

ZORK V1 Closure

Independent Analysis

of

**Provisor Trial at
Thirty-eight Months**

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Revised 11 December, 2008

Executive Summary

Provisor was engaged by ZORK as a Third Party testing agency to conduct a comprehensive independent assessment of the ZORK closure. The trial work was conducted on bottles of Yalumba 2003 Pewsey Vale Riesling, sealed with ZORK V1 and ROTE (screw-cap) closure at Yalumba's Angaston bottling facility on March 24th, 2004. This document summarises the progress of work, and interpretation of the results of analysis of the wines, during the first 38 months (1143 days) following bottling. It also describes the outcome of Oxygen Transfer Rate (OTR) analysis conducted during mid-2008 on the current 'STL' closure.

All analysis was conducted according to procedures outlined in the Standard Measurement Protocols for the trial. Key closure performance results are:

SO₂	<p>The concentration of free and total SO₂ initially decreased more rapidly immediately after bottling in wines sealed with ZORK V1 than with screw-cap, and according to data generated in other studies, than wines sealed with 'Reference 2' cork closures. This is attributed to the oxygen present inside the plunger of ZORK V1 closures.</p> <p>After this initial drop, the rate of decline of free and total SO₂ in the wine sealed with ZORK V1 has been consistently slightly higher than that sealed with screw-cap.</p> <p>This work indicates that ZORK V1 offers a shelf-life of approximately 3.7 years. This may be extended by increasing the initial concentration of SO₂ in the wine. Depending on the composition of the wine (principally pH), such an increase may require a short period of storage prior to commercial release to reduce the sensory effect of an elevated concentration of SO₂.</p> <p>The expected shelf life of wine sealed with the ZORK V5 is 4.2 years. This increase has resulted from the reduction in the volume of air contained in the plunger.</p>
Sensory	<p>Sensory analysis was not repeated on this analysis occasion. The results are therefore unchanged from those reported on 30 March 2007, after 24 months of storage.</p> <p>At that stage, there were specific differences between the wines sealed with ZORK V1 and screw-cap. After 24 months, the only trends (defined as the observation of a significant difference between the wines on at least 3 consecutive occasions) were the ongoing observation of a "Flint/rubber" aroma in wine sealed with screw-cap (a consistent trend over a period exceeding 18 months); and the observation of higher "Acidity" on the palate of these wines.</p> <p>The general observation was that the wines sealed under screw-cap exhibit some characters consistent with 'reductive development', and those sealed with ZORK V1, 'oxidative development'. These observations were consistent with the technical performance of the closure systems (eg oxygen transmission rate; OTR), and the composition of the wines.</p> <p>There was no evidence to suggest that either closure has caused the introduction of a taint, nor removed wine aroma or flavour (scalping).</p>
OTR	<p>OTR measurements are normally conducted on a <i>Moccon</i> brand instrument, in which a sensor measures the amount of oxygen passing through or past the system under test, which may be challenged by air, or pure oxygen. As air contains approximately 21% oxygen, results of systems challenged with air must be mathematically corrected to allow comparison with those using oxygen. Results in this document are expressed as mL <u>100%</u> O₂/day.</p> <p>The OTR was measured only to the 6-month stage of the principal trial. To that point, it was 0.015 mL O₂/day for the ZORK V1.</p> <p>Subsequent to the completion of the primary trial, further OTR analysis was conducted in mid-2008 on the current ZORK STL closure by Gunn Labs, in New Zealand.</p> <p>This showed a mean OTR of 0.011 mL O₂/day; lower than previously reported, and also lower (& with lower standard deviation) than published values for natural cork.</p>

Insertion	On a previous analysis occasion, 100% of the closures tested were properly inserted onto the bottles.
Temperature	On a previous analysis occasion, ZORK V1 failed the elevated temperature test. However, 100% of bottles sealed with ZORK V3 showed no wine loss when heated to 40°C for 8 hours in a subsequent trial. ZORK V5 should behave similarly. All bottles sealed with ZORK V1 and screw-cap leaked when frozen. The ZORK-sealed closures remained intact despite these conditions. The screw-cap closures had visible damage, and the majority were partially removed from the bottle.
Closure version changes	Since the initiation of this trial there have been 4 improvements of the closure. The recently-released V5 has three small vertical vents in the side of the plunger. This was done to reduce the likelihood of the ZORK 'stopper' (i.e. the outer cap and plunger, after the tamper-proof tear band is removed) pushing out when reinserted into a bottle of wine which is nearly full, or contains considerable CO ₂ .



