TESTING FOR IMPACT OF LEAK DETECTION SMOKE / VAPOUR ON EVAPORATIVE EMISSION CONTROL CANISTERS

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Combustion & Environment Research Group

Dr. M. D. Checkel and K. M. Frank

Department of Mechanical Engineering
University of Alberta
Edmonton, CANADA T6G 2G8

phone (780) 492-2340
fax (780) 492-2200
dave.checkel@ualberta.ca

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1.0 PREAMBLE

Charcoal canisters are used to absorb hydrocarbon vapours produced by vehicle fuel sysems and thus prevent atmospheric emissions of these compounds, some of which have significant ozone potential. There is a concern that the hydrocarbon "smoke" used in automotive leak detection could be trapped by these canisters and significantly reduce the absorptive capacity of the charcoal. This report describes a series of experiments which investigate the effects of certain oil-based mists on new and used evaporative emission control canisters.

2.0 INTRODUCTION

Motor gasoline is a volatile substance and the organic vapours released when it is allowed to evaporate in air can contribute significantly to smog formation. To prevent this, modern automobile fuel systems are partially sealed and the only vent point to the atmosphere is typically through a charcoal canister. This canister is designed to absorb a significant quantity of hydrocarbon vapour while the vehicle is not in operation and to release that vapour into the engine intake system during vehicle operation. The capability of the canister to prevent hydrocarbon emissions is related to the canister's absorption capacity ... ie the quantitative measure of how much hydrocarbon the canister can absorb under typically working conditions.

The canister is connected to the vehicle fuel system and engine intake system by a number of flow passages which may include a number of sensors and actuators. Any failures of these components and/or removal of devices will typically compromise the performance of the evaporative emission control system, leading to unacceptable hydrocarbon emissions. Automotive test and repair facilities commonly use leak testing and leak finding systems to ensure the connectivity and integrity of the evaporative emission control system lines. The leak finding systems may charge the system lines with a visible "smoke" to make it easier to pinpoint leaks in the complex under-hood and under-body geometries of motor vehicles.

The purpose of this study is to examine whether a particular "smoke" generation system has a significant effect on the hydrocarbon vapor working capacity of typical charcoal canisters. The system being considered is a Star EnviroTech Leak Detection System which uses a purified white mineral oil with additives to form very fine droplets, (about 1 μm diameter), in a nitrogen gas carrier. (Specifically, the leak detection fluid tested is Star EnviroTech Inc. UltraTraceUV™ Smoke-Producing Solution, Part No. P0716UV).

The study was conducted with in-use and new evaporative emission control canisters which were tested for hydrocarbon absorption working capacity both before and after exposure to visible mist generated by the leak detection machines. Test methods were adapted from standardized procedures used to characterize performance of evaporative emission control canisters and published in SAE papers. For example, Pittel, Weimer and Hadre[1] provide a good description of the operation of and factors influencing performance of charcoal canisters. Williams and Clontz[2] provided a similar study, including the effect of varying purge and soak times on measured canister working capacity. An earlier reference on using butane vapour to test canister load capacity for gasoline systems was provided by Johnson and Williams[3].

3.0 EXPERIMENTAL METHODS

The canister working capacities were measured with a Butane Working Capacity test procedure in which the canister is charged with n-butane vapour in a nitrogen carrier, flowing at a steady rate into the canister "Tank" port. The canister "Purge" port is blocked and a sensitive hydrocarbon detector monitors hydrocarbon content of the gases leaving the canister "Vent" port until a significant hydrocarbon breakthrough occurs, (nominally 5,000 ppm C_1 concentration). At this point, the canister test is switched to purge mode and a flow of air enters the "vent" port and exits through the canister "purge" port. This air flow is maintained at a fixed flow rate until 300 canister volumes of air have swept through the canister. The weight of the canister is monitored on a lab scale during this series of events so the weight gain during canister charging and the weight drop during purging can be measured. The weight drop during purging is taken to be the Butane Working Capacity (BWC) of the canister. Because there is some variability in readings, it is common to use an average of five or more repeat cycles to measure BWC. This report provides the individual capacity measurements as well as average BWC values.

