Market Barriers to the Uptake of Biofuels Study

A Testing Based Assessment to Determine Impacts of a 20% Ethanol Gasoline Fuel Blend on the Australian Passenger Vehicle Fleet – 2000hrs Material Compatibility Testing

Report to Environment Australia

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Orbital Engine Company

CONTENTS

APPENDICES

1. Executive Summary

This document presents the findings of materials compatibility testing completed by the Orbital Engine Company in order to assess the impact of gasoline containing 20% by volume ethanol on the Australian passenger vehicle fleet. The program is an initiative of the Environment Australia project "Market Barriers to the Uptake of Biofuels – Testing Petrol Containing 20% Ethanol (E20)". This materials testing was a continuation of the broader program of performance and durability testing program undertaken on this engine category on behalf of Environment Australia and reported in March 2003 (1), where in only a preliminary review of materials compatibility was presented since the testing was still in progress.

The materials compatibility testing focused only on the compatibility with E20. Selected components, or samples cut from components, from three representative vehicles were subjected to a 2000hr immersion test following the appropriate Society of Automotive Engineers test standards. The three vehicles were the Holden VN and VK Commodores, and the XE Falcon, each representing a different fuel system / Engine Management System type and thus encompassing most component types.

- Holden VN Commodore, electronic fuel injection with three-way catalyst, late model, closed loop control
- Holden VK Commodore, carburettor fuel system using Lead Replacement Petrol fuel
- Ford XE Falcon, electronic fuel injection, intermediate system with open loop control using Lead Replacement Petrol fuel

In addition to the immersion tests, assessments were conducted to evaluate the compatibility of the paint used on body components that may be subjected to fuel splash (such as the filler door).

Components containing polymer elements (rubber, plastic, etc) in most cases had samples subjected to both gasoline and E20 test fluids so as to compare results. Generally, metal fuel system components were only subjected to E20 as it was assumed the product's respective manufacturer would have already verified compatibility with gasoline.

Many of the metallic fuel system components that would be normally in contact with fuel were found to exhibit corrosion to varying degrees after immersion in E20. Of particular concern would be occurrences of corrosion where the potential exists for the oxide to dislodge and clog / block fuel flow to metering components or where the oxide could become trapped in between moving surfaces or components. There was some commonality in the observed performance of similar components from different vehicles and so significant results are presented in these groupings:

- Fuel pump casings (in-line and in-tank pumps), corrosion and pitting on external casing surfaces

- Fuel pump internals (rotor), pitting and corrosion on armature shaft and rotor along with tarnishing of exposed electrical contacts (connectors and commutator)
- Fuel injector, corrosion on ferrous metal surfaces and tarnishing of filter retaining ring
- Fuel regulator diaphragm, has corrosion on metal button and diaphragm material is also discoloured
- Fuel pressure regulator housing, small corrosion spots – particularly on brazed areas
- Fuel tank metal sample, corrosion formed on surface
- In-tank fuel strainer, plastic filter discoloured and metal insert has some corrosion
- Fuel sender unit, some light corrosion on underside of body and minor tarnishing of brass surfaces
- PCV valve / spool, some small spots of corrosion /pitting on surfaces
- Carburettor and associated components
    - Body, corrosion on surfaces and tarnishing of brass
    - Float valve needle and body, heavy tarnishing
    - Mixture adjusting screw, heavy tarnishing
    - Filler cap spring, some corrosion pitting
    - Plate, some surface corrosion
    - Ball, some corrosion spots
    - Diaphragm, plating of metal part has started corrode/tarnish
    - Choke pull-off - diaphragm, plating of metal part has started corrode/tarnish
- External fuel pump – diaphragm, main pin tarnished and some corrosion on plated surfaces

All the brass fuel system components were tarnished indicating oxidation had occurred. Oxidation of brass fuel and air metering jets or fuel control devices in the engine carburettor has the potential to lead to the loss of the intended nominal air and /or fuel metering, resulting in potential degradation or loss of engine function. Whilst it was observed that the electronic fuel injection systems had largely eliminated the use of brass in fuel system components, brass/copper was still in use in electrical connectors and armature components of the electronic fuel injection system. The tarnishing of the electrical components has the potential to affect component performance both as a result of the increased electrical resistance and as a result of clogging and/or abrasion due to the dislodging the oxide.

Some polymeric materials were found to have significant changes in appearance due to contact with E20 fuel. The nature of the change was dependent upon the final inspection condition – “wet” as removed from the immersion test, or “dry” subsequent to carrying out the recommended Society of Automotive Engineers dry-out procedure. In general, components that were sensitive to E20 would enlarge, distort or soften in the “wet” condition. Softening can be associated with a loss in strength, whilst distortion /enlargement has the potential to cause fuel connections to fail. However, where the sample in E20 exhibited behaviour significantly different to the sample in gasoline, these are identified below:

