Summary of Findings and recommendations read out in court on 24 July 2017

1. Section 45 of the *Coroners Act 2003* requires the coroner investigating a death to make findings, if possible, of who, how, when and where the person died, and what caused the person to die.

   (a) The identity of the deceased person is Andrew John Thwaites.

   (b) Mr Thwaites was participating in recreational scuba diving with his partner Ms Kelly-Anne Masterman on 10 August 2016 at Cherubs Cave, which is at Henderson Rock in Moreton Bay, Queensland. It was a privately arranged group of 14 experienced divers. Ms Masterman was a qualified Dive Master with 1,350 previous dives. When she met Mr Thwaites in 2011 he had completed 10 dives. By 2016 he was an Advanced Open Water Diver with 300 further dives.
   He and his partner were using their own four cylinders which he had filled at the Underwater Research Group of Queensland Inc. on 13 July 2016. They were members of the group and regularly filled their cylinders from the club's compressor.

   Their first dive was uneventful. They re-entered the water together at 1.30pm and planned to dive for 50 minutes. They descended to 27 metres and then remained around the 22–23 metre range until approximately the 10th minute of the dive. Mr Thwaites signalled to his dive partner by circular hand motions around his stomach that he was feeling unwell and indicated he was ending the dive. His partner did not perceive that he was seriously unwell or anxious or panicked.

   They commenced the ascent together but at the 11 ½ minute of the dive they became separated as they took different paths round a rock pinnacle. Mr Thwaites' partner lost sight of him. The subsequent review of Mr Thwaites' dive computer showed the rate of his ascent increased rapidly from 6 to 7.5 metres per minute, to greater than 9 metres per minute during the 12th minute of the dive. He went from 12.5 metres to 1.7 metres during that period. He may have briefly reached the surface, as the recording by the dive computer watch is at 30 second intervals.

   His partner continued the ascent and thought she recognised him from his distinctive fluorescent dive cap. He was above her, holding onto another boat's anchor line.

   For the last 15 metres below the surface there was a strong current and Mr Thwaites' partner proceeded directly to the dive boat, without a safety stop, presuming he was safe. She re-boarded the vessel at 15 or 16 minutes from the commencement of the dive (according to her two dive watches.)

   Those aboard the dive vessel Nemo had seen Mr Thwaites' fluorescent dive cap briefly at, or near, the surface of the water a couple of minutes before his partner climbed aboard. They were unaware of any problem and assumed Mr Thwaites actively descended, to continue his dive, or swim below the surface

back to the boat. He was between 40-75 metres astern when his fluorescent cap was last seen.

It took some time before there was realisation that Mr Thwaites was not aboard the nearby vessel and was indeed 'missing.' A search was commenced by the second boat in the vicinity while divers from Mr Thwaites' group returned, unaware of these events.

There was no knowledge at the time that Mr Thwaites had become severely impaired and incapacitated and subsequently drowned due to contamination of the compressed air in his cylinder.

It was determined that his second dive cylinder had 2,366 parts per million of carbon monoxide. The recommended upper level is 5 ppm.
Increased pressure at depth increases the partial pressure of both the toxic gas and other gases, including oxygen.[1] At 2,366 ppm of carbon monoxide, toxicity would be similar to that experienced from a surface exposure of 6-7,000 ppm.

As Mr Thwaites ascended his oxygen levels decreased and carbon monoxide poisoning effects continued. He lost consciousness at, or near the water's surface. He sank from 1.7 metres to 29.5 metres within around 60 seconds. From the 14th minute of the dive he remained at that level.

The expert evidence of Dr Ian Millar was accepted that Mr Thwaites' situation was irreversible from the point where he started to descend passively. It was not possible for him to be salvaged even if rescued from shortly after he commenced his final descent. The theoretical timeframe was as short as 10 seconds, maybe as long as 30–45 seconds.

Even if rescued prior to his final descent, Mr Thwaites would have been suffering severe carbon monoxide poisoning, and possibly water inhalation and subarachnoid haemorrhage. His survival would not have been guaranteed.