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1. BACKGROUND

Provisor Pty Ltd was engaged by ZORK Pty Ltd to conduct a comprehensive independent assessment of the performance of the ZORK Production version 1 (ZORK V1) closure. The results of the testing and analysis conducted on several occasions have been provided to ZORK. The most recent round of analysis included the key indicators of bottled wine shelf-life: free and total SO₂, and OD₄₂₀.

This document is an Executive Summary of the Provisor report, with additional explanatory and interpretive comments provided by Peter Leske. With 25 years experience in the wine industry, including five at The Australian Wine Research Institute as Manager of the Technical Services Group, Peter is qualified to independently audit, summarise and interpret the work. The Provisor report summarises and describes the experimental protocol, bottling plant method and analytical methods, and should be referred to for more details of the above, comprehensive analysis of the data.

Bottles of Yalumba Wine Company 2003 Pewsey Vale Riesling were sealed either with ZORK V1 or screw-cap (Pechiney *Stelvin*®) closures, at the Yalumba Wines bottling plant on March 24th, 2004. The bottling line included the 'Snow-drop' inert gas delivery system, in which a small amount of dry ice (solid CO₂) is applied to the headspace above the wine immediately after filling and before sealing. While not standard practice in the Australian wine industry, the technology has been used at Yalumba for many years and is regarded as being a highly effective means of reducing the quantity of oxygen included in the bottle at the moment of sealing. It thus offered the advantage of potentially reducing a variable that might interfere with the result of the trial: dissolved oxygen included in the bottles at filling.

The 'Snow-drop' system was used for both ZORK V1 and screw-cap closure systems. However, as the bottling line was designed for commercial-scale automatic dispensing and application of screw-cap closures, the application of ZORK V1 closures was semi-automatic.

In response to several performance issues highlighted by this work, certain elements of the ZORK V1 closure were redesigned. In both versions ZORK V2 and V3, changes were made to the tamper-evident tear-tab and plunger. In V4, the plunger was again modified to cope with variation in bottle bore dimensions; and in V5, three small vertical vents were added to the side of the plunger. This was done to reduce the likelihood of the ZORK 'stopper' (*i.e. the outer cap and plunger, after the tamper-proof tear band is removed*) pushing out when reinserted into a bottle of wine which is nearly full, or contains considerable CO₂.

The current version ZORK is V5, now known as the 'STL'.

Figure 1 – Details of the physical differences between versions of ZORK closures

CHARACTERISTIC	VERSION				
	ZORK V1	ZORK V2	ZORK V3	ZORK V4	ZORK V5 ('STL')
					
Plunger internal vol (mL)	7.50	7.54	6.26	6.26	6.26
Tear tab orientation	Vertical	Horizontal	Horizontal	Horizontal	Horizontal
Tear tab size (°)	540	720	900	900	900
Plunger size/shape	Long, pointed	Long, blunt	Short, blunt	Short, blunt	Short, blunt
Plunger diameter (mm)	20.0	20.0	20.0	20.5	20.5
External grip	None	None	None	8	8
Surface finish of cap	Gloss	Gloss	Satin	Satin	Satin
Plunger vents	No	No	No	No	Yes
Release date	January 2004	March 2004	December 2004	January 2006	March 2007

Provisor tested the OTR and leakage resistance of ZORK V3 as part of a comprehensive "Transport, stack testing and stability" trial, reported on July 7, 2005. This work showed that ZORK V3 exhibited much greater resistance to leakage when subjected to heat and pressure testing. In this work, 100% of bottles heated showed no wine loss when heated to 40°C for 8 hours. Subsequent versions of ZORK should show similar behaviour under these conditions.

2. SUMMARY OF WORK

The standardised, documented analyses can be conveniently grouped as follows according to their primary focus:

1. those assessing the oxygen permeability of both closures, which has a direct effect on wine shelf-life: analysis of oxygen transmission rate (OTR), the concentration of free and total SO₂, dissolved oxygen (DO), dissolved carbon dioxide (CO₂); and brown tint (OD₄₂₀)
2. those assessing the physical attributes of the closure: analysis of internal bottle pressure, correctness of application ("go/no-go"); leakage on heating and freezing, ease of removal of tamper-proof device; ease of extraction and reinsertion; and
3. those assessing the effect of both closures on the sensory properties of the wine.

At monthly intervals for the first six months a series of chemical, physical and sensory analysis tests were conducted on several bottles of each of the two closures.

At 10, 12, 18 and 24 months, the chemical and sensory tests were repeated.

At 38 months, the chemical tests focusing on oxygen permeability (free and total SO₂ and OD₄₂₀) were repeated. This report focuses on the results of this most recent work, and reiterates the results from previous work for all other analysis.

