The test sequence can be reanalyzed to determine which test was most critical. Typically, it is the low pressure cavity for external leaks. On a ten-speed transmission casting, it is a long process to analyze the part prints, understand the functionality of each cavity, analyze which cavity can leak into another and what is the appropriate reject level.

Then comes the step of determining a test sequence that minimizes the overall cycle time and achieves the goal of not rejecting any parts that could actually be considered acceptable.

Physical Relationship of the Cavities Inside the Main Low Pressure Case (LPC)



The Conceptual Main Case contains 8 High Pressure (HP) cavities, 4 with external walls and all 8 have internal walls

TANK CONSIDERATIONS

"If the air getting in the machine is not at a repeatable pressure or temperature, measurement drifts can occur"

TANK SIZE

Using a large enough tank will ensure that the tank pressure regulator does not need to add pressure during the fast-fill time.

Boyle's law can be used again to determine the tank size.

Vtank = volume of the "adiabatic" tank

(Ptank+Patm)Vtank+Patm Vengine =
(Ptest + Patm) Vtank+(Ptest+Patm) Vengine

(Ptank+Patm-Ptest-Patm)Vtank =
(ptest+patm-patm) Vengine

Vtank=Ptest*Vengine/(Ptank- Ptest)

So in the example,
Vtank=(2/(7.2-2)) Vengine

So Vtank= 0.384 * Vengine

This means there is a minimum tank volume, but not a maximum.

MEASUREMENT DRIFT

If the air getting in the machine is not at a repeatable pressure or temperature, measurement drifts can occur despite the adiabatic tank.

To compensate for this drift, a metal tank/heat exchanger that stores the dry filtered air at 60 PSI can be added in order to feed the Ptank pressure regulator with air at a constant pressure at ambient temperature.

Vlinep=the volume of the stabilized ambient temperature line pressure tank

PV= constant, Boyle's law

Vlinep = Vtank*Ptank/ 60 PSI

In the example
Vlinep=Vtank*7.2PSI/60PSI=0.12* Vengine

Once again, this is a minimum volume, but a larger volume will work as well.

ADDITIONAL TESTING OPTIONS

"It is ideal to get the Applications Engineer involved from the beginning of the design process."

TEST SEQUENCES

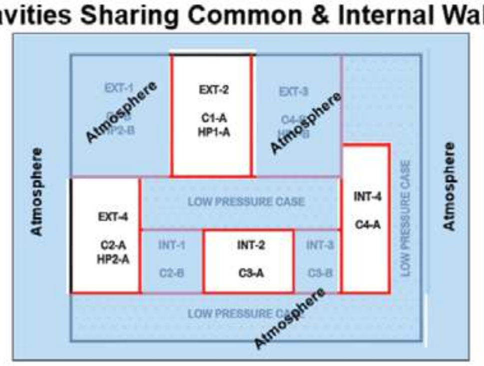
Sometimes the same cavity has to be tested twice in different configurations depending if the desire is to quantify the leak to one cavity or the other.

It is easy to make a faster test that rejects castings that could otherwise be accepted by grouping tests together.

A new recommended test sequence was devised to achieve the same test results in an overall shorter cycle time.

Below is a diagram for each test step in the sequence.

Testing for the Cross Leakage Between Cavities Sharing Common & Internal Walls

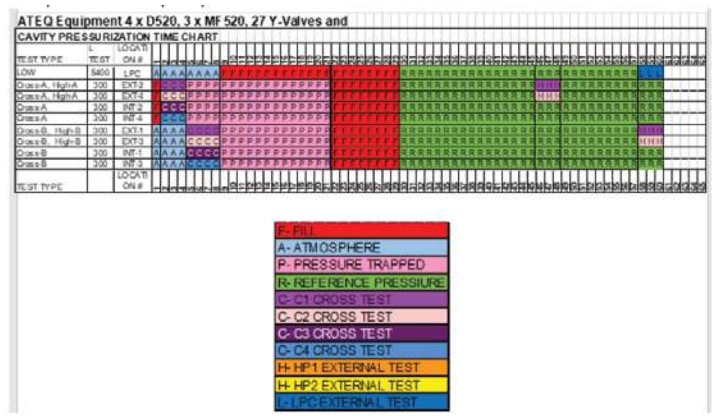


Each test sequence corresponds with a slightly different plumbing diagram of external valves, or a different number and selection of instruments.

It is ideal to get the Application Engineers involved from the beginning of the design process of the transmission leak test sequence, before the full test machines are quoted.

MULTI CAVITY COMPONENT TEST

Below is an example of multi cavity component test chart.



VENT PATCH TEST

There are several other possible tests that can be performed on a fully assembled transmission.