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[1] A Pittel, A Weimer and C Hadre, "High Vacuum Purge and Vapor Canister Performance", *Emissions Measurement & Testing 2004, SP1862*, SAE paper 2004-01-1435, SAE 2004

[2] RS Williams and CR Clontz, "Impact and Control of Canister Bleed Emissions", SAE paper 2001-01-0733, SAE 2001

[3] HR Johnson and RS Williams, "Performance of Activated Carbon in Evaporative Loss Control Systems", *SAE 1990 Transactions*, Vol 99, Sect 4, Journal of Fuels and Lubricants, SAE paper 902119, SAE 1990

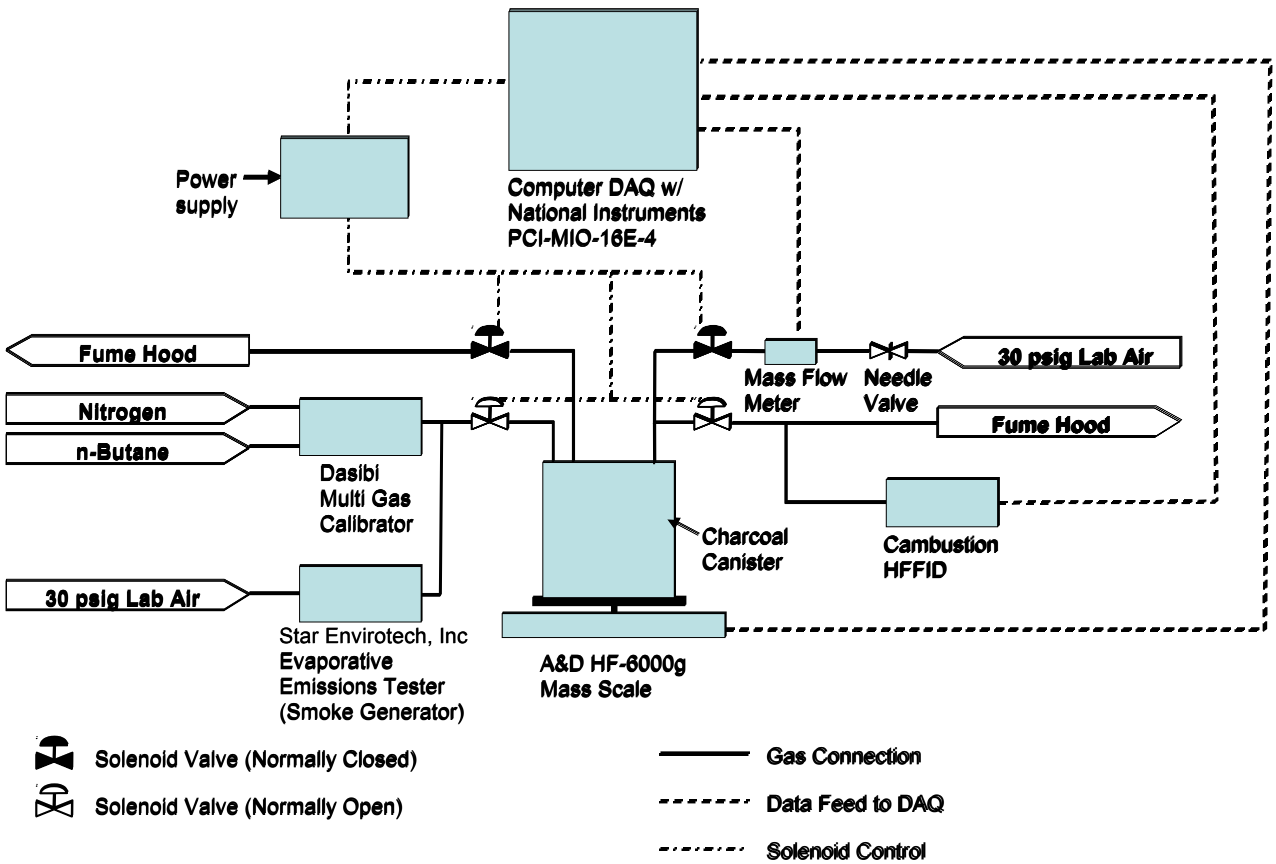

Figure 1. Schematic Diagram of Butane Working Capacity Test Apparatus in "Charge" mode.

