OFFICE OF THE STATE CORONER

FINDING OF INQUEST

CITATION:	**Inquest into the death of Stephen James Broe**
TITLE OF COURT:	Coroner's Court
JURISDICTION:	Brisbane
FILE NO(s):	COR 717/05 (3)
DELIVERED ON:	24 April 2009
DELIVERED AT:	Brisbane
HEARING DATE(s):	17 October 2008, 9-13 March & 17-18 March 2009
FINDINGS OF:	Mr Michael Barnes, State Coroner
CATCHWORDS:	**CORONERS: Inquest, deep technical recreation diving, decompression illness, investigation of diving deaths**

REPRESENTATION:

Counsel Assisting:	Mr Peter Johns
Dr Greg Emerson:	Mr David Tait SC with Mr Andrew Luchich (instructed by Avant)
Professional Association of Diving Instructors (PADI); Billionaires in Business Pty Ltd; Mr Mark Thomas;	Mr Richard Douglas SC with Mr Damien Atkinson (instructed by Herbert Geer)
Dr Alexandra Broe:	Mr Mark O'Sullivan (instructed by Tutt Down McKeering Solicitors)

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The *Coroners Act 2003* provides in s 45 that when an inquest is held, the coroner's written findings must be given to the family of the person who died, each of the persons or organisations granted leave to appear at the inquest and to various specified officials with responsibility for the justice system or other agencies with responsibility for the areas of administration referred to in any comments or recommendations. These are my findings in relation to the death of Stephen James Broe. They will be distributed in accordance with the requirements of the Act and posted on the web site of the Office of the State Coroner.

Introduction

Dr Stephen Broe was a highly accomplished medical doctor who had a passion for SCUBA diving. On 28 April 2005, shortly after midday, he emerged from the ocean a few kilometres north of Moreton Island and climbed onto a charter boat. He had just completed the final dive in a technical deep diving course he had been undertaking over the preceding couple of months. He almost immediately complained of burning pain in his chest and severe shortness of breath. Despite assistance from people on the boat, Dr Broe lapsed into unconsciousness and died a few minutes later.

These findings:

- confirm the identify of the deceased man and the time and place of his death;

- determine the medical cause of his death;

- consider whether Dr Broe was appropriately certified fit to undertake the diving course that led to his death;

- consider whether the two dives undertaken on the day of Dr Broe's death were undertaken in accordance with appropriate industry standards, including in particular whether;
  - the sequence of dive depths;
  - the time intervals between them; and
  - the decompression stops planned and executed

  were within acceptable limits.

- consider whether changes to the manner in which Dr Broe's equipment was brought back onto the dive boat at the conclusion of the dive could improve public health and safety.

- examine how the gas mix in his NITROX cylinder came to be other than what was intended.

The evidence

Social history

Stephen James Broe was born in Brisbane on 15 March 1960 as the fifth child of Mary and Matt Broe. He grew up in Rocklea and Moorooka and attended

Villanova College before going on to study medicine at the University of Queensland. In 1978 he met his future wife, Alex, also a medical student. After graduating in 1983, he started work at the Royal Brisbane Hospital and decided early to pursue a specialty in Obstetrics and Gynaecology. Stephen and Alex married in March 1988.

In late 1992 the couple had their first child, Jackson, and shortly after, the family relocated to the UK. Dr Broe secured employment at Poole Hospital in Dorset which enabled him to experience other methods of obstetric practice and extend his knowledge by training in a different system. He attained his English Obstetrics and Gynaecology qualifications and returned to Australia in 1994 before being admitted as a Fellow of the Royal Australian College of Obstetricians and Gynaecologists. In 1995 Alex gave birth to their second son, Michael.

In the following years, Dr Broe undertook further training at the Royal Women's Hospital and Mater Public Hospital. He remained a visiting specialist at the Mater Public for a number of years after attaining his Fellowship. He then set up a private practice, initially at Ballow Chambers on Wickham Terrace, and later at the Mater Private Medical Centre in South Brisbane.

He had many interests outside of medicine including photography, music and sport.

He was 45 years old when he died.

The court has had the benefit of an elegant and profound account of the impact of his death on Alex, Jackson and Michael. It is clear Dr Broe was an integral part of a close and loving family.

I offer the family my sincere condolence for their great loss.

Medical history

It is acknowledged by Dr Alex Broe that Dr Broe had an ongoing struggle with weight control. At the time of his death he had a body mass index of 34 and weighed approximately 120kg.