- Fuel sender float, material starting to breakdown (some rust also on metal lever)
- PCV valve, separation of parts due to swelling of the plastic housing
- Hoses (various rubber components), enlarged diameter, end delamination and loss of formed shape when immersed and whilst shape and size returned upon drying the hoses where typically hardened – generally more so for the E20 sample
- Hoses – fuel tank pipe, enlarged diameter
- Fuel regulator diaphragm, discolouration of both samples (swelling and distortion of E20 sample)
- Paint removed from various fuel injector casings and also from other fuel rail assembly parts
- Plastic components which were incompatible with the E20 such as hoses, filter housings and screens and some o-rings were notably discoloured
- Gaskets, such as those made from cork, seemed to be particularly incompatible with E20 and were visibly distorted /cracked after being dried out
- In some cases adhesives and electrical potting mix were also seen to be weakened by the immersion in E20

The impact of the results obtained during materials compatibility testing can be summarised as follows:

- For metallic fuel system components that have exhibited corrosion when in contact with E20 fuel.
  - This is considered a concern since the potential exists for the oxide to dislodge and become trapped in between moving components or to clog/block components responsible for fuel metering and/or delivery.
  - The potential exists, depending upon the severity of the oxidation and the actual final location of the dislodged oxide, to cause engine failure.

- For all the brass fuel system and electrical components that were tarnished indicating an oxidation process had occurred.
  - This is considered a concern since the oxidation of brass fuel and air metering jets or fuel control devices in the engine carburettor has the potential to lead to the loss of the intended nominal air metering and /or fuel metering, or control.
  - This is also considered a concern since oxidation of electrical contact surfaces has the potential to reduce conductivity.
  - The potential exists, depending upon the severity of the loss of metering and/or control, to result in the degradation or loss of engine function.

- For polymeric materials found to have significant changes in appearance due to contact with E20 fuel.
  - This is considered as unacceptable since the changes have the potential to result in fuel leakage.

In addition to the 2000hr testing conducted on the components described above, specific testing was conducted to assess the compatibility of the gasoline and E20 fuel mixes on the paint applied to the vehicle body. For this, fuel filler door components were subjected to an extended evaluation. At the conclusion of the testing, staining of the white coloured component was equally evident with both test fuel types. However, the E20 fluid was also recorded to have degraded to condition of the adhesive holding the dust seal on this component.

2. Introduction

The Commonwealth Government of Australia, represented by Environment Australia, is investigating the effects of higher ethanol blends in fuel on the Australian vehicle fleet. This investigation is to provide information to the Government on the impacts of noxious and greenhouse emissions, vehicle performance and durability from the use of 20% by volume ethanol blended with gasoline (E20). This study will then be used to aid the Government to set the national fuel standards as provided by the Fuel Quality Standards Act 2000.

Environment Australia, under the auspices of the Ethanol task force, commissioned an issues paper with the aim of seeking public comment on setting the appropriate ethanol limit in automotive fuel (3). This paper extensively covered the issues related to using ethanol as an automotive fuel. In particular it refers to two earlier trials conducted in Australia. The first trial in 1980-83 (5) examined the impacts of E15 (15% ethanol). The second in 1998 (6) comprised an intensive field trial of ethanol/gasoline blend E10 (10% ethanol) in vehicles. The data from these trials, plus evidence from the submissions to the issues paper, lead to the conclusion that generally blends up to 10% are accepted as being suitable for the Australian fleet. Currently, however, there is not general consensus on the applicability of higher ethanol concentration blend fuels for the Australian vehicle fleet.

One of the conclusions that can be drawn from the submissions to the issues paper was the lack of current Australian data on the effects of higher ethanol blends (E20) on the Australian fleet. In order to rectify this, Environment Australia has commissioned testing on vehicles and components under tender No. 34/2002 (2). Subsequently, Orbital Engine Company has been contracted by Environment Australia to undertake an engineering program related to the use of 20 percent ethanol blend fuel in the Australian market. The conclusions drawn from the phase 2A program report have in part led to the Australian Federal Government moving to set a 10 per cent limit for the blend of ethanol in petrol (11).

The work reported upon here completes the tender activities for the material compatibility assessment of automotive sector components.

3. Test Fuel Management

The test program required Orbital to procure sufficient quantities of fuel grade Ethanol and Gasoline (both Unleaded Petrol (ULP) and Lead Replacement Petrol (LRP)). These fuels were used as the blend stocks for the preparation of the various ethanol blended fuels required for both the vehicle and materials compatibility testing phases of the program.

3.1 Engine and Fuel System Materials/Component Compatibility Gasoline

The fuel system component compatibility gasoline had no specific requirements, apart from being representative of domestic fuel supply. Accordingly, the fuel used for the fuel system component compatibility testing is the locally available ULP and LRP sourced from the BP Kewdale terminal in Western Australia.

3.2 Ethanol

The fuel grade ethanol was sourced from the Manildra Group in New South Wales and CSR Ltd. Yarraville Distillery in Victoria. This fuel was delivered at the end of October 2002. A total of five 205L drums were received. The packaging identified the contents as SMS 100 F21, containing one percent by volume ULP as a denaturant. The drums were marked according to the identification protocol as E1 – E5.

A further batch of fuel grade ethanol was sourced from CSR Ltd. This fuel was delivered during December 2002. A total of four drums were received and marked according to the identification protocol as E6 – E9.