During canister charging, the Dasibi Multi-Gas Calibrator and Smoke Generator were connected to the "Tank" port on the charcoal canister. The canister "Purge" port was closed and the "Vent" port was vented to atmosphere while being sampled by a FID hydrocarbon detector.

For canister purging, the "Tank" port was closed, the "Purge" port was opened and the "Vent" port was connected to a lab air supply flowing at 2 L/minute.

Figure 1 provides a schematic of the equipment used to measure canister BWC. To achieve consistent results, the charcoal canister and scale were isolated in a fume hood and the measurement sequence was controlled by a computer and data acquisition system which ran repeated test cycles for each situation. For capacity testing purposes, the canisters were initially charged to saturation before beginning a repeated series of 300-volume purges and saturation re-charges.

Exposure to leak detection system "smoke" was accomplished by supplying a flow directly from the Star EnviroTech evaporative emissions leak tester to the canister "Tank" port. This simulates having a leak tester connected to an evap hose system without leaks so that its entire flow is run through the canister, (ie canister port left open). "Smoke" exposure was timed at 5 minutes (representing a typical "smoke" test operation), 15 minutes (representing an unusually long "smoke" test operation), and 60 minutes (representing a lifetime of "smoke" exposure concentrated in a single session). It should be noted that the evaporative emissions canister would normally be isolated before leak testing and would thus be exposed to much less "smoke" than in these tests. In these tests, it was noted that the "smoke" flow was sufficient to flow visible "smoke" through the canister and out the vent.

4.0 RESULTS AND ANALYSIS

Typical data traces recorded during a canister charge cycle are shown in Figure 2. When tests are run sequentially with no intervening soak time, the hydrocarbon trace at the canister "Vent" port tends to stay near zero for most of the charge period and then rise rapidly as hydrocarbon "break-through" occurs. This behaviour is illustrated by the lower HC trace in Figure 2. If tests are run following a significant period of "soak" time following a previous charge or incomplete purge, diffusion during the soak period puts more HC close to the canister "Vent" port and results in a significant hydrocarbon slip rate during the charge cycle. This behaviour is illustrated by the higher HC trace in Figure 2. Williams and Clontz[2] showed the same trend and also found that the apparent fill capacity was reduced after a soak period. This is one of the reasons that the canister's working capacity is actually measured during the purge part of the cycle as shown in Figure 3.

The third trace on Figure 2 shows the gain in canister mass during the fill cycle. The rate of gain, (just under 1 gram/minute), agreed well with the rate of butane supply to the canister, (0.92 g/min).