It also summarises the results of a separate set of analysis conducted by Gunn Labs, New Zealand, in mid-2008. In this work samples of the current STL closure were subjected to OTR analysis using a Mocon Ox-Tran2/21MH device.

3. INDICIES of OXYGEN PERMEABILITY/SHELF-LIFE

3.1 Free and total SO₂ (measured until 38 months)

The results for both free and total SO₂ (Figures 2 and 3) in wines sealed with screw-cap are somewhat anomalous at the latest analysis occasion, with very little change and an apparent slight increase respectively observed over the past 14 months.

Despite the anomalies, the loss of both free and total SO₂ has been consistently higher, and in most cases more variable between replicates, in the wines sealed with the ZORK V1 closure than those sealed with screw-cap, for the period since bottling.

The concentration of free SO₂ in wines sealed with ZORK V1 is now approaching that described by Godden et al (2001) in The Australian Wine Research Institute 'closure trial' as the point at which obvious oxidation may be observed in a white wine: 10 mg/L.

The Provisor report, extrapolating from the data gathered to date, concludes that the shelf-life of a wine sealed with ZORK V1 is expected to be approximately 3.7 years. Further discussion of this observation follows.

Figure 3.2.1: Free SO₂ Decay After Bottling

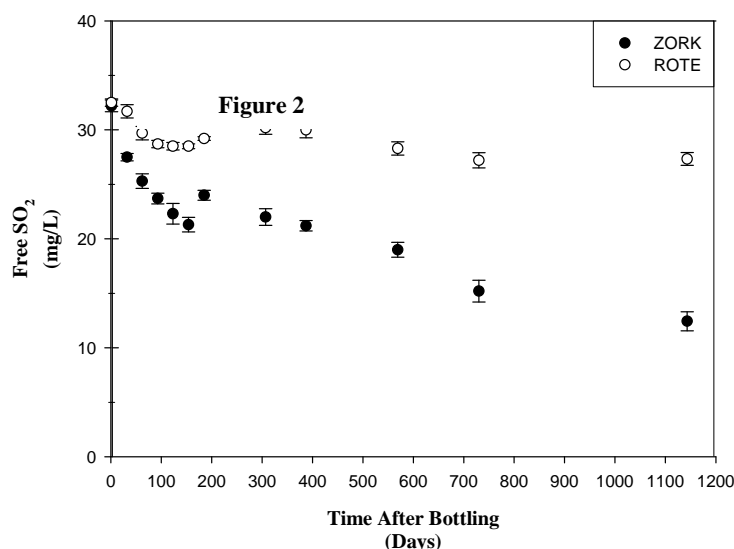
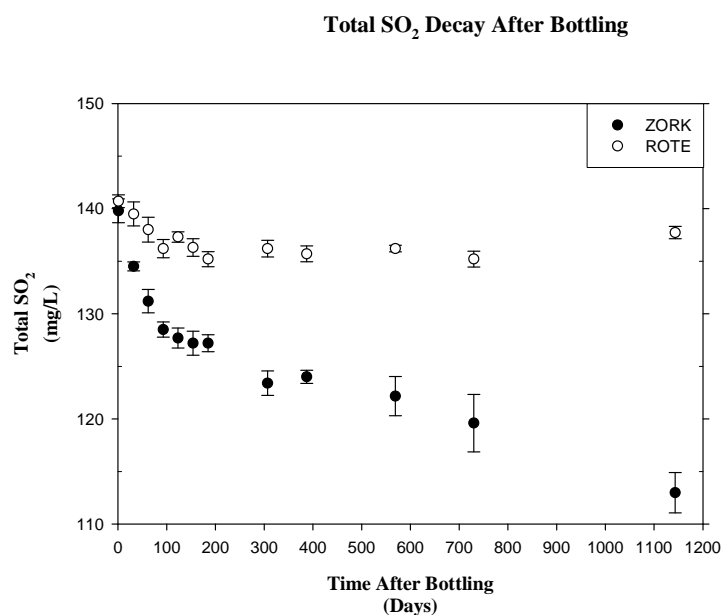


Figure 2. Concentration of free SO₂ in the wine, sealed with either ZORK V1 or screw-cap closures, over 38 months storage. The rate of decline of total SO₂ reflects that of free SO₂.

Figure 3. Concentration of total SO₂ in the wine, sealed with either ZORK V1 or screw-cap closures, over 38 months storage.