In 2000, he saw a cardiologist in relation to chest pains. Dr Alex Broe advises that after investigation these were not thought to be of cardiac origin. Rather, they were considered to be 'atypical' or non cardiac in nature and diminished with activity. No treatment was suggested.

In 2002, Dr Broe sought advice from Dr Dan McLaughlin, a neurologist in relation to persistent severe headaches. They were investigated and it was considered they were exercise induced. It was suggested he take a nonsteroidal anti-inflammatory drug such as Voltaren before strenuous exercise. Dr Alex Broe reports that he did not complain of headaches after taking Voltaren and the frequency of the headaches abated.

In August 2003 Dr Broe was noted to be hypertensive after completing a dive medical conducted by Dr Bob Long at the Wesley Hospital. He had some

initial treatment and further testing in January 2004. In a letter dated 8 April 2004, Dr Michael Stowasser, who was then investigating Dr Broe's high blood pressure, noted the atypical chest pains 'persist' as at that date.

Initially no anti-hypertensive medication was prescribed with Dr Stowasser finding Dr Broe's blood pressure to be *'really not too bad'*. This changed in November 2004 when Dr Stowasser prescribed the medication Midamor after he diagnosed Dr Broe to be suffering from primary hyperaldosteronism or Conn's syndrome.

A sleep study performed on 8 October 2004 revealed Dr Broe suffered from severe obstructive sleep apnoea (OSA). In late 2004 he began using a CPAP machine. Although medical records suggest it worked well, Dr Broe was unable to use it with any degree of consistency (as is common). He explored the use of different masks in early 2005, but otherwise focussed on a reduction in weight in order to better manage the condition. There had been some modest success in regards to weight loss prior to his death.

Dr Broe also suffered from seasickness. It emerged subsequent to his death that he was taking the epilepsy medication Phenytoin to combat this.

Diving history

Dr Broe was consistently described in the evidence as a passionate, competent and confident diver. His final dive was his 131st. He was clearly an enthusiastic student with a particular interest in his equipment and the scientific underpinnings of diving practice.

Dr Broe regularly enrolled for diving trips and courses run by Prodive; a retail diving franchise operating stores at Bulimba and Milton.

He was certified as a recreational scuba diver in 2003 and subsequently completed numerous other courses offered by Prodive. These included certification as an Open Water Diver, Wreck Diver, Deep Diver, Rescue Diver, Enriched Air Nitrox (Max 40% Oxygen) Diver, Equipment Specialist and SCUBA Air Fill Operator. These courses satisfied the skill pre-requisites for entry to the Technical Deep Diver Course which he was undertaking at the time of his death.

What is technical diving?

The course Dr Broe was undertaking was designed by a U.S. firm, Diving Science and Technology (DSAT). It was designed for the Professional Association of Diving Instructors (PADI); to be distributed to and used by their accredited members and students. PADI is the world's largest diver training organisation and although based in the United States it is a global organisation.

Outside occupational or military environments, technical diving is relatively new, having become accessible to recreational divers in the early 1990's.[1]

[1] DSAT Tec Deep Diver Manual p.2.

The Workplace Health and Safety Queensland (WH&SQ) Industry Code of Practice for Recreational Technical Diving provides the following definition:

> *Underwater diving for recreation, other than in a swimming pool – using EANx or mixed gas; or that is decompression diving using compressed air or other gases.*

Decompression diving is diving that requires a diver to make a planned stop during ascent to decompress. As will be seen, at the depths Dr Broe was diving, the ascent required a series of different stops. EANx is a mixture of nitrogen and oxygen where the oxygen content is higher than air. It is also referred to as nitrox. In the dives conducted by Dr Broe, the divers descended to their maximum depth breathing compressed air, and, for reasons outlined below, changed to higher concentration oxygen mixes (50% and then 100%) as they approached the surface.

The DSAT training manual distributed by PADI makes a distinction between technical diving and recreational diving that doesn't depend upon whether the diving is being done for payment or pleasure. Technical diving is defined by PADI as diving which takes divers 'beyond recreational diving limits'. It is further defined as, and includes one or more of the following:

- diving beyond 40 metres;
- required stage decompression;
- diving in an overhead environment beyond 40 linear metres;
- accelerated decompression; and/or
- the use of variable gas mixtures during the dive.