3.3 Gasoline/ Ethanol Mixing Process

The process used for achieving accurate, repeatable blends of the various fuel mixtures was developed by Orbital following a review of information available from organisations such as CSR, Manildra Group, American Coalition for Ethanol, Governors Ethanol Coalition and the Alternative Fuels Data Centre. The lack of explicit technical information and references to the avoidance of “splash blending” when mixing ethanol and gasoline, led Orbital to develop a mixing process based on gravimetric measurement of the blend constituents.

Drummed fuel was stored externally under a covered bunded area surrounding the bulk fuel storage facility. The drums containing the necessary blend stocks of gasoline and ethanol were transported to the fuel preparation area and soaked at 20°C for 24 hours prior to opening and decanting of fuels. The mixing process required that the densities of the fuel constituents were measured and the mass of each constituent calculated based upon the volume required to achieve the requested blend concentration. Scales were purchased with a load cell capable of measuring large masses with a high degree of accuracy. Once measured each constituent was then decanted into the blend drum. A re-circulating pump was fitted and run for a pre-determined period of time to ensure blend homogeneity. Once blended, the drum was then labelled according to the identification protocol. The batched fuel was then stored at 20°C in the fuel storage area until required for use.

4. Materials Compatibility Test Activity.

4.1 Overview.

This activity was focussed on conducting materials/component compatibility testing following as closely as possible the relevant SAE standards J1748 (8) (polymeric material) and J1747 (7) (metallic material). SAE standard J1681 (9) was followed as closely as possible in defining the test fluids utilised for material/component immersion testing.

The testing and experimental design was not an attempt to fulfil the requirements for material qualification, actual product or process validation for the materials or components. The experiments and testing were in fact designed to highlight any non-compatibility between a material or component and the E20 blend fuel.

4.2 Engine Selection

The materials/components for immersion testing were selected on the basis of them having contact with fuel and having a high potential risk of failure, as identified by the FMEA, (5). The vehicles from which the material/components were selected were chosen as representative of the Australian vehicle fleet in terms of fuel system and aftertreatment technology as well as covering available gasolines.

The vehicles chosen were:

- Holden Commodore VN, 1990 MY.
    - Electronic Fuel Injection, Three Way Catalyst, closed loop control and ULP gasoline.
- Ford Falcon XE, 1985 MY.
    - Electronic Fuel Injection, open loop control and LRP gasoline.
- Holden Commodore VK, 1985 MY.
    - Carburettor and LRP gasoline.

4.3 Component Test Preparation

4.3.1 Test Fluids

As proposed in the tender submission, testing occurred with 0% ethanol and 20% ethanol/gasoline fuel blends. The fuel blends containing the 20% ethanol were based on standard pump fuels plus 1% corrosive water, similar to that specified in (8).

- ULP and LRP (WA pump gasoline) as required for the above vehicles.
- ULP and LRP as above with 20% ethanol and 1 % corrosive water.

4.3.2 Test Temperatures

The specified temperatures for material testing are as follows:

- Metals at 45+/-2^{o}C

- Elastomers at 55+/-2°C
- Plastics at 55+/-2°C

In order to facilitate testing of all samples at the same time, the test temperature has been standardised to 55+/-2°C. This will not adversely affect the validity of findings for the metals testing. The higher temperature is considered to be more closely aligned with the normal vehicle related operating temperature of many of the components under test. Testing was conducted in a fire protected environmental engine test cell (heated room).

4.3.3 Test Containers

The containers for this testing are specified by the SAE standards. The containers are made of high density polyethylene, with a minimum rated burst pressure of 202.7 kPa and a volume of one litre. These unique requirements have necessitated procurement from the USA.

4.3.4 Facilities

The heated room (environmental test cell) and adjacent anteroom were configured to enable testing to be undertaken in an effective and safe manner.

- The heated room is controlled to 55+/-2°C (SAE standard for material testing) and the anteroom is controlled to 23+/-2°C (SAE standard for component measurement). Temperature control of the heated room and anteroom was validated over an extended period.
- The anteroom was modified to incorporate a bench with fume hood and extraction system (see Figure 4.1). This bench was used for sample preparation and condition assessment throughout the test period.
- Fuel drums (with taps) and racks were fitted to the bench to facilitate replenishment of each fuel type. A waste fuel drum on wheels was located next to the bench.

Anteroom – fume hood, fuels and scales	**Container Racks stored in Heated Room**
	

Figure 4.1 Materials Compatibility Test Facilities

4.3.5 Procedures

Procedures covering test method, facilities control and safety were documented.

4.3.6 Sample Preparation

The SAE and ASTM test specifications are written assuming the testing of unformed (raw) material. Due to the unavailability of multiple samples of raw (unformed) material as required by the specification, testing was conducted on samples taken from formed parts or the formed parts themselves (eg O-rings and diaphragms). For some parts, complete assemblies were immersed in the fluid (eg fuel pumps). It was felt that this would replicate the in field situation. The components included a large number of metal and non-metal parts from the fuel systems themselves. A number of test pieces were cut from larger items, for example fuel tank test pieces, while the constituent components of other parts were used (eg. carburettor service kits). The metal components generally were not included for immersion in neat ULP and/or LRP as these components were assumed to be compatible with these fuels and were not expected to present any useful results. Thus some metal components were tested in E20 only, while many polymeric components were tested in ULP and/or LRP and E20 fluids. From a logistical point of view this enabled the samples to be kept to a reasonable number.

