Market Barriers to the Uptake of Biofuels Study

Marine Outboard Driveability Assessment to Determine Impacts of a 10% and 20% Ethanol Gasoline Fuel Blend on a Small Batch of Engines

Report to Environment Australia

February 2003

Orbital Engine Company

CONTENTS

APPENDICES

A	Test Fuel Specifications

B	Tabulation of All Test Ratings (10 engines, 3 fuels per engine)

C	Perth Weather and Water Conditions on various test days

1 Executive Summary

This document presents findings of testing a sample of ten Mercury Marine 15hp two-stroke outboard marine engines with gasoline containing 10% and 20% by volume ethanol (E10 and E20), completed by Orbital Engine Company. The program is an initiative of the Environment Australia project “Market Barriers to the Uptake of Biofuels – Testing Petrol Containing 20% Ethanol (E20).” The program of work as reported here, was initiated from findings of a previous program of work reported upon and submitted to Environment Australia, “A Testing Based Assessment to Determine the Impacts of a 10% and 20% Ethanol Gasoline Fuel Blend on Non-Automotive Engines” (1) completed by Orbital Engine Company. This previous program identified that the Mercury engine would stall during an on-water driveability assessment when operated on the E20 fuel blend. The stall occurred upon demand of Wide Open Throttle (WOT) acceleration after a test designed to assess the engines performance during in-gear low speed motoring. The motoring test duration is at least 10 minutes and is conducted at two different engine speeds.

Based on the sample of ten engines, the work reported here presents the statistical significance of the stall behaviour in terms of the likely impact on the general population of this engine type. The sample size also presented the opportunity to report on other on-water driveability defects related to E20 and E10 fuel blends.

In general, engine testing with the E10 fuel blend has detected little performance difference when compared with operating the engines with ULP gasoline only. The only area where a substantial impact has been identified was during demand of WOT acceleration following the in-gear low engine speed motoring test at the lowest of the two engine speeds tested. One out of the ten engines tested stalled. The statistical inference of this is to a 95% confidence level; between 0.53 and 38.1% of the general engine population of this particular engine type will experience stalling upon demanding WOT acceleration following the in-gear motoring test.

For the E20 fuel blend, the stalling characteristic was found to occur at both the engine speeds tested. For the WOT acceleration demand following lowest test speed, three of the ten engines tested stalled. The statistical inference to a 95% confidence level is that between 9.4 and 58.7% of the general engine population of this particular engine type will experience stalling. At the higher test speed one out of the ten engines tested stalled, the statistical inference to a 95% confidence level is that between 0.53 and 38.1% of the general engine population of this particular engine type will experience stalling. This engine stall characteristic presents the potential to impact on reliable engine operation. It must however be noted that all engines that stalled could be restarted immediately upon operation of the engines starting mechanism allowing acceleration of the boat.

All engines tested for WOT acceleration following the in-gear motoring test at both engine speeds accelerated the boat without hesitation when operating with neat gasoline.

The on-water testing program revealed increasing degraded performance with increasing ethanol content of the fuel blends when compared with the performance utilising gasoline only. While operating the engines on the E20 fuel blend the following operating characteristics were observed:

- Engine misfire frequency increased.
- Engine stall frequency increased.
- There was difficulty experienced in maintaining a constant engine operating speed during the in-gear motoring test.

Further details are contained overleaf.

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 (5). 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 (6) examined the impacts of E15 (15% ethanol). The second in 1998 (7) 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. 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.

An identified area of application of the gasoline engine where no known current Australian data on the effects of either E10 or E20 exists was the non-automotive engine sector. To rectify this situation, Environment Australia contracted Orbital Engine Company to undertake an engineering program targeted at identifying the potential effects of E10 and E20 on the Australian population of non-automotive gasoline engines.

This sub-program also falls under the tender No. 34/2002. The sub-program activity was reported as of 13th January 2003, (1). The findings of this sub-program identified that there was a concern with regard to the on-water driveability of the selected marine outboard engine when operating on the E20 fuel blend.

In order to understand the impact of the on-water driveability concerns on the general population of marine engines of this particular type with a suitable level of statistical confidence, further investigations on a larger sample number of engines was warranted.

2.1 Program Goals

The objective of this sub-program was to gather information about the on-water driveability of the selected marine outboard engine over a larger sample number of engines. Preliminary statistical analysis identified that a sample of 10 engines would be sufficient to identify whether an impact exists within the general population with this particular engine and the use of gasoline /ethanol blend fuels.

2.2 Methodology Adopted

The methodology adopted for this sub-program of work was to conduct an assessment of the on-water driveability of each of the 10 engines of the selected outboard type. The testing was undertaken using representative baseline gasoline and 10 and 20 percent by volume ethanol blended with the baseline gasoline.

2.2.1 Test Fuels Management

The test program required Orbital to procure sufficient quantities of a variety of fuel types. The methodology adopted has been to source the necessary baseline gasoline and ethanol from various refiners. These fuels are then used as blend constituents to produce test fuel blends for use throughout the program. Fuel identification and usage was strictly controlled in accordance with internal Quality Assurance procedures.

2.2.2 Engine Driveability Assessment

The methodology adopted to gather the experimental data was to firstly obtain an understanding of the performance of the engines on the baseline gasoline. Following this baseline, the engines were tested according to the same procedures except that E10 and E20 ethanol blend fuel was utilised. This provides three back-to-back data sets enabling the direct comparison of the performance of each engine.

Where possible, engine manufacturer standard testing procedures have been adopted within this area of the engine assessment. These testing procedures were determined through either Orbital's industry knowledge or through Environment Australia approved contact with the manufacturer.

3 Test Fuel Management

The test program required Orbital to procure sufficient quantities of fuel grade Ethanol, Unleaded Petrol (ULP) in summer grade including ULP in bulk storage on Orbital's site. These fuels were used as the blend stocks for the preparation of the various ethanol blended fuels required for engine driveability testing.

Details as to the specification of and/or the actual quality of the procured fuels can be found in Appendix A.

3.1 Engine Driveability Test Gasoline

The engine driveability test gasoline was required in ULP grade and was sourced from the Caltex Kurnell refinery in New South Wales through the

Caltex Broadmeadows terminal. The fuel was delivered at the end of December 2002. A total of nine 205L drums of ULP were received. Each drum was well labelled and accompanied with a Material Safety Data Sheet (MSDS).

The fuel was renamed for the purposes of standardization with company quality procedures and the individual drums were identified according to the following naming convention. The driveability test fuel was renamed AEN Summer ULP. The individual drums have been identified with the prefix S2 for summer batch number two and numbered according to the number of drums in the group, i.e. AEN Summer ULP S2/1 – S2/9. All driveability testing was completed with AEN Summer batch two ULP neat and with E10 and E20 as blended with AEN Summer batch two ULP.

3.2 Engine Run-in Gasoline

Specific test gasoline is only required for the engine performance assessment testing. For engine run-in, pump grade gasoline is suitable. Existing supply of locally available ULP sourced from the BP Kewdale terminal in Western Australia was used for this purpose.

3.3 Ethanol

The fuel grade ethanol was sourced from CSR Ltd. Yarraville Distillery in Victoria. This fuel was delivered during December 2002. A total of four 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 E6 – E9.

3.4 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.

3.5 Fuel Control

There were a total of 4 fuel types utilised within the test program. An inventory of fuels specific to this program was created in an excel workbook to assist with the management and control of fuel use and location.

Of particular concern was control of the blended ethanol fuel concentrations. In order to qualify the blending process, a one-litre sample was taken from each drum of blended fuel for in-house density measurement, this was compared to a calculated value based on the density of the individual constituents. The results for the fuels used for this program are tabulated in Appendix A. The ethanol volume of the blends was checked in house using a basic water extraction method. A second one-litre sample was taken and stored for independent analysis should the requirement arise.

3.6 Engine Oils Used

The marine engine testing used the Mercury Marine branded TC-W3 oil in the fuel-oil premix.

4 Engine Driveability Tests

4.1 Statistical Significance of Selected Sample Size of Engines

In order to understand with sufficient confidence, the likely impact of a failure on the total fleet of engines in the market place, a statistically representative number of engines must be tested.

The question of what is a statistically representative number of engines can only be calculated when it is known how many engines in a given sample have failed. Because of this, statistical methods are used to predict failure rate and associated confidence levels between the actual test sample and the general population.

The binomial distribution applies to tests that return either a pass or fail result. It can be used to draw conclusions on the failure rate in the general population based on a limited sample size. To estimate the number of failures in the general population, a number of tests are carried out and the number of failures are recorded. The results are summarized in the following table for sample sizes of 10 and 100 engines, with a 95% confidence in the predicted fleet failure rate.

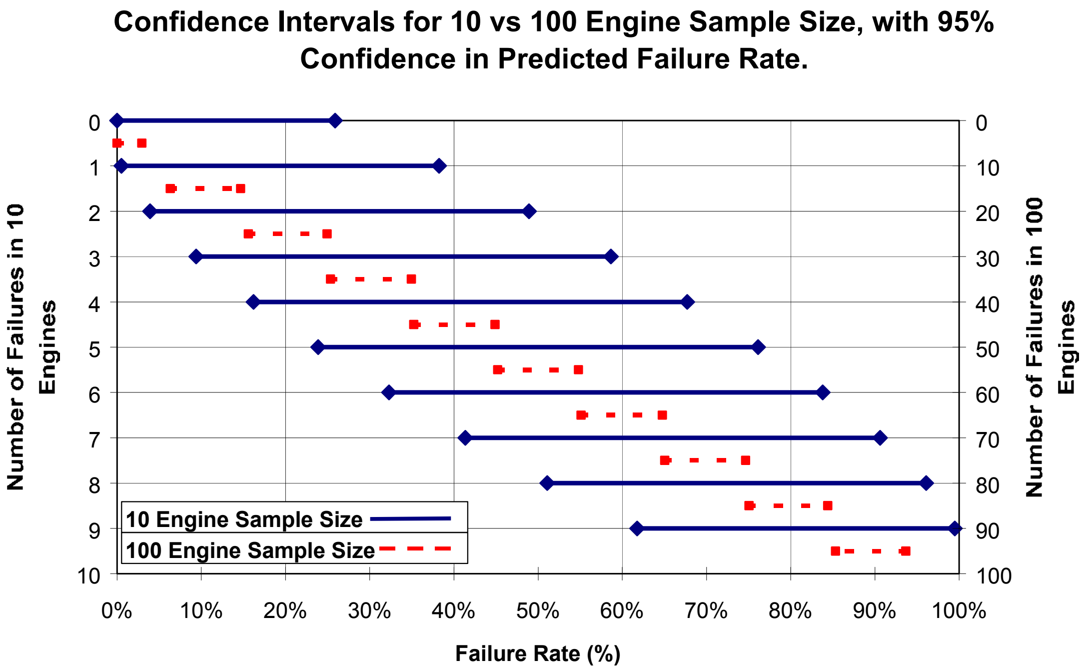


Figure 4.1.1 Confidence Intervals for 10 vs 100 Engine Sample

The confidence interval is the range of predicted fleet failure rates (%), for a given number of failures in the tested sample. It can be seen that the confidence interval narrows significantly, or the prediction becomes more accurate, with increasing sample size. This allows a much more precise prediction of the actual fleet failure which can be expected. However the exact fleet failure rate is not important in this case. It is important to identify whether a failure rate of more than a given level will occur. For this reason it is not necessary to test a large sample size.