Regulatory instruments and organisations

At the time of Dr Broe's death, regulation of technical diving fell under Part 12 of the *Workplace Health and Safety Regulation 1997*. The regulation makes specific requirements for technical dive operators in relation to documentation such as the contents of a dive safety log that it mandates must be kept.[2] It also imposes a requirement for operators to ensure at least one person on a technical diving operation is stationed as 'lookout and rescuer'.

The *Industry Code for Recreational Technical Diving* promulgated by WH&SQ is more comprehensive. It outlines a series of requirements relating to qualifications of instructors and those tasked with the mixing of compressed gas. It provides guidance on possible illnesses and dangers associated with decompression diving and recommends a series of controls to minimise risk and exposure to dangers.

A set of Australian and New Zealand standards deals with the more general area of occupational diving operations. The standards provide detailed guidance on safe diving practice and procedure in an occupational setting for depths of up to 50 metres. The standards also contain guidance and a specific form for the medical assessments of prospective divers.

[2] Contents of the dive safety log are to include, amongst other entries, the date and location of the dive, time in, time out, maximum depth, any incident or problem, the dive time and, if a repetitive dive, the surface interval time.

Fitness to dive

Requirement for medicals

There is no regulation, standard or other government instrument requiring a student on a technical diving course to pass a dive medical examination. PADI issues no instruction to their members in regards to this particular course in so far as medical examinations are concerned.

Part 12 of the *Workplace Health and Safety Regulation 1997* which deals with commercial diving operations, required staff to have a '*current*' dive medical certificate; being less than 12 months old.

Prodive Brisbane required students to complete a medical questionnaire before commencing an open water course. If any of the answers suggested the student may have health issues relevant to their capacity to dive safely, they would be required to undergo a medical examination.

Mr Rodney Bartlett, a casual employee of Prodive who conducted the technical diving course on their behalf, thought that a dive medical would have been required prior to a student conducting the technical deep diving course if one had not been undertaken in the last 12 months.

When he commenced the technical diving course, Dr Broe had not had a diving medical examination since August 2003, and so was required to have another.

As a result, Dr Broe made an appointment at the Hyperbaric Unit at Wesley Hospital where he undertook a dive medical on 24 January 2005.

Standard to be applied

A dive medical for a recreational diver would ordinarily be conducted utilising an AS/NZS 4005 dive medical examination form. Guidelines are provided for medical practitioners by Australian and New Zealand Standards in how the dive medical is to be conducted. This form is specifically for use in the recreational dive industry and requires a doctor to advise whether or not they can find any conditions which are "*incompatible with compressed gas diving*".

Standard AS/NZS 2299 provides a format for a dive medical examination which relates specifically to occupational diving. The medical practitioner is guided in the conduct of that dive medical by, what was at the relevant time, Appendix K to that standard.

Form 2299 requires the practitioner to sign a certificate entitled "*Medical Fitness Recommendation"*. The certificate provides a series of options for the practitioner to choose, ranging from "*All occupational diving*" to "*Recreational industry only"*, "*Temporarily unfit*" and "*Decision pending*" amongst others. A section is provided for comments. The practice is for this form to be forwarded to the candidate's employer, or as it eventuated in this case, the relevant dive operator.

The dive medicals undertaken by Dr Broe

Dr Broe had undergone his first dive medical on 18 August 2003 when he commenced recreational diving. Dr Bob Long, who conducted it, gave evidence at the inquest, although understandably, he had no independent recollection of Dr Broe. Notable in the documentation from that examination is the recorded blood pressure of 150/100. It was this measurement which led Dr Broe to seek further investigation resulting in a diagnosis of Conn's syndrome. Dr Long noted no conditions incompatible with Dr Broe's diving for the purposes of form AS/NZS 4005. At the time of that medical Dr Broe weighed 120kg.

Prior to commencing the technical diving course, Dr Broe had a second examination at Wesley Hospital on 24 January 2005. It was conducted by Dr Greg Emerson. It appears Dr Broe specifically requested he be assessed pursuant to AS/NZS 2299 notwithstanding its intended use for occupational diving.

Dr Emerson, understandably, also had limited independent recollection of the dive medical conducted on Dr Broe. He did, though, specifically remember Dr Broe due to a discussion the pair had in relation to the relative progress of their diving careers. Dr Emerson was 40 years of age at the time of the medical and was quite fit. Notwithstanding this, he had just given up diving as a result of a scare on a recent diving trip. He was therefore intrigued, if not somewhat surprised, that Dr Broe was taking up this particularly risky version of the sport at the age of 44 and with a young family to consider.