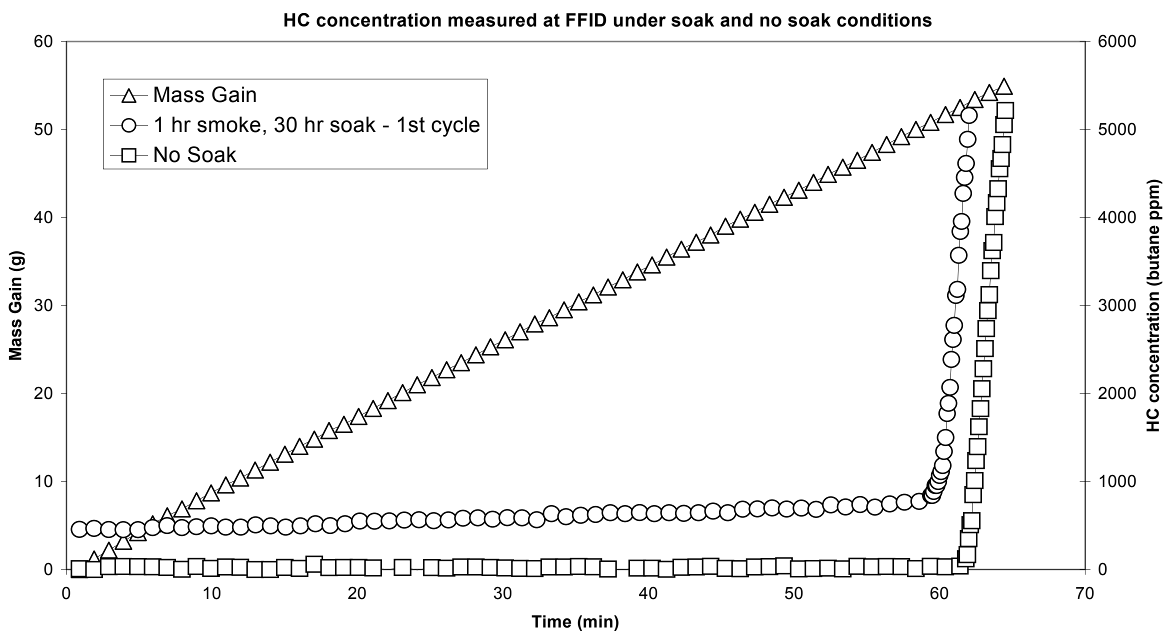

Figure 2. Mass gain and hydrocarbon slip traces during a canister charge cycle. (In-Use 1997 Cavalier Canister). The two HC slip traces represent charging immediately after a purge cycle (lower HC emissions trace) or charging after 30 hours of soak time following a previous charge cycle (higher HC trace).

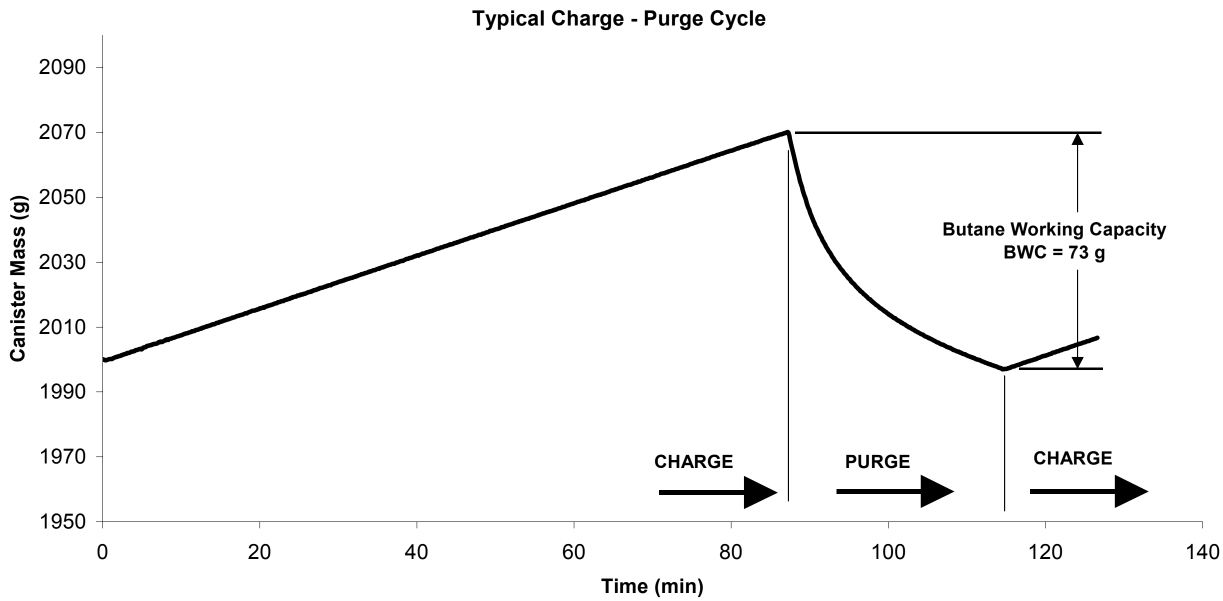

Figure 3. **Canister Weight Trace During a Typical Charge and Purge Cycle, Showing the Definition of Butane Working Capacity (BWC)**