Based on this statistical analysis and assumptions, Orbital proposed that a sample size of 10 engines should be sufficient to identify whether a problem existed. Given this sample size the predicted failure rates at 95% confidence are listed in the table below.

It should be noted that increasing the sample size will not significantly improve the demonstration of whether a problem exists or not, it will however refine the prediction of actual fleet failure rate.

Number of Engines Tested	Number of Failures	Comments About the Failure Rate in the General Population
10	0	There is a 95% probability that engine failure is less than 25.9%
10	1	95% probability that engine failure is greater than 0.53 and less than 38.1%
10	2	95% probability that engine failure is greater than 3.9% and less than 48.9%
10	3	95% probability that engine failure is greater than 9.4% and less than 58.7%

Table 4.1.1 Failure Rate in General Engine Population

As an example, see Table 4.1.1, should 3 engines fail out of the sample of 10, there is a 95% confidence that within the engine population at least 9.4% of the engines in the market will fail.

4.2 Engine Selection

The engine selection methodology was extensively described in the preceding report from the Orbital Engine Company (1). The Mercury Marine 15hp was selected following a consultative process with manufacturers and with the approval from Environment Australia with regard to consultation process. Environment Australia reviewed the engine selection process and endorsed the choice of recommended product.

A total of 10 engines were procured for this follow-on evaluation program, consisting of 9 new engines and 1 carried over from the earlier test program. For the purposes of overall quality control, the engine in each product has been assigned a code. These codes will be the primary reference used throughout this report, with the last two digits referring to engine number. The selected test engines are listed in Table 4.2.1.

Engine Code	Engine Type	Comments
AENME04	Mercury 15hp	Carried forward from earlier EA test program
AENME05	Mercury 15hp	New engine
AENME06	Mercury 15hp	New engine
AENME07	Mercury 15hp	New engine
AENME08	Mercury 15hp	New engine
AENME09	Mercury 15hp	New engine
AENME10	Mercury 15hp	New engine
AENME11	Mercury 15hp	New engine
AENME12	Mercury 15hp	New engine
AENME13	Mercury 15hp	New engine

Table 4.2.1 Selected Test Engines

4.3 Engine Test Description

A summary of the tests undertaken throughout the program is outlined below. Each engine was assessed using each of the three fuel blends. Since a number of engines were tested in this driveability assessment program, there is some variation expected between results on the same fuel due to engine-to-engine variability and carburettor settings even though best efforts have been made to ensure all engines have completed similar run-in preparations and have similar carburettor settings.

4.3.1 Engine Instrumentation

The only instrumentation installed to the engines was a Mercury Marine QuickSilver^{TM} Digital tachometer, while engine AENM004 carried over from the earlier EA test program included other instrumentation not required for the driveability tests. This tachometer attaches to the ignition lead of cylinder #1 and provides a digital read out of engine speed.

4.3.2 Engine Driveability Tests

Engine driveability performance was assessed so far as it may be influenced by the selection of fuel blend. All of the testing was “on-water driveability” related, requiring the product to be tested in the field.

4.3.2.1 Engine run-in

The nine new engines for this sub-program were run-in following the manufacturer’s recommended procedure. This requires the engine to be progressively operated at different part-load settings for the first tank full (25Litres) of fuel at the manufacturer’s recommended break-in oiling rate of 25:1 fuel:oil. To expedite and ensure similar run-in process, the new engines were installed in Orbital’s marine tank. Two engines were run in tandem, with Orbital’s data acquisition and control system automatically running the engines through the run-in schedule shown in Figure 4.3.1. The schedule was repeated until the first tank of fuel was consumed. Pump ULP (refer section 3.2) was used as the run-in fuel for all nine engines.

For the run-in only, engine idle speed was adjusted marginally higher then the recommended speed at 850rpm so as to give a better margin against stall during the schedule.

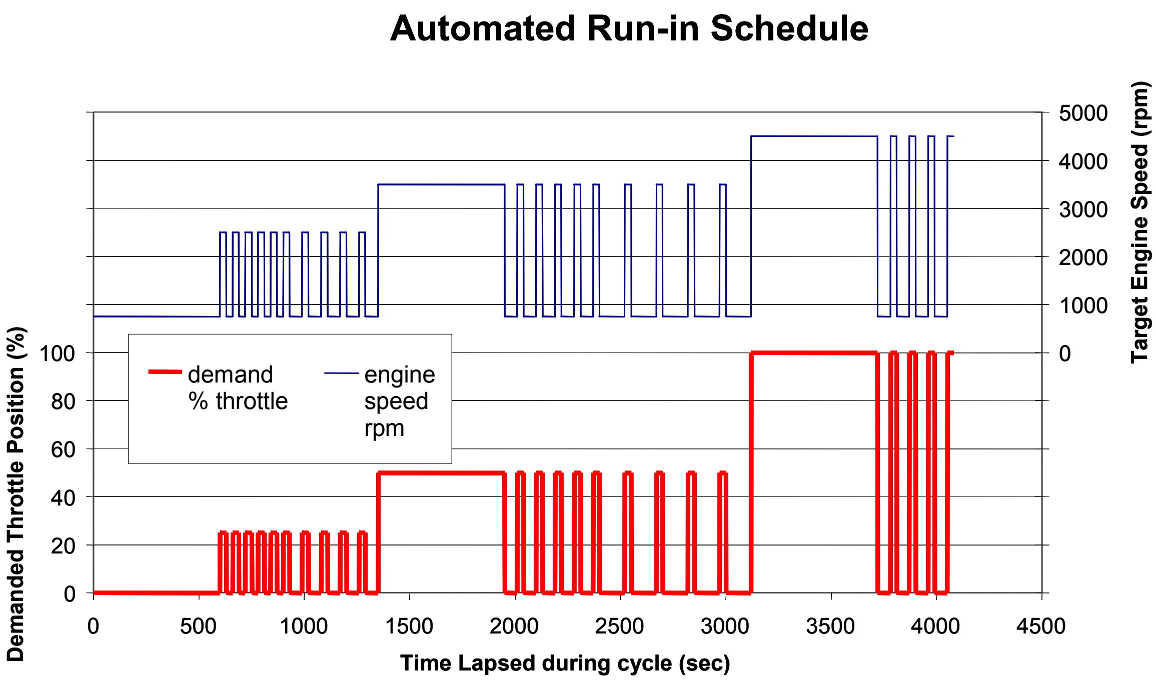


Figure 4.3.1 Automated Run-in Schedule

4.3.2.2 Engine Carburettor Setting for Driveability Tests

The carburettor of each engine was adjusted according the manufacturer's recommendations using ULP fuel.

Firstly, once the engine was warmed up, the idle speed was adjusted as recommended in the operation manual (9) to 750rpm using the Quicksilver tachometer.

Secondly, the carburettor "Slow Speed Mixture Adjustment" was set. The procedure is outlined in the extract from the operator's manual below:

1. Before starting engine, turn the slow speed mixture screw in until it is lightly seated then back it out 1-1/2 turns.
2. With the boat tied securely to dock, start engine and allow it to warm up.
3. Shift the outboard to forward gear and reduce engine speed to idle.
4. Turn the slow speed mixture screw slowly in until the engine starts to misfire or stall due to a lean mixture. Note the position of the screw slot.
5. Turn the slow speed mixture screw slowly out until the engine starts to "load up" or fire unevenly due to a rich mixture.

6. Set the slow speed mixture screw midway between the rich and lean settings. When in doubt, set the mixture slightly rich rather than too lean.

Thirdly, the idle speed was re-checked to ensure it had not drifted as a result of the slow speed mixture adjustment.

4.3.2.3 Engine Driveability Assessment

Marine engine driveability was evaluated by means of a subjective “Jury Test”. The basic “Jury Test” used in the evaluation of the AENME04 engine in the previous testing (1) was expanded to include some additional characterisations. These additional characterisations sought to formally record performance characteristics that were identified in the earlier testing program. It is customary to expand and repeat the “Jury Test” as performance nuances are identified, and so based on previous knowledge this was done. The expanded performance assessment was performed for all ten engines, including AENME04, so that judgement and scaling parity would apply. Testing includes:

- Transient and orientation running tests
- Fuel tank “run-dry” re-start tests

A particular area of focus following the results of the earlier program was extended trolling and post-trolling performance. Trolling is where the engine is run in-gear at a low speed for the purpose motoring the boat in low speed zones on the river or in marinas. Trolling assessments were done with the engine set at two speeds to identify if results would be speed dependent. In addition to subjectively assessing performance during the trolling, the performance during the post-troll accelerations was also characterised.

Rating of each assessment parameter was by two independent testers.

5 Engine Driveability Results

5.1 Engine Driveability

Engine driveability with the three fuel blends was assessed using the “Jury Test” subjective rating system, see Table 5.1.1. Various aspects of driveability were rated, including fuel tank “run-dry” startability. A digital tachometer was used with each engine to confirm that each engine was reaching operating targets such as trolling and peak engine speeds during testing.

It should be noted that for this small engine category, boat loadings such as number of occupants and water conditions are likely to have a significant influence on measured results. As a consequence, it is generally acknowledged practice to only rate some performance factors such as acceleration for smoothness of operation and not specific acceleration times.

No.	ASSESSMENT	PERCEPTABLE TO
1	Not Acceptable	Anybody
2	Not Acceptable	Average Customer
3	Not Acceptable	Average Customer
4	Objectionable	Average Customer
5	Borderline	Critical Customer
6	Barely Acceptable	Critical Customer
7	Fair	Critical Customer
8	Good	Critical Customer
9	Very Good	Critical Customer
10	Excellent	Trained Observer

Table 5.1.1 “Jury Test” rating system

Engine stall upon demand of acceleration or upon demand of a change of engine state is given a rating of “1” as this is deemed to be unacceptable by anyone’s standard. Misfire, hesitation and other run quality issues may be rated in the “2 – 6” region depending upon the observer’s perception.

Testing was conducted at daylight ambient temperatures during the period January 15th through February 3rd on Perth metropolitan waters. Generally temperature conditions were higher than 21^{o}C. Details of the prevailing weather conditions can be found in Appendix C of this report.