The following measurements and recording of characteristics of the test samples were taken where applicable to establish the initial condition of each sample.

- Weight
- Dimensions
- Hardness (rubber and plastics)
- Photographic record.

These sample measurements and recordings were again taken where possible at interim periods within the test period of 2000 hours, and upon completion of the 2000hr test period both prior to and after drying.

4.4 Experimental Data

With the immersed samples having reached the target 2000hours, the components were inspected, then dried in accordance with the SAE procedure, and re-inspected. The results of these inspections are presented in the attached reports in Appendices A, B and C. Significant results are discussed below and where significant the photographic evidence is repeated. Where a sample exhibited similar behaviour when immersed in ULP and/or LRP and E20 test fluids, the result was not considered to be critical with respect to compatibility. Only when the E20 result was markedly different to ULP/LRP was the incompatibility highlighted.

4.4.1 Holden VN Commodore 2000hr Inspection Results.

A listing of the components presenting a clear visual incompatibility with the E20 test fuel mix is identified. These components, unless specified or not tested with the ULP test fuel, have shown no visual incompatibility with the ULP test fuel.

The following metal fuel system components have been identified with evidence of corrosion:

- In-tank fuel pump (casing), corrosion and pitting on external casing surfaces
- In-line fuel pump (casing), corrosion and pitting on external casing surfaces
- In-line fuel pump (rotor), pitting and corrosion on armature shaft and rotor along with tarnishing of exposed electrical contacts
- In-line fuel pump (terminals), tarnishing of contacts
- In-line fuel pump (magnet), minor corrosion spots
- Fuel injector, corrosion on metal surfaces
- Fuel regulator diaphragm, has corrosion on metal button and diaphragm material is also discoloured
- Fuel tank metal sample, corrosion formed on surface
- In-tank fuel strainer, plastic filter discoloured and metal insert has some corrosion
- Fuel sender unit body (in-tank system), some light corrosion on underside
- PCV valve, some small corrosion spots on surfaces
- Fuel pressure regulator housing, small corrosion spots – particularly on brazed areas

	
In-tank fuel pump, VN5ULPE20, Initial Condition	In-tank fuel pump, VN5ULPE20, 2000hr Condition Note: corrosion and pitting on casing's external surfaces

Figure 4.2 In-tank fuel pump – E20

	
In-line fuel pump rotor, VN14AULPE20, Initial Condition	In-line fuel pump rotor, VN14AULPE20, 2000hr Condition Note: pitting and corrosion on armature shaft

Figure 4.3 In-line fuel pump – E20

	
Fuel regulator diaphragm, VN29AULPE20, Initial Condition	Fuel regulator diaphragm, VN29AULPE20, 2000hr Condition Note: discolouration of the diaphragm material and corrosion

Figure 4.4 Fuel regulator diaphragm – E20

The use of brass fuel system components seems limited in this EFI system and where present are mainly as an electrical connection. These electrical connections were observed to be heavily tarnished following immersion in E20.

Polymeric components identified as presenting with distortion are:

- Fuel sender float (in-tank system), material starting to breakdown (some rust also on metal lever) – see Figure 4.5
- Hose – fuel tank vent, enlarged diameter
- Hose – fuel tank pipe, enlarged diameter
- Hose – return, enlarged diameter and end-delamination
- Hose – fuel regulator, loss of bend shape and end-delamination – see Figure 4.6
- Hose – vapour pipe connection, end-delamination
- Boot – in-tank fuel pump, appears softened and swollen
- Fuel injector, paint removed from casing
- Fuel rail connecting pipe, paint being removed

	
Fuel sender float (in-tank system), VN4BULPE20, Initial Condition	Fuel sender float (in-tank system), VN4BULPE20, 2000hr Condition Note: material starting to breakdown (some rust also on metal lever)

Figure 4.5 Fuel sender float – E20

The risk with the breakdown of polymer materials is that there are particles loose in the fuel system that can cause clogging or blockage of filters, pumps, fuel injectors or other elements of the system.

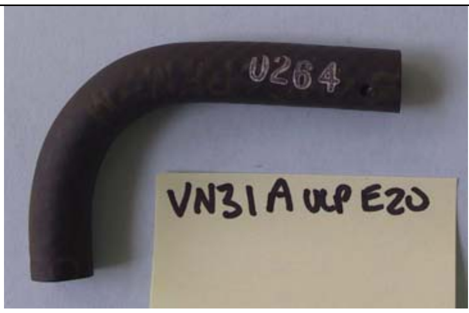	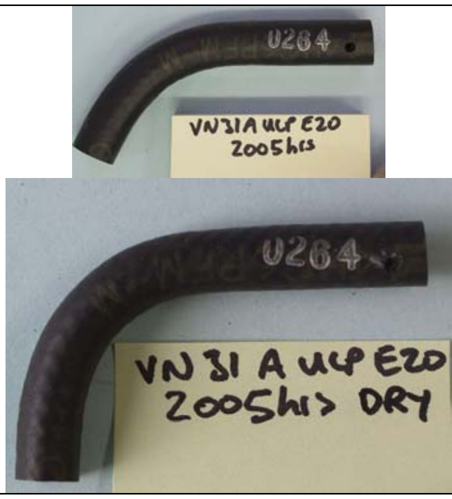
Hose – fuel regulator, VN31AULPE20, Initial Condition	Hose – fuel regulator, VN31AULPE20 2000hr Condition Note: loss of bend shape (when immersed) and end-delamination. Shape mostly returns when dried.