Mr Thwaites' body was recovered the following day on 11th of August 2016 by police divers.

The source of contamination of Mr Thwaites' air cylinder was the electrically powered air compressor owned, operated and maintained by the Underwater Research Group of Queensland Inc. Contamination occurred within the air compressor due to;

(a) internal production of contaminants from operating temperatures outside the normal parameters and the breakdown of the compressor lubricating oil, coupled with
(b) the ignition of lubricating oil in overheated compressor cylinders.[2]

2. It was unknown whether the ignition event was of a short or long interval. A short event could explain how one tank might have quite different levels of carbon

[1] Dr Millar Exhibit M2.1
[2] Mr W Hunt Ex E

monoxide to another. The process was similar to 'dieseling.' In the context of an oil cooled electric compressor, if you have hot oil, high temperatures and the right compression, the oil can ignite, creating carbon monoxide and carbon dioxide gas within the compressor.

3. The expert review of the compressor undertaken by Mr William Hunt identified the following factors associated with the overheating causing production of carbon monoxide within the compressor:

    (i) Lack of formal system of appropriate maintenance and monitoring,
    (ii) Physical damage to the stage I piston and barrel and the stage II discharge valve housing, caused by overheating,
    (iii) Inadequate ventilation of the compressor room,
    (iv) Exhausted/inactive filter columns,
    (v) Inappropriate fittings in filtration column non-compliant in size and composition,
    (vi) Absence of temperature gauge,
    (vii) Absence of compressor manuals to guide servicing and maintenance.

4. Some members of the Club were aware from about 6 August 2016 that the compressor was making an unusual noise, and was not efficiently filling tanks. A 'blown gasket' was presumed. The compressor remained in use on 13 July and was subsequently repaired on 18 July 2016. The compressor was used on 27 July, 1 August and 3 August but ultimately failed and the compressor seized on 8 August 2016.

5. The members of the club using the compressor to fill their diving tanks had no understanding or appreciation of the potential risk of contamination of air from the poorly maintained compressor.

6. The members of the club did not reference the Australian Standards applicable to production of breathing air for filling portable cylinders (Australian Standard 3848.)

7. The members of the Club did not have any mechanism on the premises to test for contamination of tanks filled from the compressor, nor did they pursue external testing.

8. The members of the Club undertook all maintenance and repairs of the compressor from within their own membership without independent external technical involvement.

(c) Mr Thwaites died on 10 August 2016.

(d) Mr Thwaites died at Cherubs Cave, Henderson Rock, Moreton Bay in Queensland.

(e) The cause of Mr Thwaites' death was carbon monoxide poisoning causing unconsciousness underwater and drowning.

Coroner's Comments s. 46 Coroners Act 2003

1. **Mr Thwaites' death was tragic and avoidable. It is to be hoped that knowledge of the circumstances of his death will help to prevent another similar tragedy.**

2. The inquest was greatly assisted by the expert advice and submissions provided by Dr Ian Millar, Mr John Lippmann and Mr William Hunt. I will read out some only of the comments relating to public health, and ways to prevent deaths occurring in similar circumstances in the future.

3. **Dr Ian Millar**'s expert evidence as a hyperbaric medicine and specialist in diving medicine was accepted[3]. He has researched and developed expertise in breathing air compressors installed at hyperbaric facilities around the world. Mr Thwaites died due to carbon monoxide toxicity which caused incapacitation and resultant drowning. The primary issue and root cause of his death was contamination of air within the compressor from which he filled his tanks.