Averages and standard deviations are calculated for the rating data gathered for each engine operating on the three fuel types, see Appendix B. Table 5.1.2 below is a summary of the areas assessed by the Jury Test method and the average of the ratings assigned for each fuel type.

	Ratings for Fuel Type		
Driveability	**ULP**	**E10**	**E20**
1) Docking/Manoeuvring	10.0	10.0	10.0
2) Fast Shift	10.0	10.0	9.8
3) Vibration	7.8	7.9	7.9
4) Smoke	7.9	8.0	8.0
5) Noise	7.0	7.0	7.0
6) Idle (neutral and in-gear)	7.9	7.9	7.3
7a) Trolling @ 1450rpm	7.6	7.4	6.6
7b) Post-Troll Accel (1450rpm)	8.0	7.9	7.3
7c) Trolling @ 1000rpm	8.0	7.8	7.4
7d) Post-Troll Accel (1000rpm)	8.0	7.1	5.8
8) Steering and Tilt	7.9	7.9	7.8
9a) Fast Acceleration	8.0	8.0	7.5
9b) Slow Acceleration	8.0	8.0	7.8
Re-Fuel Start "run dry"			
# Pulls to Start	1.23	1.13	1.27
Idle Rating	7.9	8.0	8.0
Run Rating	8.0	8.0	8.0

Table 5.1.2 Average "Jury Test" Ratings for Engine Driveability

A tabulation of the test ratings for all engines is given in Appendix B. Data gathered during the test program is best analysed using graphical techniques. Radar plots are conventionally used to pictorially present differences identified in the averaged driveability performance rating. The driveability performance has been divided into five performance groups each comprising a number of parameters for assessment. A radar plot is utilised to present the differences identified for each parameter in the performance group. Focus can then be given to individual engine performance for a particular assessment parameter within a performance group. The performance groups with their particular assessment parameters are summarised in Table 5.1.3 below:

Group #	Group Name	Assessment Parameters
1	Basic Performance	Docking / Manoeuvring Fast Shift Vibration Smoke Noise
2	Trolling Performance	Idle Trolling @ 1450rpm Trolling @ 1000rpm Post-Troll Acceleration (1450rpm) Post-Troll Acceleration (1000rpm)
3	General Performance	Steer-Tilt Acceleration (Fast) Acceleration (Slow)
4	Tank "Run Dry" Starting	Start1, # pulls Start2, # pulls Start3, # pulls
5	Post Tank "Run Dry" Performance	Start1, Idle and Run Start2, Idle and Run Start3, Idle and Run

Table 5.1.3 Performance Grouping of Assessment Parameters used for Radar Plots

5.1.1 Basic Performance

The assessment identified little variation in the basic performance of the engines in the areas of docking/manoeuvring, vibration, smoke and noise as seen in Figure 5.1.1.

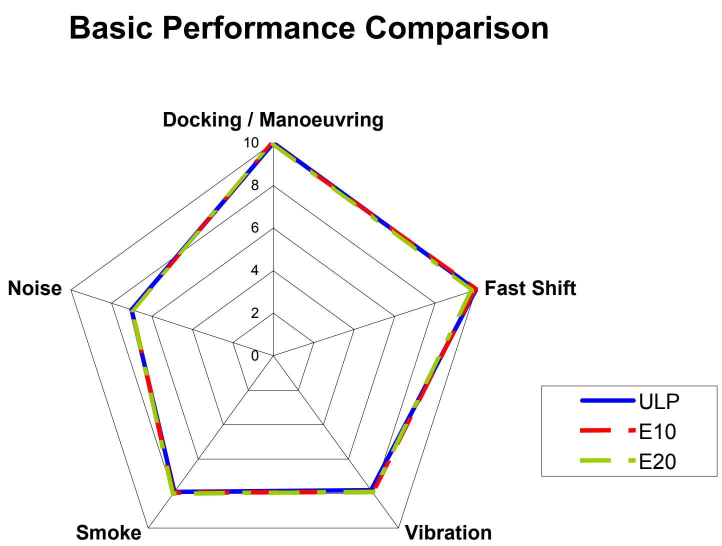


Figure 5.1.1 Radar Plot of Average Basic Performance

5.1.2 Trolling Performance

The results in Figure 5.1.2 show a clear trend of reducing performance rating with increasing ethanol content in the fuel. In the radar plot most performance indicators have only been degraded from an average “8” to an average “7”. Only the “post-troll acceleration from 1000rpm” is rated lower than this scoring an average result in the “5 - 6” range for E20.

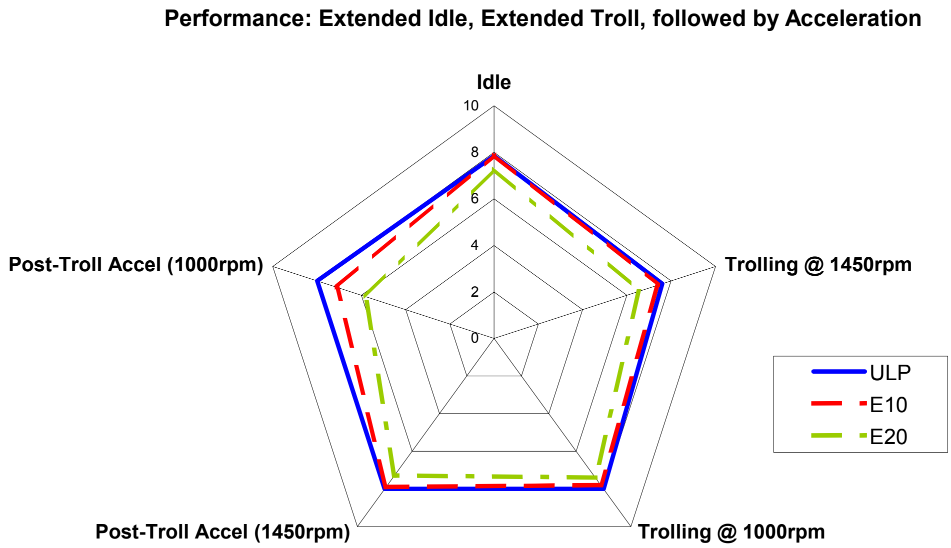


Figure 5.1.2 Radar Plot of Average Trolling Performance

Further insight can be gained by examining the max/min parameter ratings and individual ratings assigned for each of the ten engines. Figure 5.1.3 below identifies the maximum and minimum ratings awarded during the testing for the ULP and E20 fuel only. It was found that one engine running on E20 stalled on three of the five assessment parameters.

The best performing engines operating on E20 fuel were rated no differently to best performing engines operating on ULP fuel. This was also found to be the case with the engines while operating on the E10 fuel.

The data summary for individual engine ratings (see Table 5.1.4) shows that three engine out of the ten engines tested stall during the acceleration test that follows the extended 1000 rpm troll when operating on the E20 fuel blend, and one engine out of the ten stalled during the acceleration test that follows the extended 1450rpm troll.

One engine was found to stall upon acceleration demand following the extended 1000 rpm trolling test while operating on the E10 fuel blend.

All engines were rated as “8” upon acceleration demand following all extended trolling tests when operating on the ULP fuel.

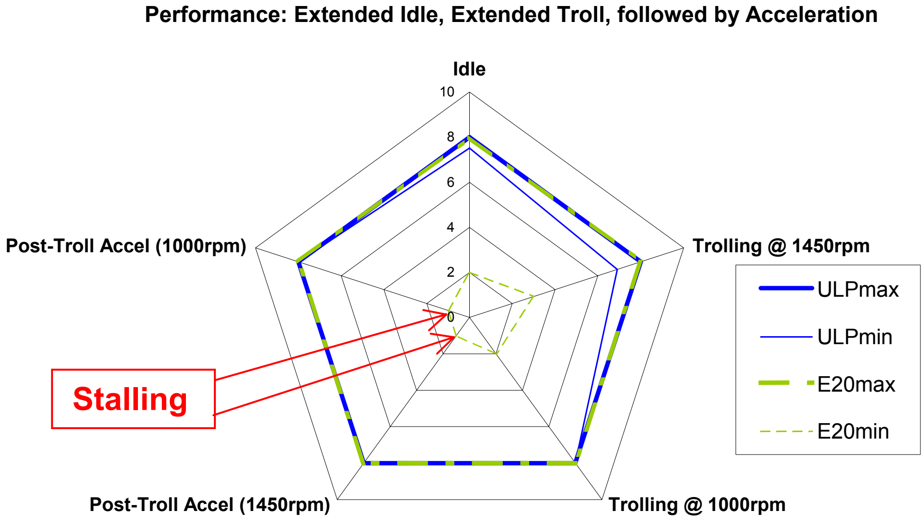


Figure 5.1.3 Radar Plot of Trolling Performance (max/min), ULP and E20 Fuels Only

A general increase in the frequency of misfires was noted on all engines tested during both the extended trolling tests when operating the engines on the ethanol fuel blends. The higher the misfire tendency during trolling, the lower the resulting awarded rating. Three engines out of the ten engines tested were rated at “5” or less due to the increased misfire tendency when operating on the E20 blend fuel while one engine was rated at “5” when operating on the E10 blend fuel.

A further impact of the E20 fuel blend was revealed during the trolling performance testing. One engine out of the ten tested was rated as “2” during the 1000 rpm troll test due to a high degree of difficulty in holding a constant engine speed when operating on the E20 blend fuel.

For the idle test, one engine out of the ten tested stalled during the idle test when operating on the E20 fuel blend, a rating of “2” was awarded as there was no change of engine state demanded.