Figure 4.6 Formed fuel hoses – E20

Deformation and end-delamination of hoses, such as that shown in Figure 4.6 would seem to be representative of the performance of hoses throughout this fuel system.

Further details of the components immersion tested can be found in Appendix A-1.

4.4.2 Holden VK Commodore 2000hr Inspection Results.

A listing of the components presenting a clear visual incompatibility with the E20 test fuel mix is identified. These components, unless specified are not tested with the LRP test fuel, have shown no visual incompatibility with the LRP test fuel.

The following metal base engine components have been identified with evidence of corrosion:

- Carburettor body, corrosion on surfaces and tarnishing of brass fittings – see Figure 4.7
- Carburettor float valve needle, heavy tarnishing
- Carburettor float valve body, heavy tarnishing
- Carburettor mixture adjusting screw, heavy tarnishing – see Figure 4.8
- Filler cap spring, some corrosion pitting
- Carburettor – plate, some surface corrosion
- External fuel pump – diaphragm, main pin tarnished and some corrosion on plated surfaces
- Fuel gauge sender, minor tarnishing of brass surfaces
- Carburettor – ball, some corrosion spots
- Carburettor – diaphragm, plating of metal part has started corrode/tarnish
- Choke pull-off - diaphragm, plating of metal part has started corrode/tarnish
- Fuel pump, EFI, tarnishing of connector
- Fuel pump wire, EFI, tarnishing of wire

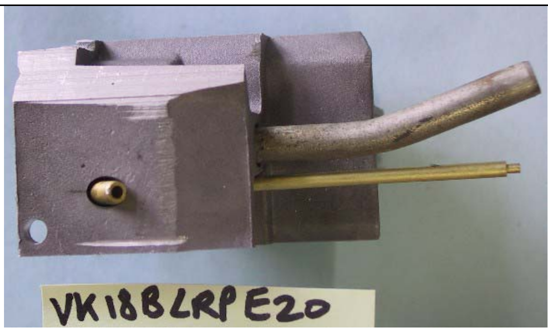	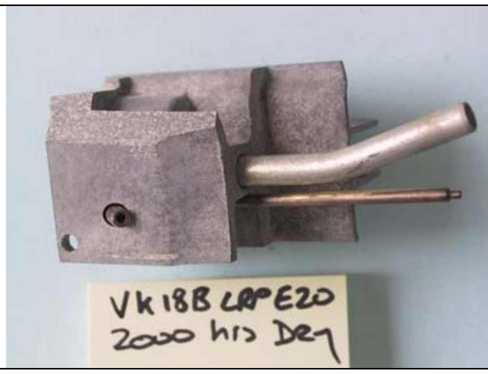
Carburettor body, VK18BLRPE20, Initial Condition	Carburettor body, VK18BLRPE20, 2000hr Condition Note: corrosion of aluminium surfaces and tarnishing of brass fittings

Figure 4.7 Carburettor body – E20

 	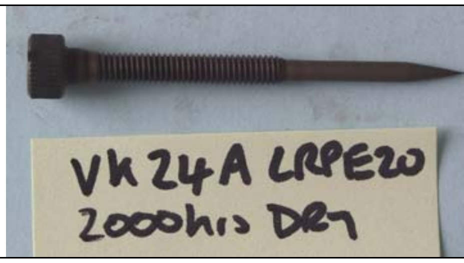
Carburettor mixture adjusting screw, VK24ALRPE20, Initial Condition	Carburettor mixture adjusting screw, VK24ALRPE20, 2000hr Condition Note: tarnishing evident

Figure 4.8 Carburettor mixture adjusting screw – E20

The tarnishing of all the brass fuel system components immersed in the E20 test fuel indicates that an oxidation process has occurred. Even if tarnishing was seen with the samples in LRP, it was notably worse for parts immersed in LRP. Tarnishing of electrical connectors made of brass/copper was also evident.

Polymeric components identified as presenting with distortion or other signs of incompatibility such as discolouration are:

- PCV valve, components have separated as polymer has distorted / swelled – see Figure 4.9
- Fuel pump, external – gasket, swelling and some signs of cracking (distortion once dried) – see Figure 4.10
- Fuel sender and pump unit (filter capacitor), insulator shows signs of splitting
- Float needle valve & seat Assy – washer, coating on washer starting to blister
- Fuel filter, external, discolouration of plastic housing
- Vapour Canister - filter, sponge separating
- Carburettor – gasket, surface dye breaking down
- Choke pull-off - filter, discolouration of plastic
- Tee – fuel filler / vent, discolouration of plastic

A number of the hoses tested exhibited changes during immersion, but as these changes (discolouration and swelling) were evident on both LRP and E20 samples the changes are not considered to be of high concern.