If it is assumed that the amount of oxygen dissolved into the wine during filling and sealing is similar for both closure types, the most significant initial difference between the two closures is the volume of air (and thus oxygen) entrained in the hollow plunger of ZORK. This gas diffuses across the plastic material from which the plunger is made at a relatively high rate (0.192 mL/day; measured as part of this work), into the headspace above the wine.

Thus, the 'total package oxygen' (TPO) of the ZORK V1 closure is the sum of:

- oxygen included in the headspace at the moment of sealing +
- oxygen in the plunger +
- oxygen passing through or past the oxygen barrier disc (measured by the OTR).

In contrast, the TPO of the screw-cap closure is the sum of:

- oxygen included in the headspace at the moment of sealing +
- oxygen passing through or past the oxygen barrier disc (measured by the OTR).

The volume of air in the plunger of the ZORK V1 closure was 7.50 mL. According to calculations performed by Provisor, the corresponding volume of oxygen will result in the consumption of approximately 12 mg/L free SO₂. As shown in Figure 1, the volume entrained in the ZORK V2 plunger is 7.54 mL; and in the ZORK V3, V4 and V5 closure, 6.26 mL. ZORK V3, V4 and V5 will therefore result in lower initial SO₂ loss than ZORK V1 and V2.

This entrained oxygen is the likely cause of the initial, faster loss of SO₂ observed in the wine sealed with ZORK V1 closures. It can be expected that after this oxygen is consumed any subsequent SO₂ loss observed is caused by the oxygen permeating the oxygen barrier disc. This appears to be the case, as noted above: while variable, the mean rate of SO₂ loss (free and total) has generally declined over time.

3.2 OTR

The oxygen transmission rate of the ZORK V1 closure (Table 1) was consistently slightly higher than that of the screw-cap closures for the 6 months that it was measured.

The OTR of both was low, being near the limits of precision of the instrument being used and substantially lower than that cited in the literature of natural cork. Importantly, from a quality management perspective, the variability within both the ZORK V1 and screw-cap closures used (as determined by the standard deviation (SD) of the results obtained from several replicates) was similar, and much lower than that cited for cork.

The OTR of ZORK V1 was unaffected by the "stack pallet" and "stability" trials reported by Provisor on July 7, 2005.

Further OTR analysis was undertaken by another laboratory (Gunn Labs, NZ) and reported by Provisor on 4 December 2008 [Report no. PR08308(a)]. This work provided the OTR data below, summarised along with the published OTR of other closures.

Table 1: OTR values for a range of closure types

Closure	Mean OTR (and SD) (mL O ₂ /day) ¹
ZORK V1	0.071
ZORK V3	0.037
ZORK STL ² (V5)	0.011 (SD 0.0028)
Cork ⁴	0.0005–0.584
Technical cork ⁴	0.003–0.006
Screw-cap ⁴	0.0010–0.0038
Injected synthetic ⁴	0.012 – 0.015
Extruded synthetic (Nomacor ³)	0.015 – 0.044

Notes:

1. Converted in some cases from 21% to 100% O₂ basis. Results in this document are expressed as mL 100% O₂/day.
OTR measurements are normally conducted on a *Mocon* brand instrument, in which a sensor measures the amount of oxygen passing through or past the system under test, which may be challenged by air, or pure oxygen. As air contains approximately 21% oxygen, results of systems challenged with air must be mathematically corrected to allow comparison with those using oxygen.
2. Provisor Report Note no. PN08308(a)
3. Nomacor website: http://www.nomacor.com/products_main.php
4. Godden et al (2001)

The OTR of the current 'STL' ZORK is well below that of the V3 closure, as well as most other closure systems, as cited in Table 1.

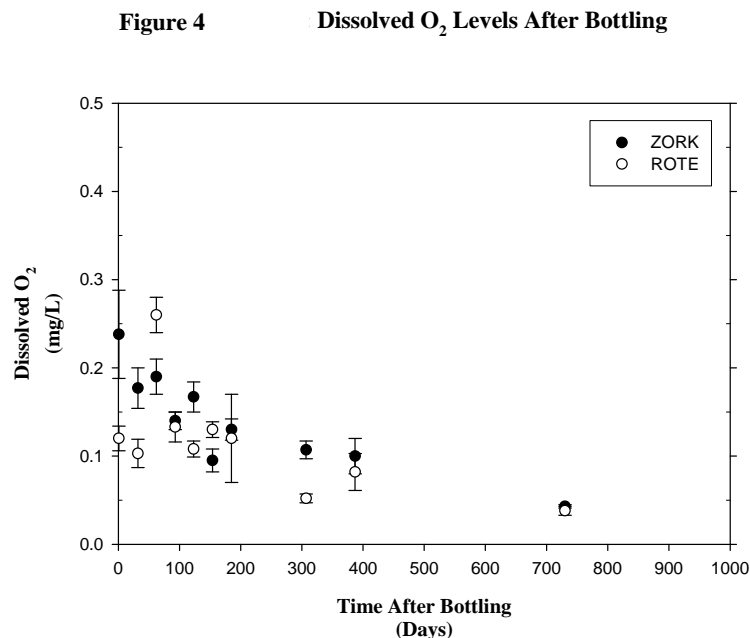
3.3 Dissolved Oxygen (measured until 24 months – Figure 4)