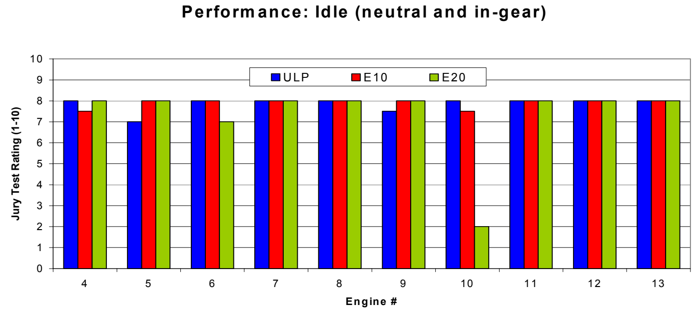
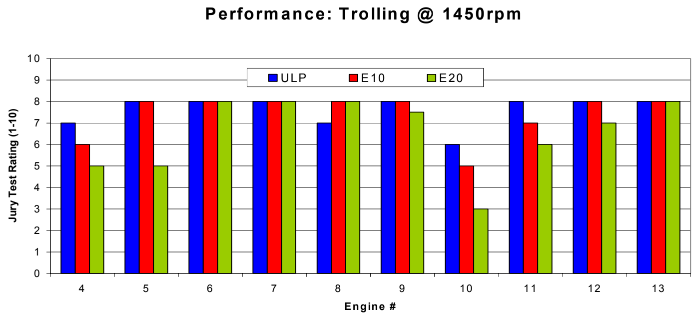
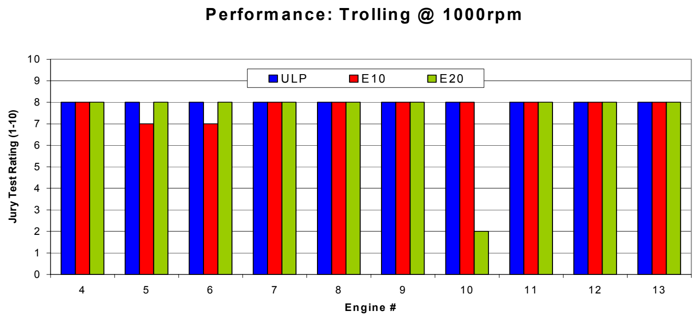
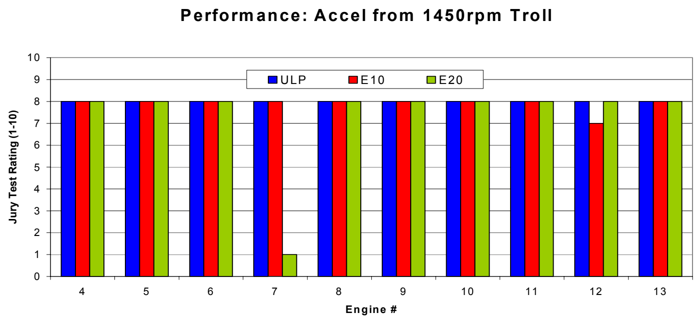
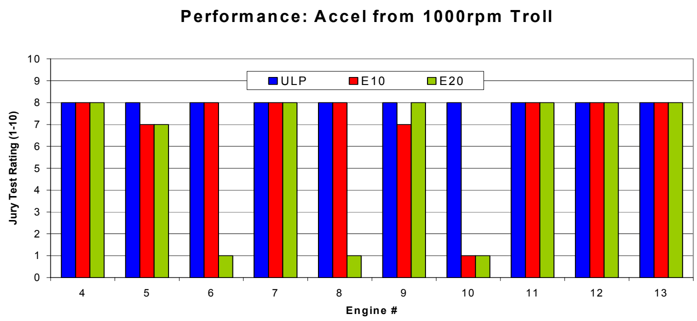
Individual Engine Ratings	# Rated less than "5"
	ULP = 0 E10 = 0 E20 = 1
	ULP = 0 E10 = 0 E20 = 1
	ULP = 0 E10 = 0 E20 = 1
	ULP = 0 E10 = 0 E20 = 1
	ULP = 0 E10 = 1 E20 = 3

Table 5.1.4 Individual Assessment Ratings – "Trolling Performance"

5.1.3 General Performance

General performance assessment was conducted via a series of tests where operating conditions were changed frequently so as to ensure that there was no extended pre-conditioning of the engine in any one particular mode. The steer/tilt tests were conducted so as to identify if engine orientation would highlight further short comings. The acceleration tests were performed during general boating rather than after an extended trolling period. As seen in Figure 5.1.4 the performance on all fuel types was generally consistent, with only one unrepeatable stall on engine AENME10 pulling the average rating for the engines down marginally when operating with the E20 fuel blend.

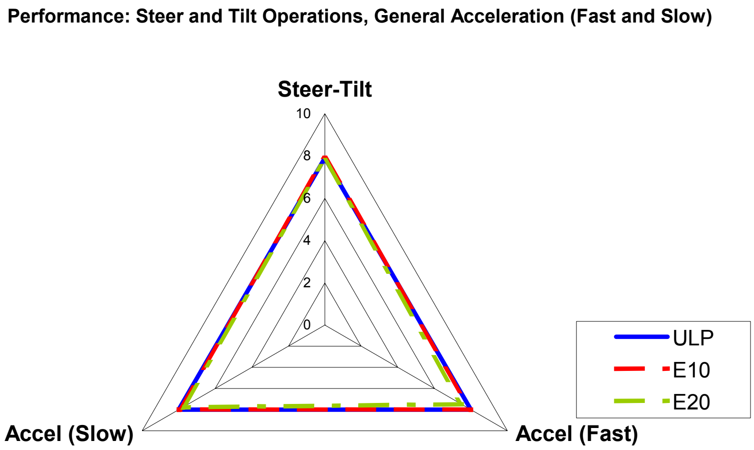


Figure 5.1.4 Radar Plot of General Performance

5.1.4 Tank “Run Dry” Assessment

Three consecutive tank “run dry” simulation tests were conducted with each fuel blend on each engine to ensure a reasonable data sample was gathered. The number of pulls to start the engine each time and a rating of idle and run performance after the start was recorded. The data is shown in Figure 5.1.5 and Figure 5.1.6. On average, startability as assessed by this test method was comparable for all fuel types with engines taking 1.25 pulls on average to start. Idle and run quality following the starts was rated between “7” and “8”, with no one engine operating on any fuel type exhibiting noteworthy performance degradation.

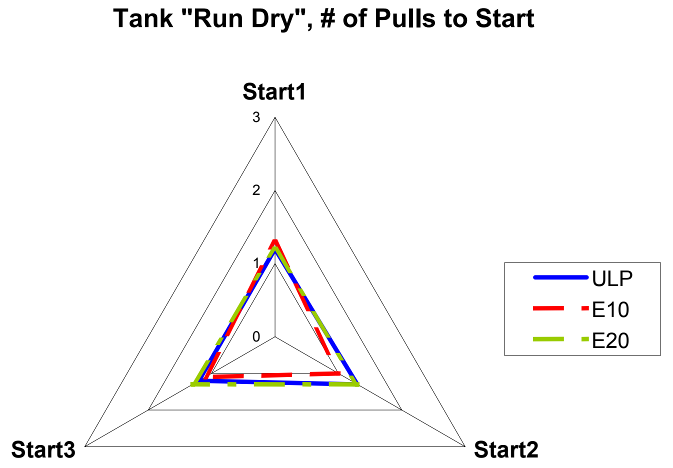


Figure 5.1.5 Tank “Run Dry” Startability Performance

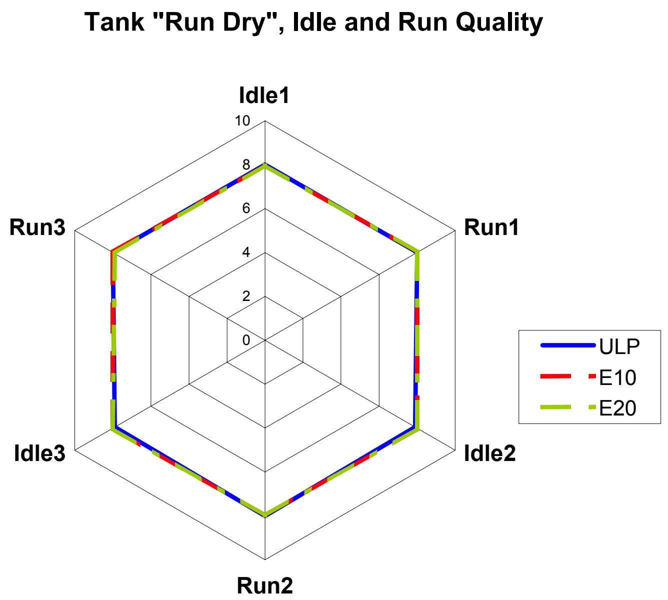


Figure 5.1.6 Tank “Run Dry” Post Start Idle and Run Performance

5.2 Discussion

This report summarises the results of the on-water driveability testing of ten Mercury 15hp outboard 2-stroke engines operating on gasoline only and two gasoline ethanol fuel blends of 10 and 20% by volume ethanol. The industry standard “Jury Test” subjective rating system was adopted as the assessment method.

Within the basic performance group of tests, all engines operating on all fuel types were assessed as at least fair (a “7” rating) or better indicating acceptable overall performance for this group of tests.

The performance group of tests where the greatest number and most significant impacts were identified was the trolling performance group. It is clear that the number and significance of the identified impacts increases with increasing ethanol content in the fuel. No trolling test parameter was rated less than “6” for any engine when operating on ULP fuel. When operating the ten engines on the E10 fuel blend, one engine had two assessment parameters rated at “5” or less with one rated with a “1”. The parameter receiving the “1” rating on this engine was the post 1000 rpm troll acceleration, due to engine stall. Statistically it can be shown with 95% confidence:

- Between 0.53 and 38.1% of the general engine population of this particular engine type will experience stalling upon demanding engine acceleration following an extended 1000rpm troll while operating on an E10 blend fuel.

No engine stalled upon acceleration demand following the 1450 rpm extended troll when operating on the E10 fuel blend.

When operating the engines with the E20 blend fuel, the frequency of impacts increased. Three of the ten engines tested stalled upon acceleration demand following the 1000 rpm extended troll test. Statistically it can be shown with 95% confidence:

- Between 9.4 and 58.7% of the general engine population of this particular engine type will experience stalling during the acceleration following an extended 1000rpm troll while operating on the E20 blend fuel.

The acceleration demand test following the 1450rpm extended troll test showed that one engine of the ten engines tested stalled when operated with the E20 fuel blend. This data indicates that the stalling characteristic upon acceleration demand following an extended troll is not confined to one engine speed. Statistically it can be shown with 95% confidence:

- Between 0.53 and 38.1% of the general engine population of this particular engine type will experience stalling upon demanding engine acceleration following an extended 1450rpm troll while operating on an E20 blend fuel.

Upon all engine stalls it was possible to restart immediately with one pull on the starter cable, accelerate and drive away.

A number of other low ratings were given to engine AENME10 along with engines AENME4 and AENME5 receiving borderline acceptance (rating “5”) for the trolling test at 1450 rpm when operating on the E20 blend fuel.

Within the general performance group of tests, all engines were found to perform with no detectable differences when running on the E10 fuel blend.

Only one engine stall on engine AENME10 was detected after the fast acceleration test once the engine was idling when running the engines on the E20 fuel blend. This stall was not repeatable and therefore this assessment parameter received a rating of “3”.

For the final two performance groups, Tank “Run Dry” Starting and Post Tank “Run Dry” Performance, all engines on all fuels performed such that no detectable performance differences were identified.

It appears most likely that the identified stalling characteristic along with the other impacts identified when operating the engines with ethanol fuel blends are due to a combination of degraded carburettor hot fuel handling capability (fuel volatility influence, see (2)) and enleanment related to the ethanol blend (enleanment, see (2)) producing an excessively weak or lean fuel air mixture which degrades normal engine operation, as associated with use of ULP fuel only.