<table>
<tr><td>
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<tr><td>PCV valve, VK13ALRPE20, Initial Condition</td><td>PCV valve, VK13ALRPE20, 2000hr Condition
Note: Components have separated as polymer has distorted/swelled</td></tr>
</table>

Figure 4.9 PCV – E20

Whether the PCV would separate in a vehicle situation would need to be verified.

<table>
<tr><td>
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<tr><td>Fuel pump, external – gasket, VK7CLRPE20, Initial Condition</td><td>Fuel pump, external – gasket, VK7CLRPE20, 2000hr Condition
Note: swelled when immersed and showed signs of surface cracking</td></tr>
</table>

Figure 4.10 Fuel pump gasket – E20

Early on, the rubber sheets of the carburettor diaphragm had started to separate due most probably to the incompatibility of the adhesive with the fuels (both LRP and E20). This would not be considered a concern since the materials are clamped together in the assembly by the carburettor housing components. However, the sample immersed in E20 also showed signs of distortion due to swelling and this could be a concern.

	
Carburettor diaphragm, VK19CLRPE20, Initial Condition	Carburettor diaphragm, VK19CLRP & VK19CLRPE20, 2000hr Condition Note: in both the rubber sheets have separated, but the sample in E20 has also distorted due to swelling

Figure 4.11 Carburettor Diaphragm – E20

The discolouration of plastics and the breakdown of gasket and sponge materials is a potential concern.

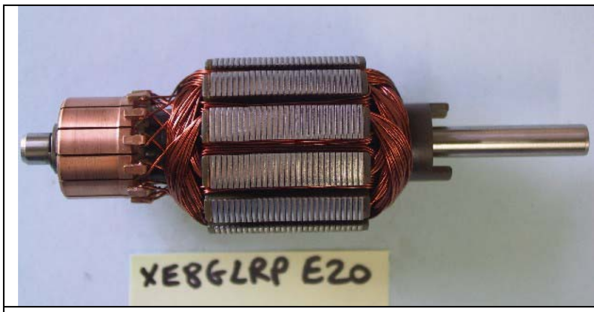
Further details of the components immersion tested can be found in Appendix B-1.

4.4.3 Ford XE Falcon 2000hr Inspection Results.

A listing of the components presenting a clear visual incompatibility with the E20 test fuel mix is identified. These components, unless specified are not tested with the LRP test fuel, have shown no visual incompatibility with the LRP test fuel.

The following metal base engine components have been identified with evidence of corrosion:

- Fuel pump terminals, tarnishing
- Fuel pump commutator, tarnishing – see Figure 4.12
- PCV valve spool, small amount of surface pitting
- Fuel tank – metal neck, some surface corrosion in spots
- Filler cap spring, small pit marks on surface
- Filler cap ring, some plating lost
- External fuel pump plate, some small spots of corrosion
- External fuel pump casing, some pitting on casing surface
- Carbon canister – lid, some small pit marks
- Carbon canister – screen, some surface attack and corrosion spots under the paint
- Fuel injector filter, tarnishing of retaining ring



Fuel pump armature and shaft, XE8GLRPE20, Initial Condition	Fuel pump armature and shaft, XE8GLRPE20, 2000hr Condition Note: tarnishing of commutator

Figure 4.12 Fuel pump armature an shaft – E20

The use of brass fuel system components seems limited in this EFI system and where present are mainly as an electrical connection. These electrical connections were observed to be heavily tarnished following immersion in E20.

Overall the corrosion severity is less than that observed on the components from the other fuel systems. The most significant concern is the heavy tarnishing of brass/copper components normally associated with an electrical role, for example the fuel pumps commutator.

Polymeric components identified as presenting with distortion are:

- Fuel sender unit, adhesive or potting mix being dissolved
- Fuel pump relief valve, swelling of the sealing ball (as well as tarnishing of the brass body)
- PCV valve, separation of parts due to swelling of the plastic housing – see Figure 4.13
- Fuel regulator diaphragm, discolouration of both samples (swelling and distortion of E20 sample) – see Figure 4.14
- Fuel injector, paint removed
- Fuel injector o-ring, discolouration
- Carbon canister – gasket, small tears

It should be noted that hoses were not specifically tested for this fuel system as it was expected that their compatibility performance would be represented by those tested from the VK and VN fuel systems.

	
PCV valve, XE15ALRPE20, Initial Condition	PCV valve, XE15ALRPE20, 2000hr Condition Note: separation of parts due to swelling of the plastic housing

Figure 4.13 PCV – E20

Whether the PCV would separate in a vehicle situation would need to be verified.