4. Dr Millar put forward a number of recommendations aimed to improve safety for divers and reduce the likelihood of death caused by contamination of breathing air. The first was :

   (i) **All Breathing air compressors be fitted with a carbon monoxide alarm.** (Handheld carbon monoxide gas analysers are available for between $200-$300. Single use carbon monoxide testing balloons that change colour cost between $10 and $20 each. These are best suited for divers who travel occasionally to locations where they are uncertain of compressed air quality.) Dr Millar suggested if a requirement for carbon monoxide alarms was established, the measurement instrument industry would respond with suitable products at reasonable cost. To save lives, carbon monoxide alarms do not need to have the same sensitivity to measure 5 ppm of carbon monoxide as required by periodic hydrostatic air testing of compressed air cylinders. An alarm threshold of 50, or even 100 ppm would be sufficient to prevent death.

   (ii) **The Australian Standards 3848 for breathing air from compressors should be promoted to inform appropriate selection of compressors fitted with filtration systems designed for breathing air production.**

   (iii) **Compressor systems for production of breathing air should be maintained and repaired by competent persons, trained according to manufacturers' recommendations, and using approved parts.**

   (iv) **There should be targeted information and education about safe use of breathing air compressors, including proper maintenance to prevent contamination. Education is necessary to improve understanding of**

[3] Exhibit M2.2

the very real risks of carbon monoxide contamination. The importance of filling with air from properly installed and operated compressors with filtration equipment which has been properly maintained is paramount. It is suggested that government funding is provided to Divers Alert Network to deliver a targeted education and awareness campaign around the risks and how to improve safety for divers filling their tanks with 'breathable air' from compressors.

Dr Millar suggested –

5. **Registration of all high pressure breathing air compressors. dependent only upon the intended or actual use of the compressor to supply humans with compressed breathing air.**

6. **Mr John Lippmann** is the Founder, Chairman and **Director of Research of Divers Alert Network Asia Pacific, (DAN)** which has 14,000 members, half of whom are based in Australia. Mr Lippmann has forty years of dive experience and is totally committed to improving safety for recreational divers.

7. Mr Lippmann identified many issues in common with Dr Millar, which I will not repeat. Some of the additional comments were :

(vi) Three monthly gas analysis of air from the compressor and also following any modification or repair. These requirements should apply to dive clubs as well as commercial operators and be encouraged for private users.

(v) Testing of at least one cylinder filled at each operation of a breathing air compressor

(vi) Creation of appropriate training/certification system for filling compressed breathing gas tanks for diving

8. Some of Mr Lippmann's comments to improve safety went beyond matters pertinent to establishing the cause or contributing factors in Mr Thwaites's death. It is not implied that these additional matters were causative or contributory to Mr Thwaites' death. They are however safety issues raised in the context of events around Mr Thwaites' death and are included for consideration for that purpose.

(vii) Inclusion of a diver recall procedure in a boat safety or pre-dive briefing

(viii) Encouraged use of written pre-dive briefing checklists to ensure coverage of important information

(ix) Bare boat charterers to provide checklist to hirers detailing what services are provided and what services are not provided, including diver recall procedure. Return of the document signed by the hirer confirms they have read and understood the services provided and they will provide other services necessary to provide safe conduct of the dive.

9. **Mr William Hunt**, provided invaluable technical expertise regarding breathing air compressors based on forty years' experience in the industry, and what can go wrong. He was a member of the Australian Standards Committee which wrote the standard for breathable air when filling portable cylinders. He did not specifically make recommendations.

10. His message was succinct :

(x) There is a longstanding Australian Standard (38348 and/or 2299) for breathing air produced by air compressors when filling portable cylinders. It does not say to whom it applies, it states the quality and standards which must be adhered to for air that is being produced for breathing by humans

……Comply with this standard.

He said-

(xi) Compressors such as the very old Ingersoll-Rand electrical compressor, which was designed to be cooled by air flow around it and lubricant oil within it, can overheat and ignite oil within the compressor, generating contaminants including odourless, tasteless, toxic carbon monoxide.

Finally, Mr Hunt said-

(xii) If a compressor is not properly configured, filtered, operated, maintained and competently repaired with appropriate parts, there is a risk of such an internal ignition and combustion event. Contamination of the compressed air can occur.