The concentration of Dissolved Oxygen (DO) was subject to substantial variation, both between analysis occasions and within replicates of both closure types on each occasion.

It appears that the means of excluding oxygen at bottling was more effective in the bottles sealed with screw-cap closures, as might be expected on the bottling line designed and built for this system.

Assuming that any oxygen entering the package reacts with the wine and the anti-oxidants within, it is unsurprising that DO has not increased with time. However, other evidence of its presence (loss of SO₂, etc) is apparent.

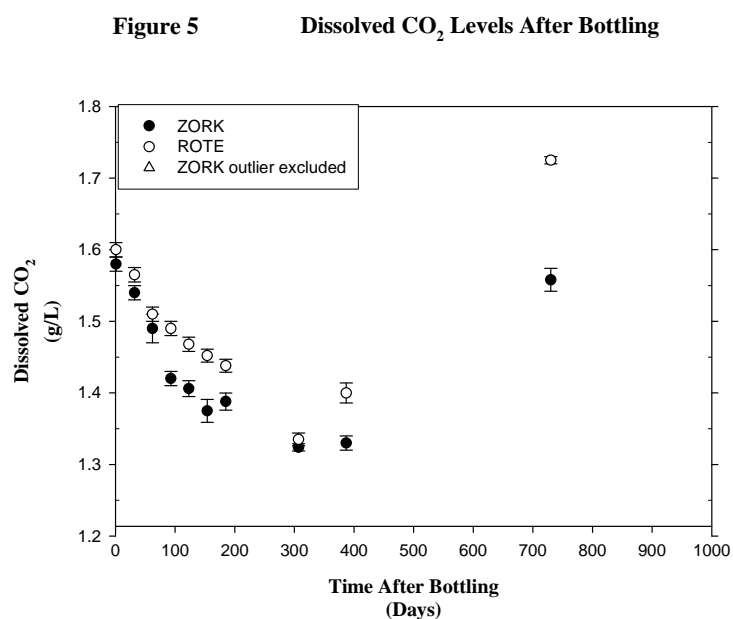
Figure 4. Concentration of dissolved O₂ in the wine, sealed with either ZORK V1 or screw-cap closures, over 24 months storage.



3.4 CO₂ (measured until 24 months – Figure 5)

The concentration of CO₂ in the wine declined consistently in bottles sealed with both closures throughout the period, until the most recent analysis occasion. The results obtained at 24 months are anomalous; given that there is no evidence of microbiological spoilage, there is no reason that the concentration of CO₂ in the wine would increase. Verification of these results has been requested.

Figure 5. Concentration of dissolved CO₂ in the wine, sealed with either ZORK V1 or screw-cap closures, over 24 months storage.



3.5 OD₄₂₀ (measured until 38 months – Figure 6)

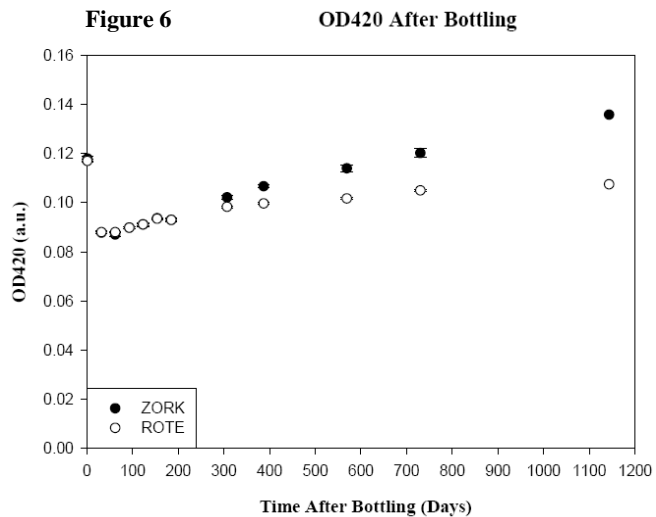
An increase in OD₄₂₀ (brown colour) is expected as white wine ages and/or oxidises. After an initial drop in OD₄₂₀ in bottles of wine sealed with both closures, there was no difference observed in the intensity of brown colour between the wines sealed with screw-cap or ZORK V1 up until 6 months of storage.