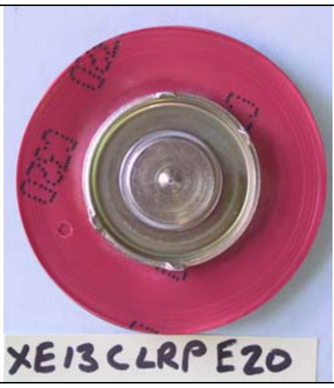
	
Fuel Regulator diaphragm, XE13CLRPE20, Initial Condition	Fuel Regulator diaphragm, XE13CLRPE20, 2000hr Condition Note: discolouration (both), swelling and distortion in E20

Figure 4.14 Fuel regulator diaphragm – E20

Further details of the components immersion tested can be found in Appendix C-1.

4.5 Paint Test Activity.

4.5.1 Overview.

This activity is focussed on conducting testing to assess the impact of the E20 fuel blend on the paint finish in the vicinity of the fuel filler cap. To this end, the ISO 2812-1 International Standard (10) was adopted and followed as closely as possible. This standard sets out the methodology for the determination of the resistance of paints and varnishes to liquids.

The experiment and testing is designed only to highlight any potential incompatibility between the paint finish and the E20 fuel blend. The testing and experimental design is not an attempt to fulfil the requirements of qualifying the applied finish as being compatible with the E20 fuel blend.

4.5.2 Component Test Preparation.

4.5.2.1 Test Fluid.

As proposed in the tender submission, testing occurred with neat gasoline and the E20 fuel blend. Test fluids adopted for the evaluation reported here are:

- Standard unleaded gasoline (WA pump gasoline)
- Standard unleaded gasoline with 20% ethanol by volume

4.5.2.2 Test Sample Selection and Preparation.

Rather than testing the fuel filler cap or a section the car's bodywork, the door to the filler location was used for convenience. Test samples were chosen based on the fact that the new vehicle manufacturers utilised two base materials for the filler door, plastic and sheet metal. The vehicles chosen to provide the filler doors were the Holden Commodore (AENHO01 and ANEHO06) and the Ford Falcon (AENFO02 and AENFO07) for plastic and metal filler doors, respectively. The location and surrounds of the fuel filler doors are shown in Figure 4.15. Both the filler doors types met the dimensional requirements of the standard in terms of area.

The filler doors from the test fleet were used as they have a true factory finish paint coating, unlike parts purchased as spares which are supplied unpainted. One filler door of each material type was exposed to ULP and one to E20.

	
Ford: Metal fuel filler door, plastic splash surround	Holden: Plastic fuel filler door, metal splash surround

Figure 4.15 Vehicle Fuel Filler Door Location and Surrounds

The test Standard outlines several options for the application of the liquid to the sample. Method 3 (spotting method) was selected as it was deemed to be most representative of the likely fuel contact in the field where fuel may splash during re-fill and subsequently evaporate. The methods not chosen were either full immersion or prolonged blotting; neither representative of in-field contact.

4.5.2.3 Fixtures, Test Conditions, and Facility

The testing occurred in the material compatibility testing anteroom area allowing air free access to the test samples. The anteroom temperature was controlled to the specified 23+/-2°C, the same as specified for the material compatibility testing.

The test samples were mounted horizontally on fixtures facilitating the application of the recommended droplet sizes and placement as described in the standard, see Figure 4.16. Each test sample was exposed to the respective test fluid every 24 hours during the working week.

	
Template used to ensure droplets are placed in the same position and in accordance to the Standards recommendations.	The same template is used with all fixtures. The fixtures are designed to hold the samples in the horizontal orientation.

Figure 4.16 Vehicle Fuel Filler Door Test Fixtures

The application and exposure periods are not specified in the Standard. As a consequence the application frequency adopted was chosen to represent a high fuel tank re-fill frequency while the overall test period is a program timing related choice. Periodically and at the end of the target exposure period the test samples are inspected for deterioration from a visual perspective and also analysed to determine if there was degradation in the paint finish based on a measured change in the paint thickness in the area exposed to the test fluid.

4.5.2.4 Test Observations

A total of 1848hrs of exposure were accumulated. At the end of this period the following observations were noted:

- No evidence of paint peeling
- No evidence of blistering
- No evidence of crazing
- No evidence of dulling
- Some evidence of staining (white painted fuel filler door only)
- Some degradation of the adhesive attaching the dust seal (Commodore part)

The staining is only evident on the white painted fuel filler door sample. To the naked eye the staining shown is slightly now more prominent on the sample exposed to E20 than to the baseline ULP sample. The staining has been captured in Figure 4.17. The paint finish between the two filler door types is notably different given the difference in base material and paint type (the Ford component has a “metallic” paint finish, on a sheet metal part). These surface finish variations may be reasons in addition to the base colour that have contributed to the staining on one sample type and not the other.

The adhesive used to secure the dust seal on the Commodore part has been weakened by contact with the E20 test fluid resulting in the seal being partially detached.

	
Commodore fuel filler door subjected to ULP test fluid.	Commodore fuel filler door subjected to E20 test fluid.

Figure 4.17 Staining on fuel filler doors

5. Discussion and Conclusions.

The testing data shows that the E20 test fuel demonstrates potential incompatibility with selected fuel system components utilised in the VN and VK Commodores, and the XE Falcon. These findings are based on visual inspection and physical measurement of the component after 2000hours of immersion time.