Semi Permeable Vent Patch Test
Some transmissions have semi permeable patches to let the pressure equalize between a cavity that usually contains electronics, and the atmosphere, without letting any liquid water in.

The ATEQ D620 can run a quick air flow test to verify that the patch is present, that it is not a double patch, or that the patch is not torn. This test can also be made at a subassembly level.

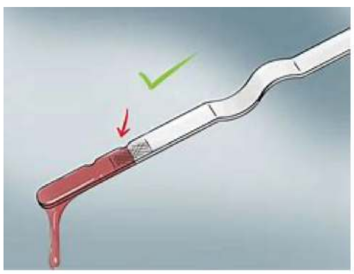
FURTHER TESTING

"The flow meter leak test provides insight to which channel is leaking, but the tracer gas sniffer diagnoses exactly where the leak is."

FLUID LEVEL TEST

Instead of weighing the fluid added in the transmission, it is possible to measure the fluid level using air.

The ATEQ Voluteq quickly measures the remaining air volume after filling with the fluid.



SO FLOW METERS ARE ALWAYS BEST?

Manufacturers are now convinced that the flow meters are so much better than pressure decay testers and that they will specify flow meters for their next leak test machines.

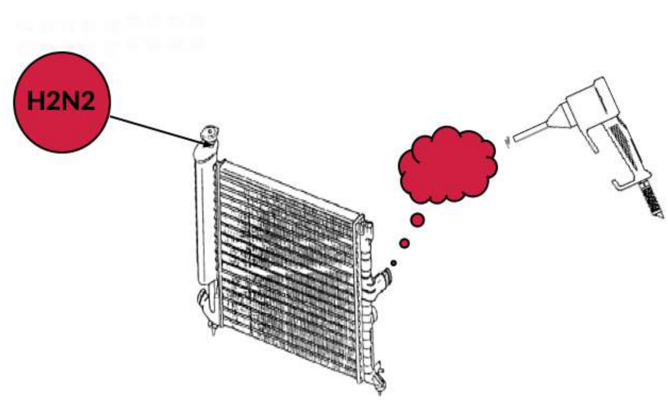
However, it is important to understand that although the right ATEQ flow meters are more adapted for this specific application and give better results when used properly, any other flow meter plumbed freely will not yield the same desired results.

Also, even with good ATEQ flow meters available, ATEQ Application Engineers typically recommend a differential pressure decay tester on most leak test applications, if it is the right solution for the application.

LOCATING LEAKS

For failure analysis, it is possible to locate small leaks on a big transmissions by using soapy water or tracer gas sniffing.

The flow meter leak test provides insight to which channel is leaking, but the tracer gas sniffer diagnoses exactly where the leak is. Gas sniffing is also useful for trouble shooting locations of potential leaks on the test fixture itself.



DRAWBACKS	ADVANTAGES
EXPENSIVE	LOCALIZATION
SPECIALIZED OPERATOR	VERY SENSITIVE
	GREAT VOLUMES

CONCLUSION

"A good instrument helps to find smaller leaks faster but having access to a knowledgeable local applications engineering can be just as essential."

APPLICATIONS ENGINEERS

ATEQ Application Engineers are familiar with many different applications. They can use their knowledge and your specifications to help design the application properly right from the beginning to save money in design and reduce scrap costs.

ATEQ application engineers are professionals trained in leak testing technology and because ATEQ has many locations around the world, there is likely an engineer within driving distance of your plant to help.

A good instrument helps to find smaller leaks faster but having access to a knowledgeable local applications engineering can be just as essential.

LEAK TESTING ACADEMY

ATEQ's Leak Testing Academy offers various courses on leak testing topics. Classes are taught by experienced instructors and cover testing principles, theories, formulas, demonstrations, instrument programming, fixture design, safety and best practices.

Sign up for our training courses at www.atequsa.com/training

Since 1975, ATEQ has been establishing locations around the world along with an extensive application portfolio comprised of thousands of components manufactured by world-renowned companies.

After a project is complete, ATEQ's global support network will continue to remain readily available to customers for repairs, troubleshooting, standard or ISO 17025 calibrations, preventative maintenance and training with on-site options available.

Contact ATEQ if you would like to learn more about transmission leak testing or need guidance towards an application testing solution.
leaktestingacademy@atequsa.com

More articles and white papers can be found at www.leaktestacademy.com

Leak Testing Academy

Measurement Education and Studies

NOTE

This application and situation discussed in this paper does not refer to one client's application. What is described is a mix of various applications and clients, not a single transmission test. The leak levels mentioned are changed on purpose to not divulge any details of what happens in one particular transmission plant.