However, since this time the OD₄₂₀ of the wine sealed with ZORK V1 has increased compared to that sealed with screw-cap. The difference between the two wines is steadily increasing with time.

This is consistent with the higher OTR and rate of SO₂ loss observed in the wines sealed with ZORK V1, and supports the observations of the sensory panel.

The OD₄₂₀ of the wine sealed with ZORK V1 is now higher than at bottling. It remains below that reported by Peng, Duncan, Pocock and Sefton (1998) as being “unacceptable” by an independent panel. In this work, 50% of panellists considered a wine to be unacceptably brown when the OD₄₂₀ reached 0.18 au.

Figure 6. Concentration of OD₄₂₀ in the wine, sealed with either ZORK V1 or screw-cap closures, over 38 months storage.



Key:

Blank cell = not significant at F probability <0.05 level

* = significant difference at F probability <0.05 level

** = highly significant difference at F probability <0.01 level

*** = very highly significant difference at F probability <0.001 level

'Z' (ZORK) or 'R' (screw-cap) denotes the closure with the greater mean attribute rating.

The results at 24 months differed from those at 18 months in several key areas.

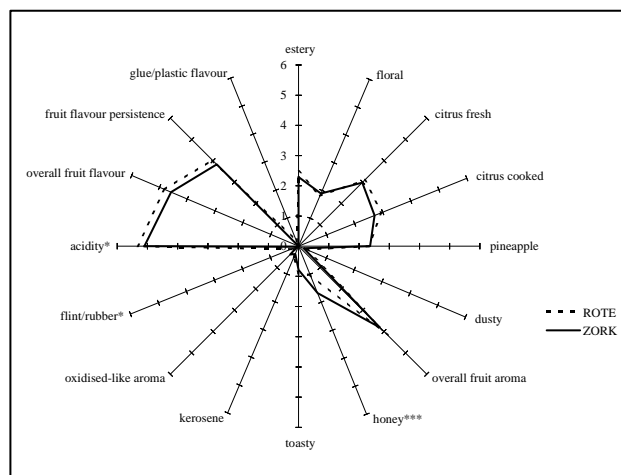
What appeared at 18 months to be an emerging trend of greater "Oxidised" aroma in wine sealed with ZORK V1 has not continued. However, significantly more intense "Honey" aroma has been observed in this wine for the first time on consecutive occasions.

Both "Oxidised" and "Honey" aromas are consistent with the other symptoms of oxidative development in the wine. Their impacts on wine quality are quite different, however. An "Oxidised" character is undoubtedly negative in any white wine of 24 months of bottle age; however a "Honey" aroma could be considered positive in a Riesling wine after some bottle maturation.

The one consistent aroma trend remaining at 24 months is the observation that the wine sealed with screw-cap has significantly higher "Flint/rubber" character. In addition, the wine sealed with screw-cap has been consistently observed, over 3 analysis occasions, to have greater palate "Acidity".

The important issue is the relative intensity of the attributes: see Figure 7. While the sensory panel has consistently observed a significant difference in the intensity of some specific aroma attributes between wines sealed with the two closures, the intensity of some of these attributes (specifically, "Flint/rubber" and "Oxidised") is much less than others such as "Overall fruit" and "Citrus fresh". In other words, the aromas of both wines are dominated by characters including "Citrus fresh", "Citrus cooked", "Estery" and "Floral", rather than the secondary characters attributed to the closures: "Flint/rubber" or "Oxidised".

Figure 7. Schematic representation of the relative intensity of aroma and palate attributes at 24 months



The wine sealed with screw-cap has exhibited a significantly higher "Flint/rubber" aroma for over 18 months, but no higher "Reduced" palate attribute has been observed at any stage. It is likely that the observed aroma is of similar nature and origin to the "Reduced" characters reported by Godden et al (2001), and discussed extensively by other authors such as Limmer (2005 a and 2005 b). All of these authors attribute this character to the low oxygen transmission rate of the screw-cap closure.

Thus, the most helpful interpretation of these observations at this stage is that while the sensory panel can clearly and consistently distinguish the wines sealed with the two closures on the basis of the difference in "Flint/rubber", and to a lesser extent "Oxidised" aromas, these characters may not be apparent when the wines are assessed individually, or by an untrained taster. This is likely to change with ongoing bottle maturation.