Generally, if the fuel system components immersed in the gasoline test fuel showed some change in appearance, so would the same component in E20. This is not considered to be of significant concern. It is only when the component immersed in E20 is the only one to show a change in appearance that incompatibility need be suspected.

A summary of the components suspected of incompatibility with E20 when tested in accordance with the procedures used is given below.

Metal fuel system components.

- Fuel pump casings (of VN in-line and in-tank, XE pump), corrosion and pitting on external casing surfaces
- Fuel pump internals (rotor of VN), pitting and corrosion on armature shaft and rotor along with tarnishing of exposed electrical contacts (VK connectors, VN and XE connectors and commutator)
- Fuel injector, corrosion on ferrous metal surfaces (VN) and tarnishing of filter retaining ring (XE)
- Fuel regulator diaphragm (VN), has corrosion on metal button and diaphragm material is also discoloured
- Fuel pressure regulator housing (VN), small corrosion spots – particularly on brazed areas
- Fuel tank metal sample (VN), corrosion formed on surface
- In-tank fuel strainer, plastic filter discoloured and metal insert has some corrosion
- Fuel sender unit, some light corrosion on underside of body (VN) and minor tarnishing of brass surfaces (VK)
- PCV valve / spool (VN and XE), some small spots of corrosion /pitting on surfaces
- Carburettor and associated components (VK)
    - Body, corrosion on surfaces and tarnishing of brass
    - Float valve needle and body, heavy tarnishing
    - Mixture adjusting screw, heavy tarnishing
    - Filler cap spring, some corrosion pitting
    - Plate, some surface corrosion
    - Ball, some corrosion spots
    - Diaphragm, plating of metal part has started corrode/tarnish
    - Choke pull-off - diaphragm, plating of metal part has started corrode/tarnish
- External fuel pump – diaphragm, main pin tarnished and some corrosion on plated surfaces (VK)

Polymeric components.

- Fuel sender float (VN), material starting to breakdown (some rust also on metal lever)
- PCV valve (VK and XE), separation of parts due to swelling of the plastic housing
- Hoses (various rubber VN components), enlarged diameter, end delamination and loss of formed shape when immersed and whilst shape and size returned upon drying the hoses where typically hardened – generally more so for the E20 sample
- Hoses – fuel tank pipe, enlarged diameter
- Fuel regulator diaphragm, discolouration of both samples (swelling and distortion of E20 sample), VN and XE.
- Paint removed from various fuel injector casings (VN and XE) and also from other fuel rail assembly parts (VN)
- Plastic components which were incompatible with the E20 such as hoses (VK), filter housings and screens (VN, VK, XE) and o-rings (XE) were notably discoloured
- Gaskets, such as those made from cork, seemed to be particularly incompatible with E20 and were visibly distorted /cracked after being dried out (VK)
- In some cases adhesives and electrical potting mix (VK, XE) were also seen to be weakened by the immersion in E20

Brass /copper components.

- All brass fuel system components were identified as tarnished indicating an oxidation process had occurred.
- All brass /copper electrical components were also identified as tarnished.

The impact of the results obtained during materials compatibility testing can be summarised as follows:

- For metallic fuel system components that have exhibited corrosion when in contact with E20 fuel.
  - This is considered a concern since the potential exists for the oxide to dislodge and become trapped in between moving components. This situation would most likely result in accelerated wear of these components surfaces.
  - This is also considered a concern if the potential exists for the oxide to dislodge and clog/block other fuel system components thus impairing their functioning to specification.
  - The potential exists, depending upon the severity of the oxidation and the actual final location of the dislodged oxide, to cause engine failure.

- For all the brass /copper components that were tarnished indicating an oxidation process had occurred.

  - This is considered a concern since the oxidation of brass fuel and air metering jets or fuel control devices in the engine carburettor has the potential to lead to the loss of the intended nominal air metering and /or fuel metering, or control.
  - This is considered a concern since the oxidation on electrical connections has the potential to reduce electrical conductivity as well as acting as a source of wear and abrasion.
  - The potential exists, depending upon the severity of the loss of metering and/or control, to result in the degradation or loss of engine function.

- For polymeric materials found to have significant changes in appearance due to contact with E20 fuel.
  - This is considered as unacceptable since the changes have the potential to result in fuel leakage.

With regard to assessments conducted to examine the affect of fuels on the body paint and finish, 1848hrs of exposure were accumulated with the following observations noted:

- No evidence of paint peeling
- No evidence of blistering
- No evidence of crazing
- No evidence of dulling
- Some evidence of staining (white painted fuel filler door only)
- Some degradation of the adhesive attaching the dust seal (Commodore part)

6. References.

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9. SAE Recommended Practice, Jan 00. “Gasoline, Alcohol and Diesel Fuel Surrogates for Materials Testing” SAE J1681.
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7. Acronyms

ASTM	American Society for Testing and Materials
E10	Gasoline blended with 10 % Ethanol
E15	Gasoline blended with 15 % Ethanol
E20	Gasoline blended with 20 % Ethanol
EA	Environment Australia
FMEA	Failure Mode Effect Analysis
MSDS	Material Safety Data Sheet
SAE	Society of Automotive Engineers.
ULP	Unleaded Petrol.