The testing of engine AENME04 (carried over from the previous program) revealed it did not display the stalling characteristic upon demand of acceleration following the 1000 rpm extended troll while operating on the E20 fuel blend, as reported previously in (1). This engine was however rated with borderline acceptance for another trolling performance assessment parameter as described above. It should be noted that there was a significant difference in the ambient temperature conditions between the two test times. The initial test, as reported in (1), occurred at an ambient temperature of approximately 30 ^{o}C, while the test reported here occurred at an ambient temperature of approximately 23 ^{o}C. This temperature related behaviour is to be expected and is not a reflection of the robustness of the test. The effects of ambient conditions, particularly temperature and fuel volatility on hot engine operation is clearly described in (2).

6 Conclusions

Based on the outcome of the testing undertaken within the program of work designed to uncover and confirm the potential on-water driveability impacts of both a 10% and 20% by volume ethanol and gasoline fuel blend on this engine population, the following conclusions can be drawn:

In general there is little concern related to the impact of the E10 blend fuel, with all engines performing without detectable differences to the ULP fuel performance on a significant majority of the assessment parameters. Within the trolling performance group of tests however, ethanol related impacts begin to be identified. A stall was identified on one engine out of the ten engines tested and hence statistically it can be shown with 95% confidence that between 0.53 and 38.1% of the general population of this particular engine type will experience stalling upon demanding engine acceleration following an extended 1000 rpm troll.

The testing outcome shows the number and the range of impacts identified increases when the engines are operated on the E20 fuel blend. The stalling characteristic upon demanding engine acceleration was found to occur following the trolling test at both engine speeds tested. Statistically it can be shown with 95% confidence that between 0.53 and 38.1% of the general population of this particular engine will experience stalling upon demand of engine acceleration following an extended 1450 rpm troll. For the acceleration demand following the 1000 rpm troll, statistically at a 95% confidence level, between 9.4 and 58.7% of the general population of this particular engine type will experience stalling. This engine stall characteristic blend presents the potential to impact on reliable engine operation. All engines that stalled could be restarted immediately upon operation of the starting mechanism allowing the engine to accelerate the boat.

In general, there was a degradation of engine performance with ethanol fuel blends particularly within the trolling group of tests. The degradation increased with increasing ethanol content in the fuel. Engine misfire frequency increased and engine stalls occurred while operating the engine on the both E10 and E20 fuel blends. There was difficulty in maintaining boat speed during trolling when operating the engine with the E20 fuel blend.

7 References.

1. Orbital Engine Company, 2003. “A Testing Based Assessment to Determine Impacts of a 10% and 20% Ethanol Gasoline Fuel Blend on Non-Automotive Engines”
2. Orbital Engine Company, 2002. “A Literature Review Based Assessment on the Impacts of a 10% and 20% Ethanol Gasoline Fuel Blend on Non-Automotive Engines”
3. Orbital Engine Company, 2002. “A Technical Assessment of E10 and E20 Petrol Ethanol Blends Applied to Non-Automotive Engines. Failure Mode and Effects Analysis of Engine Function and Component Design for Mercury Marine 15hp Outboard and Stihl FS45 Line-Trimmer Engines”
4. Orbital Engine Company Tender No. 34/2002 “Market Barriers to the Uptake of Biofuels Study – Testing Petrol Containing 20% Ethanol”
5. Environment Australia, 2002. “Setting the Ethanol Limit in Petrol. An Issues Paper”
6. CSR Chemicals Ltd, 1983, “Enhanced Extension of Petrol with Aqueous Alcohol”, National Energy Research Development and Demonstration Council (NERDDC) Project 81/1432, Final Report.
7. Apace Research, 1998, “Intensive Field Trial of Ethanol/Petrol Blend in Vehicles”, Energy Research and Development Corporation (ERDC 339), Project No. 2511.
8. Engineering statistics 2nd Edition, Bowker, Albert Hosmer and Lieberman Gerald J., Prentice-Hall, Inc. (1972),ISBN 0-13-279455-1
9. Mercury Marine, Fond du Lac, Wisconsin USA, 2002. “Outboard Operation, Maintenance & Warranty Manual”.

8 Acronyms

EA	Environment Australia
E10	Gasoline blended with 10 % Ethanol by volume
E20	Gasoline blended with 20 % Ethanol by volume
MSDS	Material Safety Data Sheet
rpm	revolutions per minute (engine speed)
ULP	Unleaded Petrol
WOT	Wide Open Throttle

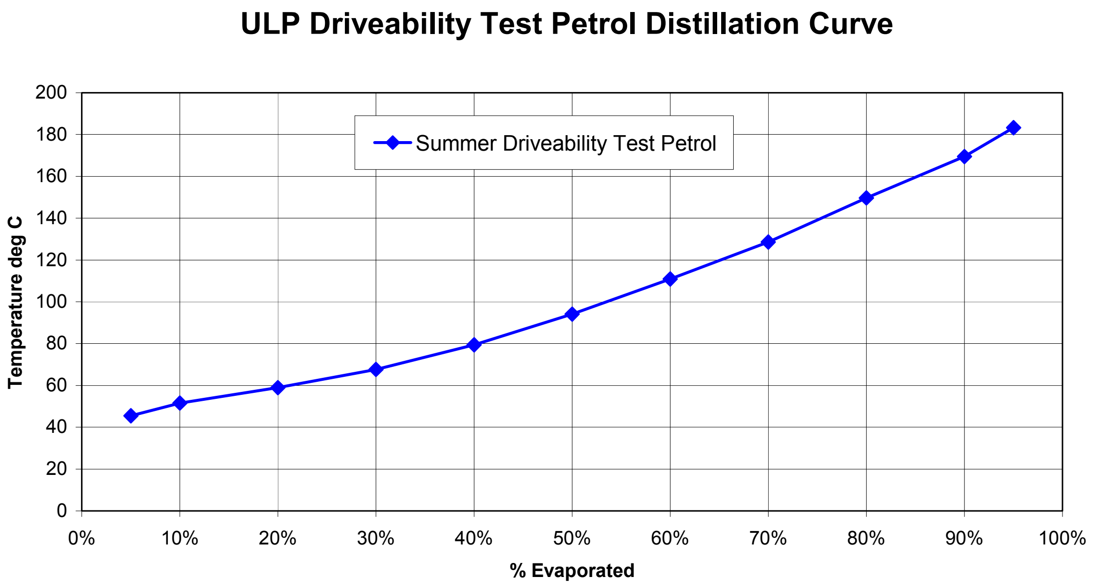
Appendix A

Test Fuel Data / Reports

Attachments:

1. Fuel data
2. ULP Test Fuel Distillation Curve
3. CSR Ethanol Product Specification
4. Orbital Test Fuel Density and Ethanol Concentrations

Caltex driveability test petrol		
Property	**Result ULP**	**Method**
Density @ 15 deg C kg/l	0.7358	ASTM D4052
Distillation		ASTM D86
IBP	32.4	
5%	45.5	
10%	51.5	
20%	58.9	
30%	67.6	
40%	79.4	
50%	94.1	
60%	110.9	
70%	128.6	
80%	149.7	
90%	169.5	
95%	183.3	
EP	212.6	
Residue %	1.1	
Benzene, Vol %	0.41	LM301
Oxygen	-	
Existent Gum, mg/l	8	ASTM D381
Motor Octane Number	81.4	ASTM D2700
Research Octane Number	91.2	ASTM D2699
Reid Vapour Pressure, 37.8 deg C, kPa	62	ASTM D323



FOR FURTHER INFORMATION CONTACT:
CSR LIMITED - YARRAVILLE DISTILLERY
265 WHITEHALL ST
YARRAVILLE VICTORIA 3013
PHONE: 1800 819 618
FAX: 1800 647 260
ABN: 90 000 001 276

PRODUCT SPECIFICATION SHEET ETHANOL
100 Fuel Grade
(Special Methylated Spirits)

CODE
100SGF21

CAS Number: 64-17-5

PARAMETER	TEST METHOD	SPECIFICATION LIMIT
DESCRIPTION	BP73 & BP98	Clear colourless liquid free from matter in suspension and apart from water consisting essentially of ethanol.
STRENGTH	BP73 & BP98	99.4% (min.) ethanol v/v at 20°C
WATER CONTENT	CSR AP-09-27	1.0% by weight (max.)
ALKALINITY	BP98	Alkalinity to Phenolphthalein - Nil
ACIDITY	BP73 & BP98	0.005% by weight (max.) as acetic acid.
CLARITY OF SOLUTION	BP98	Sample diluted in the ratio 1:19 with water remains clear
ALDEHYDES & KETONES	BP73	100ppm as Acetaldehyde (max.)
REDUCING SUBSTANCES	BP73	10 minutes (min.)
NON-VOLATILE MATTER	BP98	0.005% mg/100ml (max.)
OTHER ALCOHOLS	BP73	Passes Test

Tests are carried out in accordance with the requirements of British Pharmacopoeia 1973 and British Pharmacopoeia 1998.
Safe handling information for this product can be obtained from the MSDS.
Product is manufactured under a certified Quality System.

FORMULA	**DENATURANT**	**SPECIFIC GRAVITY (Max @ 20°C)**	**CONCENTRATION (Nominal)**
F21	Unleaded Petrol	0.793	1% v/v

Special Methylated Spirits is ethanol which has been denatured in accordance with Regulations under the Spirits Act.