The observation of higher scores for a variety of fruit-related aromas and flavours in the wine sealed with screw-cap closures is consistent with other indicators of the oxygen transfer performance of this closure system compared to that of ZORK V1, and are also consistent with the analysis of the wine.

There is no evidence that either closure is causing the introduction of an exogenous 'taint', or removal of wine aroma or flavour (scalping).

6. COMMENT: OENOLOGICAL IMPLICATIONS OF RESULTS TO DATE

The Provisor report includes extensive comparisons of the rate of SO₂ loss from ZORK V1 and screw-cap closures with that provided by Godden et al (2001) in The Australian Wine Research Institute 'closure trial'. It also discusses the nominal point at which that study notes that obvious oxidation may be observed (evident in the form of brown colour, decreased fruit freshness and probable aldehydic aromas and flavours) in a white wine: a concentration of free SO₂ of 10 mg/L. This is the point at which shelf-life can be considered to have expired.

It has been shown that the concentration of free and total SO₂ in a wine bottle sealed with ZORK V1 (and thus probably also ZORK V2, V3, V4 and V5) will initially decrease at a rate faster than that of screw-cap, as the oxygen in the plunger diffuses into the headspace and reacts with the wine. Assuming that all other factors are equal and ignoring the effect of any oxygen dissolved into the wine as a result of the bottling process, a wine sealed with ZORK V1 should lose approximately 12 mg/L more free SO₂ than wine sealed with screw-cap, in the first few months. After this time, the rate of SO₂ loss will be broadly similar to, if slightly faster, than that of screw-cap.

These characteristics will lead to a wine sealed with ZORK maturing differently to that sealed with screw-cap or cork.

Two effects are likely. Firstly, the concentration of SO₂ in wine sealed with ZORK V1 will initially decline more quickly than either screw-cap or a 'typical' cork. This initial loss of free SO₂ has previously been shown as complete at approximately 60 days, but this time will depend on many factors and cannot be predicted with confidence. If desired, winemakers may compensate for this initial loss by increasing the concentration of free SO₂ in the wine at bottling.

Secondly, due to the slightly higher OTR of ZORK V1 than screw-cap, a wine with a given concentration of free SO₂ will have a shorter shelf-life if sealed with ZORK V1 than screw-cap. However, the most recent data suggest that the mean OTR (and importantly, degree of likely variation in performance from closure to closure) compare very favourably with all other closure systems, and is superior to many.

Figure 8. Actual and predicted free SO₂ loss from the wine sealed with ZORK V1, showing the likely time at which the concentration reaches 10 mg/L.

Figure 8: Estimated Shelf-life based on Free SO₂ Degradation

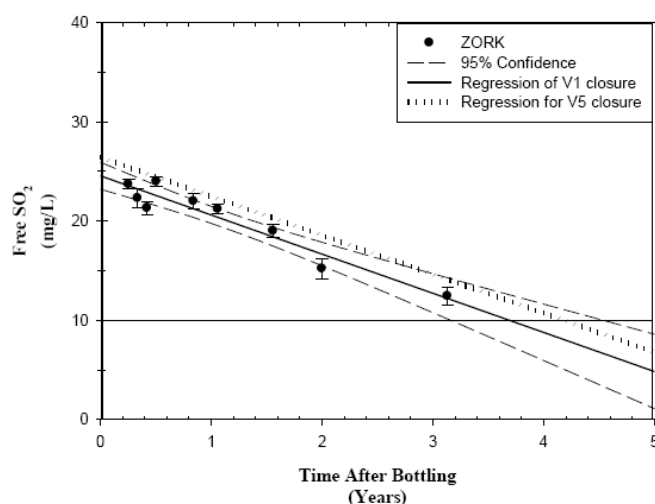


Figure 8 shows the extrapolation to this point. It indicates that the effective shelf-life of the wine in this study will be approximately 3.7 years. The expected shelf life of wine sealed with the ZORK V5 is 4.2 years. This increase has resulted from the reduction in the volume of air contained in the plunger (a 17% decrease from 7.50 to 6.26 mL; Figure 1).

Winemakers may extend the total shelf-life of a wine by increasing the concentration of SO₂ at the time of bottling. As some winemakers are choosing to bottle wine sealed with screw-caps with a slightly lower concentration of SO₂ than that sealed with cork, the concentration required for ZORK is closer to that of cork.

It must be noted that an increased concentration of SO₂ may not be desirable in products made for commercial release shortly after bottling, as it may exceed its aroma threshold (a function of wine pH and fruit intensity) for a finite period.