The BWC behaviour of an in-use charcoal canister subjected to repeated tests is shown in Figure 4. The tests shown in the figure cover four test periods. Before the first period, this canister was removed from an in-use automobile and subjected to an initial saturation butane charge cycle and 24 hour soak. Following this pre-treatment, the canister was repeatedly charged and purged seven times to establish a Baseline behaviour pattern. During this Baseline testing, the canister exhibited higher mass loss in the first two purges. This might be related to the highly loaded state of the canister after its initial conditioning or the fact that it had previously been in service at lower ambient temperatures than the 25 C test temperature in the lab. However, the canister capacity rapidly adapted to the charge and purge test regime and BWC stabilized at 55.2 grams (+/– 0.38 grams standard deviation) for the final 5 of 7 Baseline tests.

Following this Baseline, the same canister was exposed to leak detection "smoke" and re-tested several times. The first two "smoke" exposures were for 5 minutes each. This time represents a typical automotive service test period. (However, the canister vent was open so the full production of the smoke machine ran through the canister rather than the canister being sealed to build up system pressure and force smoke through a leak elsewhere in the system. Hence the actual "smoke" exposure of this canister was higher than should occur in normal automotive testing). The third "smoke" exposure was for 15 minutes and the fourth for 60 minutes. The cumulative "smoke" exposure, (85 minutes of smoke machine output passing through the canister), would represent a much greater exposure than would be reasonable for a lifetime of vehicle maintenance.

With each new series of tests following the smoke exposure, there was a tendency for the first charge / purge cycle to involve lower quantities of butane than subsequent cycles. It is