**SPECIFICATIONS WITH RED TEXT BOXES ARE CONTROLLED COPIES. BLACK TEXT BOXES ARE UNCONTROLLED COPIES
THE LATEST ISSUE CAN BE OBTAINED UPON REQUEST**

Orbital Test Fuel Density and Ethanol Concentrations

Date	Fuel Type	OEC Fuel #	S.G. @ 20degrees C	Measured Ethanol Concentration (%)
	OPERABILITY FUEL			
	Ethanol	34	0.797	
6/01/2003	Summer ULP batch #2	20	0.738317	-
14/01/2003	Summer ULP E10	26	0.745688	9.82
14/01/2003	Summer ULP E20	21	0.748005	20.1
	RUN-IN FUEL			
6/01/2003	Perth ULP	3	0.745	-

Appendix B

Tabulation of All Test Ratings

Attachments:

1. ULP Test Ratings (10 engines)
2. E10 Test Ratings (10 engines)
3. E20 Test Ratings (10 engines)

ULP Fuel Tests

		Performance Tests													Tank "Run-dry" Simulation									Tank "Run-dry"		
Engine #	Fuel Type	Docking / Manoeuvring	Fast Shift	Vibration	Smoke	Noise	Idle	Trolling @ 1450rpm	Trolling @ 1000rpm	Post-Troll Accel (1450rpm)	Post-Troll Accel (1000rpm)	Steer-Tilt	Accel (Fast)	Accel (Slow)	Start1 (demerit)	Idle1	Run1	Start2 (demerit)	Idle2	Run2	Start3 (demerit)	Idle3	Run3	Start1, # pulls	Start2, # pulls	Start3, # pulls
4	ulp	10.0	10.0	7.0	8.0	7.0	8.0	7.0	8.0	8.0	8.0	7.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	1	1	1
5	ulp	10.0	10.0	8.0	7.0	7.0	7.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	1	1	1
6	ulp	10.0	10.0	8.0	8.0	7.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	1	1	1
7	ulp	10.0	10.0	8.0	8.0	7.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	-2.0	8.0	8.0	-1.0	8.0	8.0	-1.0	7.0	8.0	3	2	2
8	ulp	10.0	10.0	8.0	8.0	7.0	8.0	7.0	8.0	8.0	8.0	8.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	1	1	1
9	ulp	10.0	10.0	7.0	8.0	7.0	7.5	8.0	8.0	8.0	8.0	8.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	1	1	1
10	ulp	10.0	10.0	8.0	8.0	7.0	8.0	6.0	8.0	8.0	8.0	8.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	-1.0	8.0	8.0	1	1	2
11	ulp	10.0	10.0	8.0	8.0	7.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	0.0	8.0	8.0	-1.0	7.0	8.0	0.0	8.0	8.0	1	2	1
12	ulp	10.0	10.0	8.0	8.0	7.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	1	1	1
13	ulp	10.0	10.0	8.0	8.0	7.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	0.0	8.0	8.0	-1.0	8.0	8.0	0.0	8.0	8.0	1	2	1
Average		10.0	10.0	7.8	7.9	7.0	7.9	7.6	8.0	8.0	8.0	7.9	8.0	8.0	-0.2	8.0	8.0	-0.3	7.9	8.0	-0.2	7.9	8.0	1.2	1.3	1.2
Stdev		0.0	0.0	0.4	0.3	0.0	0.3	0.7	0.0	0.0	0.0	0.3	0.0	0.0	0.6	0.0	0.0	0.5	0.3	0.0	0.4	0.3	0.0	0.6	0.5	0.4
Max		10.0	10.0	8.0	8.0	7.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	3.0	2.0	2.0
Min		10.0	10.0	7.0	7.0	7.0	7.0	6.0	8.0	8.0	8.0	7.0	8.0	8.0	-2.0	8.0	8.0	-1.0	7.0	8.0	-1.0	7.0	8.0	1.0	1.0	1.0

E10 Fuel Tests

		Performance Tests													Tank "Run-dry" Simulation									Tank "Run-dry"		
Engine #	Fuel Type	Docking / Manoeuvring	Fast Shift	Vibration	Smoke	Noise	Idle	Trolling @ 1450rpm	Trolling @ 1000rpm	Post-Troll Accel (1450rpm)	Post-Troll Accel (1000rpm)	Steer-Tilt	Accel (Fast)	Accel (Slow)	Start1 (demerit)	Idle1	Run1	Start2 (demerit)	Idle2	Run2	Start3 (demerit)	Idle3	Run3	Start1, # pulls	Start2, # pulls	Start3, # pulls
4	e10	10.0	10.0	7.0	8.0	7.0	7.5	6.0	8.0	8.0	8.0	7.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	1	1	1
5	e10	10.0	10.0	8.0	8.0	7.0	8.0	8.0	7.0	8.0	7.0	8.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	1	1	1
6	e10	10.0	10.0	8.0	8.0	7.0	8.0	8.0	7.0	8.0	8.0	8.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	1	1	1
7	e10	10.0	10.0	8.0	8.0	7.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	1	1	1
8	e10	10.0	10.0	8.0	8.0	7.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	-3.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	4	1	1
9	e10	10.0	10.0	8.0	7.5	7.0	8.0	8.0	8.0	8.0	7.0	8.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	1	1	1
10	e10	10.0	10.0	8.0	8.0	7.0	7.5	5.0	8.0	8.0	1.0	8.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	1	1	1
11	e10	10.0	10.0	8.0	8.0	7.0	8.0	7.0	8.0	8.0	8.0	8.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	1	1	1
12	e10	10.0	10.0	8.0	8.0	7.0	8.0	8.0	8.0	7.0	8.0	8.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	-1.0	8.0	8.0	1	1	2
13	e10	10.0	10.0	8.0	8.0	7.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	1	1	1
Average		10.0	10.0	7.9	8.0	7.0	7.9	7.4	7.8	7.9	7.1	7.9	8.0	8.0	-0.3	8.0	8.0	0.0	8.0	8.0	-0.1	8.0	8.0	1.3	1.0	1.1
Stdev		0.0	0.0	0.3	0.2	0.0	0.2	1.1	0.4	0.3	2.2	0.3	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.9	0.0	0.3
Max		10.0	10.0	8.0	8.0	7.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	4.0	1.0	2.0
Min		10.0	10.0	7.0	7.5	7.0	7.5	5.0	7.0	7.0	1.0	7.0	8.0	8.0	-3.0	8.0	8.0	0.0	8.0	8.0	-1.0	8.0	8.0	1.0	1.0	1.0

E20 Fuel Tests

		Performance Tests													Tank "Run-dry" Simulation									Tank "Run-dry"		
Engine #	Fuel Type	Docking / Manoeuvring	Fast Shift	Vibration	Smoke	Noise	Idle	Trolling @ 1450rpm	Trolling @ 1000rpm	Post-Troll Accel (1450rpm)	Post-Troll Accel (1000rpm)	Steer-Tilt	Accel (Fast)	Accel (Slow)	Start1 (demerit)	Idle1	Run1	Start2 (demerit)	Idle2	Run2	Start3 (demerit)	Idle3	Run3	Start1, # pulls	Start2, # pulls	Start3, # pulls
4	e20	10.0	8.0	7.0	8.0	7.0	8.0	5.0	8.0	8.0	8.0	7.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	7.0	1	1	1
5	e20	10.0	10.0	8.0	8.0	7.0	8.0	5.0	8.0	8.0	7.0	7.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	1	1	1
6	e20	10.0	10.0	8.0	8.0	7.0	7.0	8.0	8.0	8.0	1.0	8.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	1	1	1
7	e20	10.0	10.0	8.0	8.0	7.0	8.0	8.0	8.0	1.0	8.0	8.0	8.0	8.0	-1.0	8.0	8.0	-2.0	8.0	8.0	-3.0	8.0	8.0	2	3	4
8	e20	10.0	10.0	8.0	8.0	7.0	8.0	8.0	8.0	8.0	1.0	8.0	8.0	8.0	-1.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	2	1	1
9	e20	10.0	10.0	8.0	8.0	7.0	8.0	7.5	8.0	8.0	8.0	8.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	1	1	1
10	e20	10.0	10.0	8.0	8.0	7.0	2.0	3.0	2.0	8.0	1.0	8.0	3.0	6.0	0.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	1	1	1
11	e20	10.0	10.0	8.0	8.0	7.0	8.0	6.0	8.0	8.0	8.0	8.0	8.0	8.0	0.0	8.0	8.0	-1.0	8.0	8.0	0.0	8.0	8.0	1	2	1
12	e20	10.0	10.0	8.0	8.0	7.0	8.0	7.0	8.0	8.0	8.0	8.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	1	1	1
13	e20	10.0	10.0	8.0	8.0	7.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	1	1	1
Average		10.0	9.8	7.9	8.0	7.0	7.3	6.6	7.4	7.3	5.8	7.8	7.5	7.8	-0.2	8.0	8.0	-0.3	8.0	8.0	-0.3	8.0	7.9	1.2	1.3	1.3
Stdev		0.0	0.6	0.3	0.0	0.0	1.9	1.7	1.9	2.2	3.3	0.4	1.6	0.6	0.4	0.0	0.0	0.7	0.0	0.0	0.9	0.0	0.3	0.4	0.7	0.9
Max		10.0	10.0	8.0	8.0	7.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	0.0	8.0	8.0	2.0	3.0	4.0
Min		10.0	8.0	7.0	8.0	7.0	2.0	3.0	2.0	1.0	1.0	7.0	3.0	6.0	-1.0	8.0	8.0	-2.0	8.0	8.0	-3.0	8.0	7.0	1.0	1.0	1.0

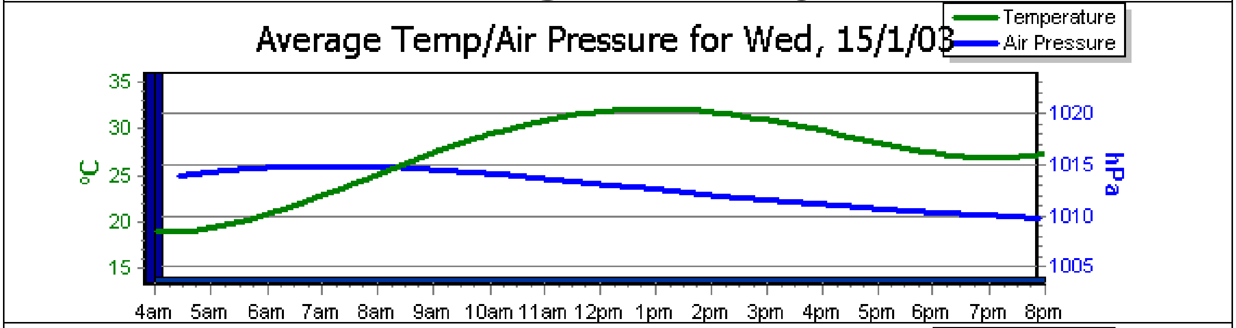
Appendix C

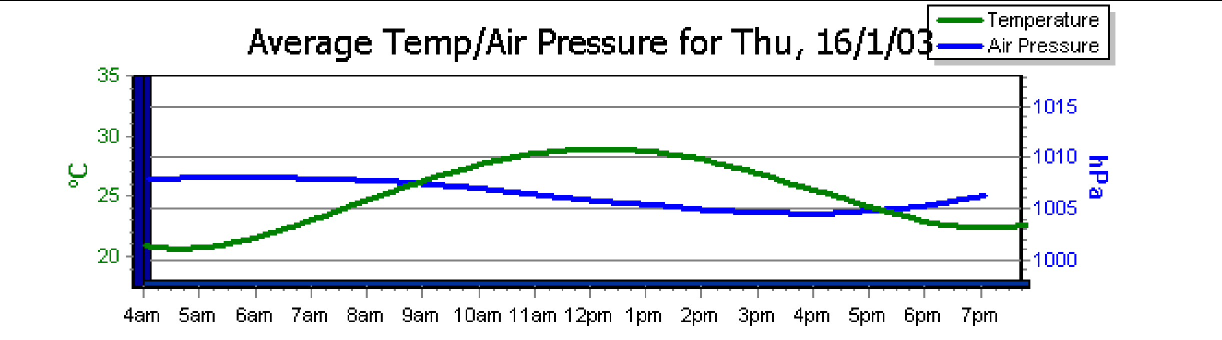
Perth Weather and Water Conditions on various Test Days