11. **There are some other issues**, questions and risks raised in the context of these events, **but again, I emphasize not directly relevant to Mr Thwaite's death.**

12. The events of 10 August 2016 occurred on a bare boat charter. On the evidence at the inquest this kind of arrangement appears to be an increasing practice with the decline of numbers of dive shops. There are potential risks to diver safety in such arrangements due to confusion over the applicability of the various legislation (*Safety in Recreational Water Activities Act 2011*, and Regulations; *Work Health and Safety Act 2011*, and Regulations; and Recreational Diving, Recreational Technical Diving and Snorkelling Code of practice 2011).

13. This particular arrangement was considered beyond the jurisdictional scope of Work Health and Safety.

14. On this particular day, there was confusion and ultimately no agreement about which individuals were performing the various roles of dive supervisor, dive master, lookout and associated responsibilities.

15. The diver recall protocol and what might be done if a diver was missing was not addressed.

16. There was no exchange of documentation (electronically) until after the event.

17. In this context it is recommended:

(xiii) that the legislation relating to recreational diving (*Safety in Recreational Water Activities Act 2011* and the *Work Health Safety Act* and Regulations together with the Recreational Diving, Recreational Technical Diving and Snorkelling Code of Practice 2011**) be reviewed.**

(six points not read out)

18. **Maritime Safety Queensland reviewed the operations of the charter vessel.** What was not remarked upon in that review was the suitability of the dive vessel which was equipped with a full chain anchor but without a tender.

19. At the end of each of the two dives on 10 August 2016, two divers failed to ascend in accordance with instructions up the full anchor chain. They surfaced some distance from the vessel. On the first occasion, the divers deployed their high visibility buoyancy devices and continued drifting. They were among the last divers to surface and the vessel Nemo was therefore able to pull anchor and retrieve them.

20. Unlike other dive vessels, the chain did not stop at approximately 30 metres with a float attached and then a rope back to the winch. This allows the Skipper or deckhand to leave the site and retrieve divers whilst allowing a position of ascent on the float for divers who may still be in the water.

21. On the second dive, two divers from the charter vessel were retrieved by a second vessel in the vicinity which was already searching for Mr Thwaites while their vessel, Nemo, waited for the return of the rest of the dive group.

22. It is emphasised there is no suggestion that this limitation of the vessel being unable to immediately pull anchor and respond, had any bearing on the circumstances of Mr Thwaites' death. It is however an issue that should be reviewed from the perspective of diver safety. It is recommended that:

(xiv) Dive vessels' capacity to immediately respond to a diver / swimmer drifting on the surface be reviewed. The review should have regard to the availability of a tender and the capacity of the vessel to pull anchor immediately without stranding remaining divers underwater without a line to return to.

23. **<u>Air testing</u>**. It was noted that police testing of air quality from Mr Thwaites' cylinder took the usual turnaround time of about 10 days. It would be helpful if the Police Dive Squad had access to an immediate testing device. This would at least alert them to identify a possible risk promptly, which could be very important for other dovers who could also have contaminated air in their tanks.

(xv) The Police Dive Squad be equipped with suitable initial testing device / capability of air quality, prior to formal testing.

24. **<u>In conclusion</u>**, the most important issue identified following Mr Thwaites' tragic death was the need for education to alert divers of the risk of contamination when filling their cylinders. The risk of carbon monoxide contamination is a lethal risk, and a 'sniff' test will do nothing to alert a diver to the odourless gas. Divers can improve their own safety by informing themselves of the Australian standard for breathable air.

25. Divers should recognise that contamination can come from the external environment, but also from an internal ignition and combustion within an air compressor. This can occur if the compressor is not properly configured, filtered, cooled, and maintained and repaired. This risk can include electrical compressors.

26. A hand held testing device used every time a tank is filled should be part of every diver's equipment and routine. A diver's life depends on the reliability of their air supply underwater.

27. I thank all those who have participated in, and assisted with this inquest.

The inquest is closed.

Christine Clements
Brisbane Coroner
Brisbane
24 July 2018