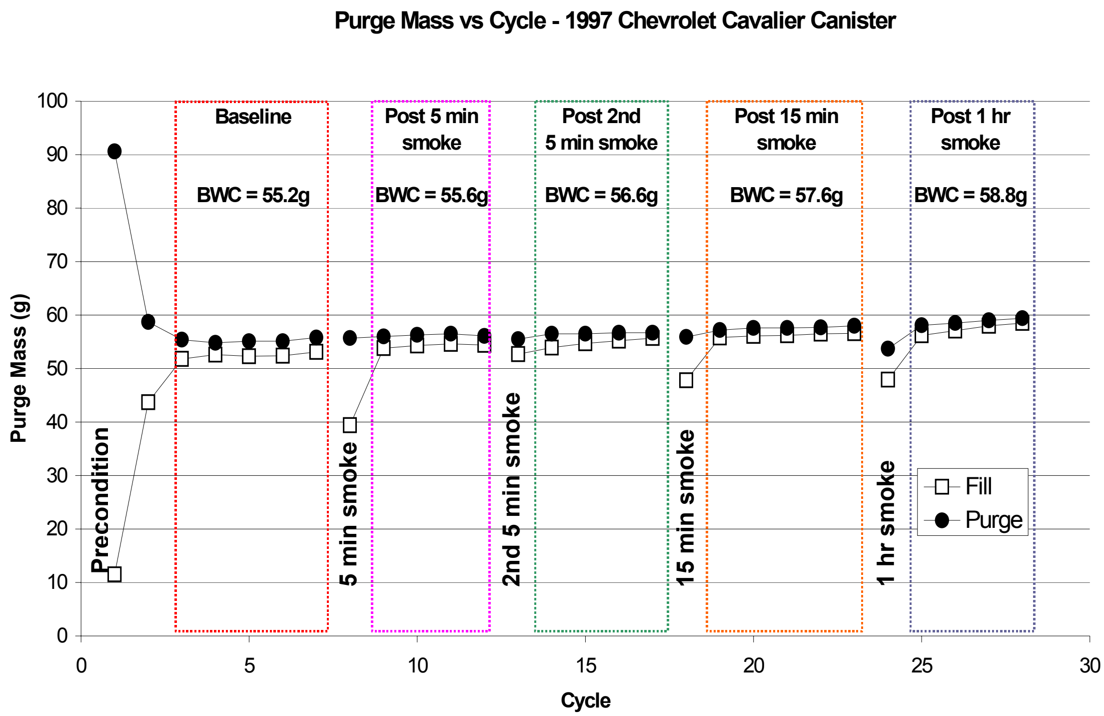

Figure 4. Butane Working Capacity Test Results for In-Use Canister Subjected to Repeated Leak Detection "Smoke" Exposure

conceivable that this is related to some interfering effect of the "smoke" chemistry. However, it could also be attributed to other effects such as the effective soak period during the smoke exposure. After the first cycle in each new series, the BWC value stabilized in subsequent cycles and the next four or five cycles were essentially repeats of one another.

It was notable that, over the series of repeated tests on this in-use canister, the average BWC gradually increased. The rise was small, about 1 gram (2%) per set of 5 fill / purge cycles. This apparent increase in working capacity might be ascribed to:

-use of butane, (a lighter hydrocarbon), which is gradually displacing heavier gasoline HC from the canister and/or

-repeated testing at 25 Celsius which is above the normal operating temperature of the vehicle prior to removal of the canister. (The canister was removed in October in Edmonton after a period of weather with typical ambient temperatures in the 0 Celsius to +15 Celsius range).

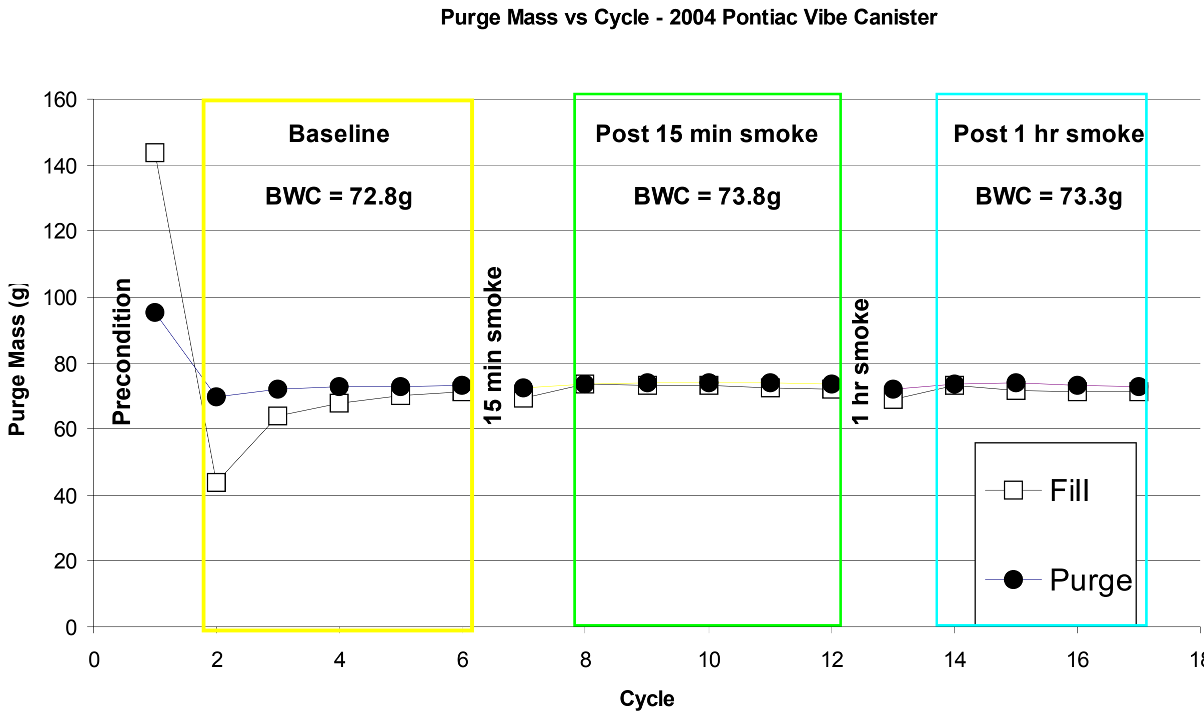

Figure 5. Butane Working Capacity Test Results for New Canister Subjected to Repeated Leak Detection "Smoke" Exposure