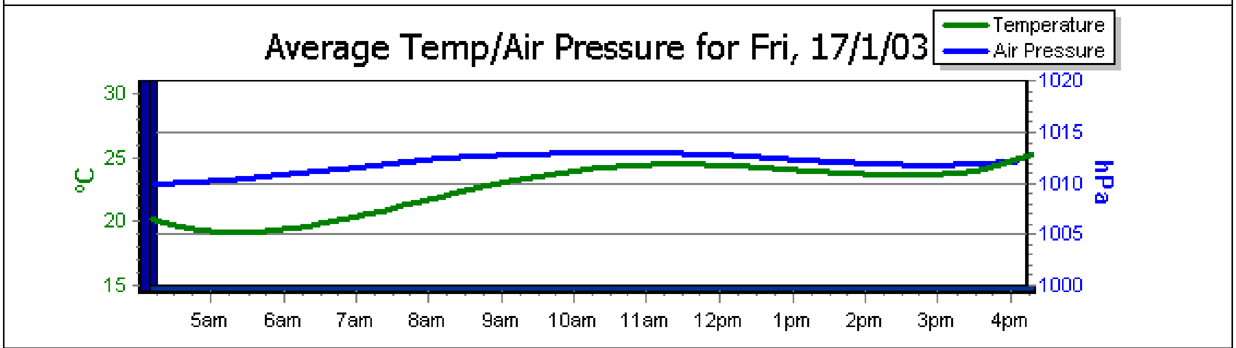
Attachments:

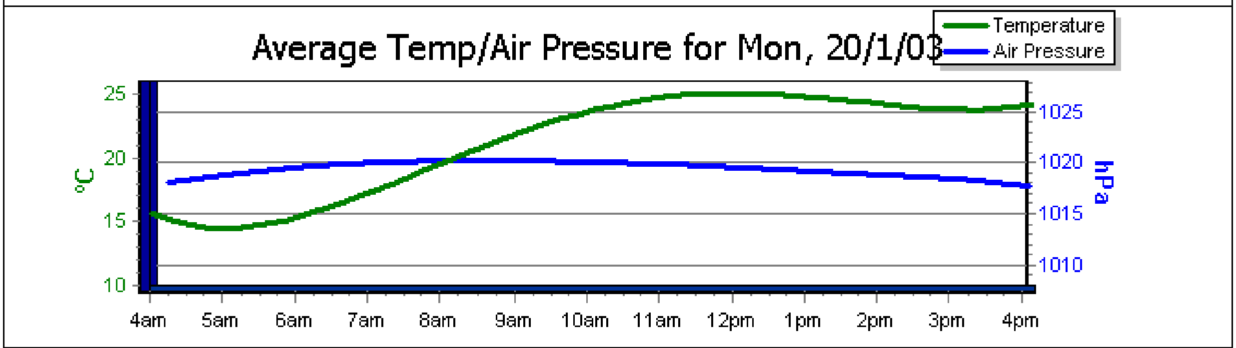
1. Daytime Air Temperature and Pressure Data
2. Typical Wind Conditions (Melville Water data used)

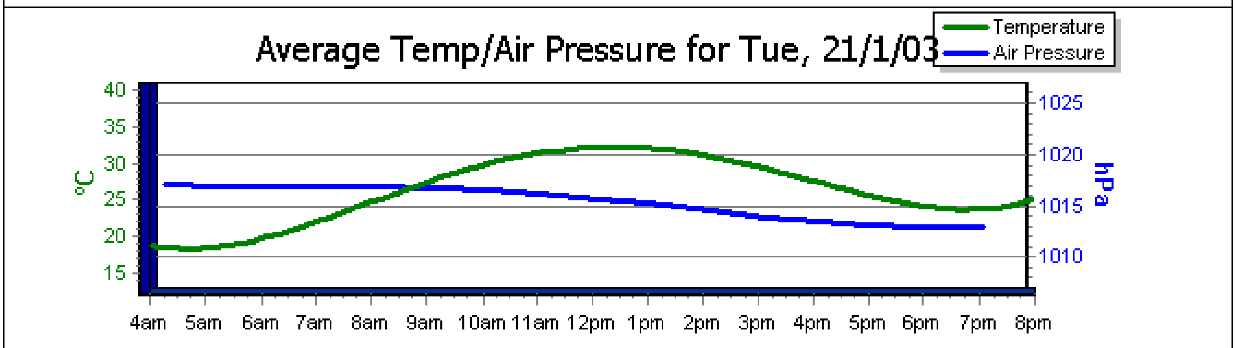
Air Pressure and Temperature During Test Days

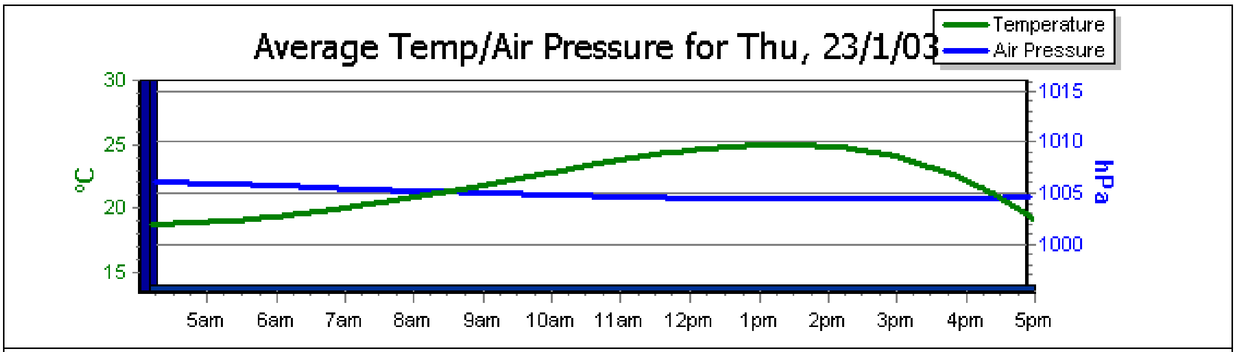


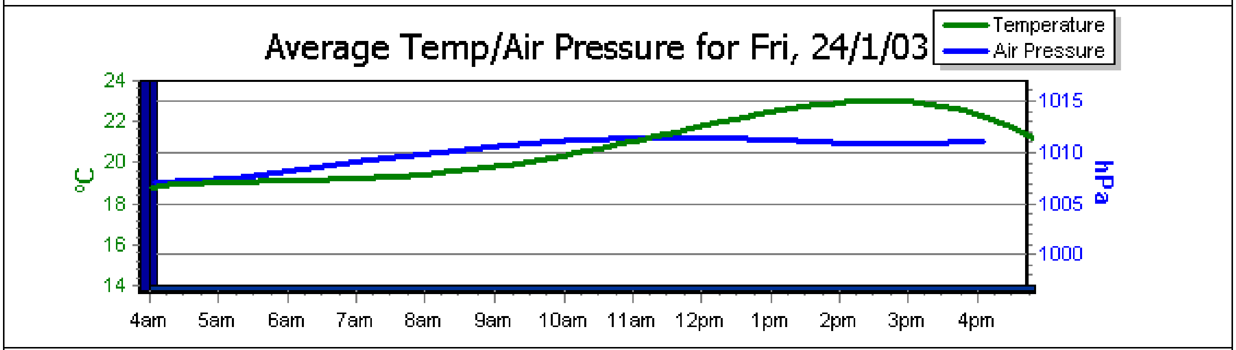


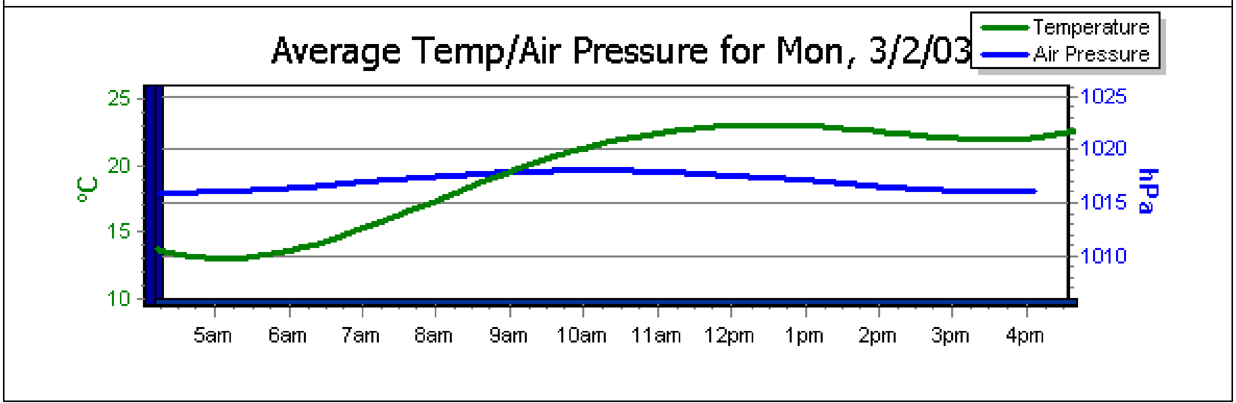






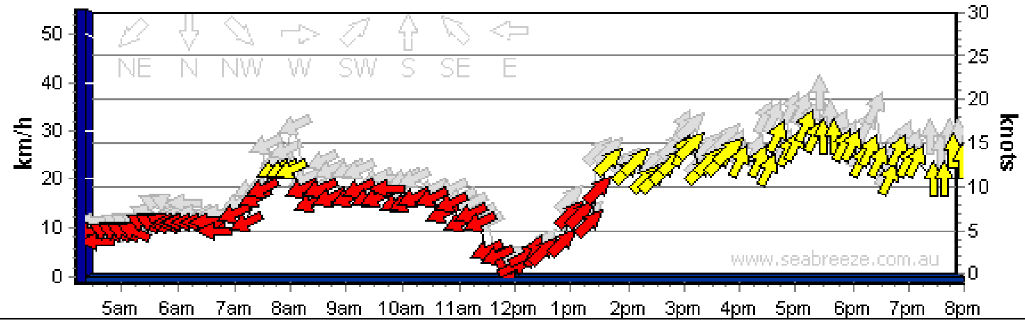

Average Temp/Air Pressure for Thu, 23/1/03
Temperature
Air Pressure
°C
30
25
20
15
hPa
1015
1010
1005
1000
5am
6am
7am
8am
9am
10am
11am
12pm
1pm
2pm
3pm
4pm
5pm