7. SUMMARY AND FUTURE DIRECTIONS

The results obtained to date allow the following observations of the performance of ZORK V1 closures:

- ZORK exhibits similar consistency of oxygen-barrier performance when compared to screw-cap, and greater consistency than that of traditional cork; and
- using data generated in other studies, ZORK offers a longer shelf-life than synthetic or low oxygen-barrier cork closures, but a shorter shelf-life than screw-cap.

Godden (2005) suggest that winemakers, in sealing a specific wine with a specific closure, are effectively 'making' a wine that will differ in future from the same wine sealed with a different closure. ZORK is an alternative closure, different to traditional systems that will yield a wine with its own specific characteristics.

The rigour applied to the independent evaluation of the ZORK exceeds most commercial trials and parallels benchmark closure research. I remain encouraged by the performance of ZORK in the trial. ZORK is a closure deserving serious consideration by winemakers.

It is considered unnecessary for further work to be conducted on the remaining bottles from this trial. The consistency of evidence from the various indicators of the closure performance over the period of testing to date is adequate to allow practical conclusions to be drawn regarding the performance of ZORK V1. Continuing the trial will add little extra value to the test results.

It is recommended that the trial be concluded with this report.



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11 December 2008





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EXECUTIVE SUMMARY 38 MONTHS**BACKGROUND**

- Provisor Pty Ltd was engaged by ZORK Pty Ltd to conduct third-party, independent tests of the performance of ZORK Version 1 (V1) and Stelvin® screw-cap closures, when used to seal a 2003 vintage Riesling wine. Chemical, physical and sensory analyses of the wines were conducted at monthly intervals for the first six months. Some of the chemical and all of the sensory tests were repeated at 10, 12, 18, 24 and 38 months.
- Since the primary trial commenced, the ZORK closure has undergone several design and manufacturing changes, and the commercially-available closure is the ZORK 'STL'. The changes were shown to have primarily improved the closure's resistance to pressure and leakage.
- This work was supplemented by further specific tests of other versions of the closure, including OTR analysis of the ZORK STL closure in mid-2008.
- Cork & screw cap comparisons have been drawn from the primary trial, and other published data.

The combined results have been tabulated. For simplicity and clarity, generalisations have been made.

Closure type	Natural cork	ZORK STL	Screw cap	Synthetic 'cork'
				
OTR (cc/day)	Variable (0.0005–0.584)	Low & consistent (0.011)	Very low & consistent (0.0010–0.0038)	Ranges & consistent (0.012 – 0.044) ¹
Free SO₂ loss	Variable	Low & consistent (after O ₂ in plunger consumed)	Very low & consistent	Dependent on individual product
Shelf life (yrs)	3-10+ (variable)	4–7 (estimate)	10+	1-6 ²
Sensory (general)	Variable development	Oxidative development	Reductive development	Oxidative development
Taint potential	Yes (principally TCA)	No	No	No
Scalp	Possible	No	No	Dependent on individual product
Storage & Handling of bottled product	Horizontal & robust	Horizontal or vertical & robust	Horizontal or vertical & susceptible to denting	Horizontal or vertical & robust
Shelf-life of unused closure	Normally 3 months	Indefinite	Indefinite	8–12 months
Temperature limit (Failure mode)	~35°C (cork pushes)	>40°C (cap vents)	~38°C (cap distorts)	~35°C (plug pushes)
Application	Fast & reliable	Fast & reliable	Fast & reliable	Fast & reliable
Extraction	Corkscrew required	Open by hand	Open by hand	Corkscrew required

Notes:

1. Dependent on individual product.

References:

- Provisor 18 month test report number PR05117 December 12, 2005
- Capone, D.; Sefton, M.; Pretorius, I.; and Høj, P. (2003) Flavour 'scalping' by wine bottle closures – the winemaking continues post vineyard and winery. Aust. New Zealand Wine Ind. Journal. 18: 5; 15-20.
- Provisor OTR test report number PR06105 – January 27, 2006
- Provisor Pressure test report number PR05103 – July 7, 2005
- Provisor Transport & Storage test report number PR06106 – February 2, 2006
- Provisor Thermal test report number PN05103 – July 7, 2005
- Provisor ZORK 38 month analysis PR 07 017 – July 2007
- Provisor ZORK STL OTR Report Note PR08308(a) – 4 December, 2008

Note: Please contact ZORK for detailed results of each test.

The rigour applied to the independent evaluation of the ZORK exceeds most commercial trials and parallels benchmark closure research. I am encouraged by the performance of ZORK in the trials. ZORK is a closure deserving serious consideration by winemakers.