The critical thing to note from testing this in-use canister is that, aside from the first charge cycle, there was no significant reduction in capacity across each of the "smoke" exposure periods. If there was any interfering effect of the "smoke" chemistry on the charcoal canister, that effect disappeared after one purge cycle and was less than the normally occurring trends with gasoline chemistry and/or temperature.

To overcome some of the uncertainties due to canister history and elution of the trapped gasoline vapour "heel" already in the canister, it is also possible to test a new canister which has not been exposed to gasoline. Figure 5 shows the results of a similar series of tests with a new canister. (GM parts for a 2004 Pontiac Vibe, 1.8L 4-cylinder, 50L fuel tank). This new canister would be presumed to have a higher capacity to meet current emissions standards including refuelling vapour recovery. Because it was tested without any prior exposure to gasoline, the uncertainties associated with the gasoline vapour "heel" would be avoided. For pre-conditioning, this canister was saturated with butane and purged once, then put into a repeated set of BWC tests.

When the canister was subjected to repeated BWC testing after this baseline saturation, it initially recorded one high capacity cycle, (presumably due to continued absorption into "heel" pore locations). This was followed by a series of cycles where the purge volume was slightly greater than the charge volume before the Baseline capacity stabilized at 73 grams of butane (+/-0.58 g).

To measure the effect of "smoke" exposure, this canister received a 15 minute and 60 minute "smoke" flow session, each time followed by a series of repeated purge / fill tests. The behaviour after each "smoke" session was similar to that of the in-use canister. After each smoke exposure, the butane charge mass before breakthrough was a little low. However, the purge mass, (used to measure BWC) was close to the previous values and, after the first purge cycle, the BWC values were back to the prior norm.

The averaged BWC values found after the 15 minute and 60 minute smoke exposures were only slightly different from the Baseline values, showing a slight increase and decrease respectively. Statistical considerations showed no relationship.

In summary, the 15 minute and 1 hour smoke exposures had no significant and lasting effect on the canister's BWC value.

5.0 SUMMARY AND CONCLUSIONS

This report describes tests on evaporative emissions control canisters to search for effects of smoke contamination with UltraTraceUV smoke-producing solution. The tests reported relate to a new and an earlier generation in-use canister. Each canister was tested to determine its Butane Working Capacity (BWC) in baseline condition and after exposure to "smoke" for periods in excess of a reasonable maintenance lifetime.

With the in-use canister, the testing procedure showed no significant decrease in BWC when the canister was exposed to smoke. The first charge / purge cycle after a smoke exposure tended to produce a lower value but this might have been an artifact of the test procedure and disappeared after the first purge. Over the period of testing this in-use canister, there was a slight but significant increase in Butane Working Capacity, probably due to continued elution of the canister's long-term gasoline "heel". This indicated that the normal variability of changing gasoline composition and temperature appeared to be greater than any contamination effect of "smoke" exposure.

With the new canister, the testing procedure showed a similar trend of a slight reduction in BWC on the first cycle after smoke exposure. Again, this is probably due to the test procedure, (a longer effective soak time) and the effect is gone after the first purge cycle. With the new canister, there was no significant trend in capacity even after the canister had been exposed to 15 minute and 60 minute sessions of leak detection smoke.

We conclude that the leak detection "smoke" produced from UltraTraceUV smoke-producing solution does not have a significant effect on automotive evaporative emission charcoal canister capacity.