Average Temp/Air Pressure for Fri, 24/1/03
Temperature
Air Pressure
°C
24
22
20
18
16
14
hPa
1015
1010
1005
1000
4am
5am
6am
7am
8am
9am
10am
11am
12pm
1pm
2pm
3pm
4pm

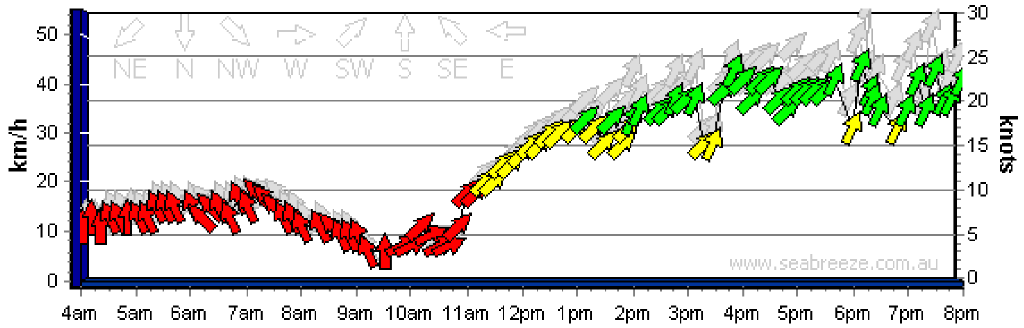

Average Temp/Air Pressure for Mon, 3/2/03
Temperature
Air Pressure
°C
25
20
15
10
hPa
1025
1020
1015
1010
5am
6am
7am
8am
9am
10am
11am
12pm
1pm
2pm
3pm
4pm

Typical Wind Conditions During Test Days

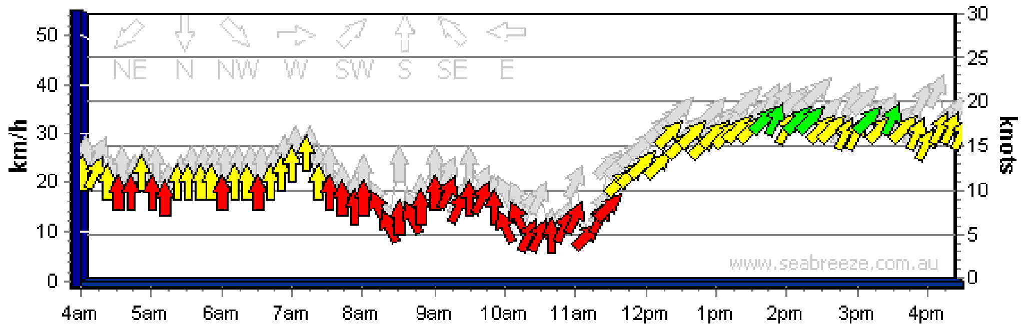
MELVILLE WATER for Wednesday, 15/1/03



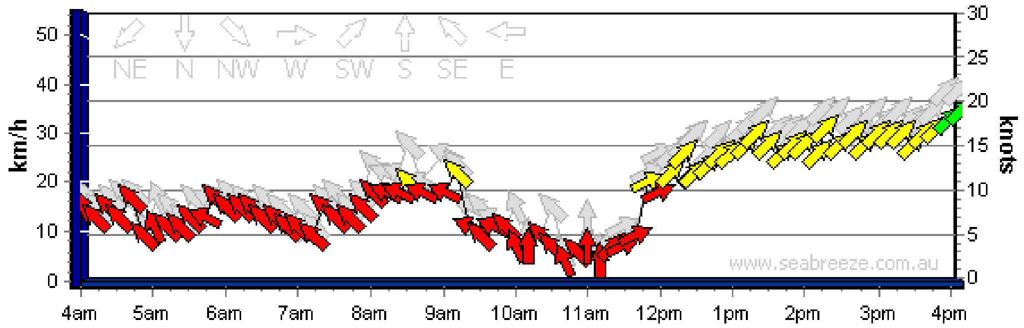
MELVILLE WATER for Thursday, 16/1/03

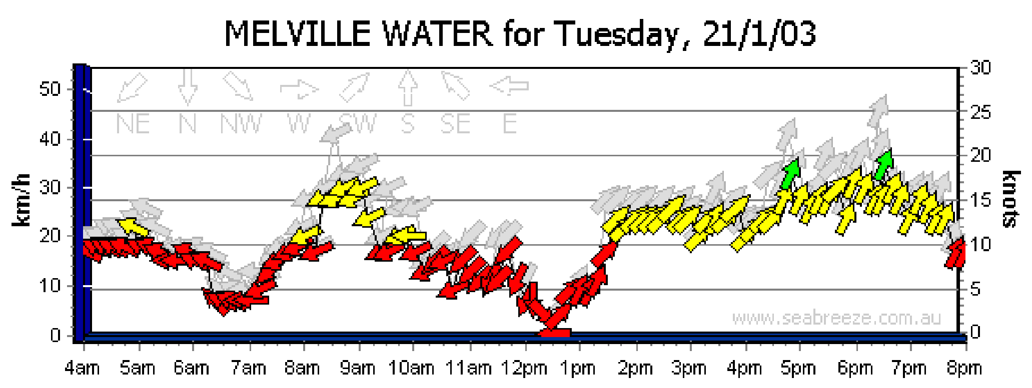


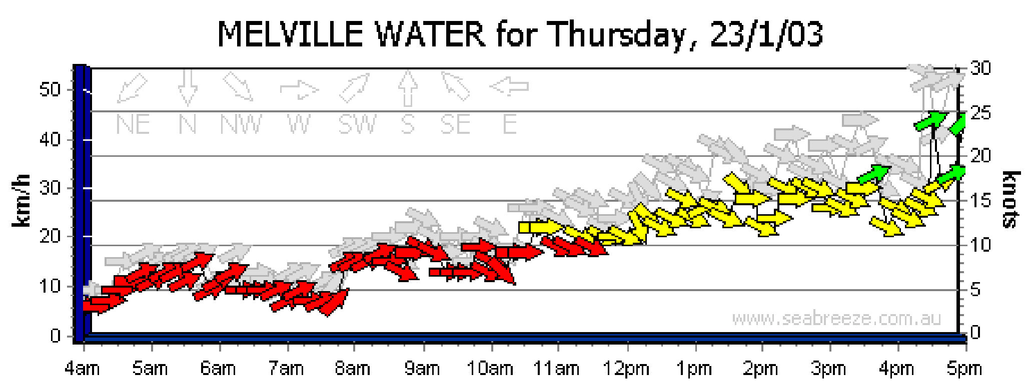
MELVILLE WATER for Friday, 17/1/03

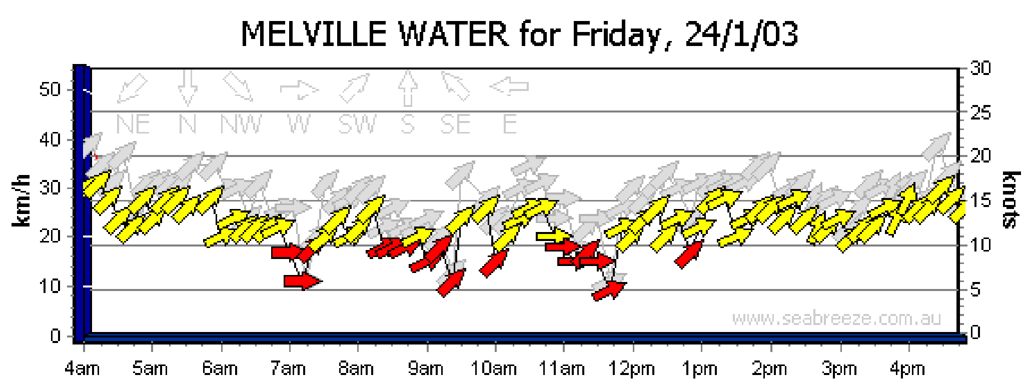


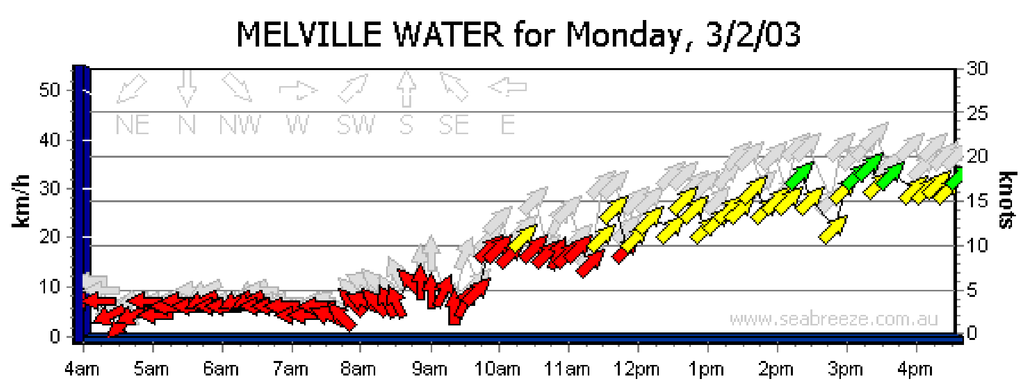
MELVILLE WATER for Monday, 20/1/03




MELVILLE WATER for Tuesday, 21/1/03
km/h
knots
NE N NW W SW S SE E
0 10 20 30 40 50
0 5 10 15 20 25 30
4am 5am 6am 7am 8am 9am 10am 11am 12pm 1pm 2pm 3pm 4pm 5pm 6pm 7pm 8pm
www.seabreeze.com.au


MELVILLE WATER for Thursday, 23/1/03
km/h
knots
NE N NW W SW S SE E
0 10 20 30 40 50
0 5 10 15 20 25 30
4am 5am 6am 7am 8am 9am 10am 11am 12pm 1pm 2pm 3pm 4pm 5pm
www.seabreeze.com.au


MELVILLE WATER for Friday, 24/1/03
km/h
knots
NE N NW W SW S SE E
0 10 20 30 40 50
0 5 10 15 20 25 30
4am 5am 6am 7am 8am 9am 10am 11am 12pm 1pm 2pm 3pm 4pm
www.seabreeze.com.au


MELVILLE WATER for Monday, 3/2/03
km/h
knots
NE N NW W SW S SE E
0 10 20 30 40 50
0 5 10 15 20 25 30
4am 5am 6am 7am 8am 9am 10am 11am 12pm 1pm 2pm 3pm 4pm
www.seabreeze.com.au