In the questionnaire Dr Broe filled out and provided to Dr Emerson, he mentioned being diagnosed with Conn's syndrome and taking Moduretic for his high blood pressure.[3] Sleep apnoea is listed and disclosure is also made of a need to take sea sickness medication. There is no reference to the headaches and chest pains referred to earlier.

It does not appear that Dr Broe's height and weight were measured at the time of the medical. Dr Emerson may have relied on the figures as recorded during pulmonary diagnostic testing in November 2004 where Dr Broe's height was recorded as 185cm and his weight as 115.5kg. Dr Emerson was dismissive of BMI as a tool for assessment in dive medicals, preferring to rely on overall body shape and fitness. Dr Broe ticked the box on the questionnaire confirming that he had undergone an ECG. At the inquest, Dr Emerson was adamant that he had taken this to mean an ECG conducted for the purposes of Dr Broe's 2003 dive medical.

Dr Emerson could, understandably, not recall whether he inquired further as to what medication Dr Broe was taking for sea sickness. He was sure that if informed Dr Broe was using Phenytoin he would have strongly advised him against its use in conjunction with diving.

Dr Emerson stated that he formed the opinion that Dr Broe's high blood pressure was adequately controlled by medication. At the medical Dr Broe

[3] This, like Midamor, is a potassium sparing diuretic used in the treatment of hypertension.

recorded blood pressure of 140/90. The diastolic reading was on the limit of that suggested allowable in the AS/NZS Standard.

Dr Emerson could not recall the extent to which he discussed Dr Broe's sleep apnoea. He is adamant the nature of the testing and the severity of the diagnosis recorded in Dr Broe's medical records from late 2004 were not disclosed. In supporting his decision not to require any further investigation into Dr Broe's sleep apnoea before recommending him fit to dive, Dr Emerson stated that he would have relied heavily on Dr Broe having undertaken 122 SCUBA dives without incident. He was also mindful that as a full time gynaecologist, Dr Broe was clearly functioning at a level where Dr Emerson could reasonably infer he was not adversely affected by daytime somnolence.

Dr Emerson ticked the box "*All occupational diving*" and made no comments or recommendations. Its effect was to clear Dr Broe for any and all occupational diving.

Expert Evidence on risk factors

Age

Advancing age is commonly referred to in text book discussions of the predisposing factors for decompression illness. However, Dr Simon Mitchell, a widely published and well recognised expert in dive medicine, notes that there is no consensus as to the magnitude of the risk that age contributes. At the inquest, it was suggested by several witnesses that the expensive equipment required to undertake technical diving meant that as a matter of practicality it tended to be undertaken by a significant proportion of divers approaching middle-age, in most cases without incident. Nevertheless, I accept that advancing age is a risk that should always be discussed with prospective divers who are middle aged or older.

Obesity

Dr Carl Edmonds is a widely published and recognised diving medical expert and, among other achievements, he was the founder and first president of the South Pacific Underwater Medical Society (SPUMS). He was strongly of the view that obesity was a proven predisposing factor for decompression illness. He eloquently explained the theoretical basis for this. Fat is often referred to in the context of decompression sickness as a "*slow*" tissue; this means it absorbs and also releases nitrogen more slowly. It absorbs more than four times as much nitrogen by volume as does blood. For this reason Dr Edmonds sees body fat content as a particularly important issue for divers conducting long and deep decompression dives.

Dr Edmonds developed further on this theory to suggest the slow release of nitrogen from fat was another reason why the comparatively quick decompression schedules put forward by computer decompression models would be dangerous for such dives.[4] The use of oxygen over a short period during decompression would allow nitrogen to be quickly released from the blood but, in theory, would not allow sufficient time for nitrogen in slow tissue

[4] The computer decompression models are discussed in detail below.

to be excreted. Dr Edmonds was critical of some studies suggesting obesity was not a predisposing factor to decompression sickness on the basis that they failed to adequately consider such deep and long dives as those conducted by Dr Broe.

Dr Mitchell accepted this criticism, in part, and in so far as it relates to those specific studies, but maintained that the link between obesity and decompression sickness was yet to be satisfactorily established by experimentation. He noted that many individuals with an obese body mass index do dive and that a mild degree of obesity is usually tolerated by dive medical examiners.

Other experts who gave evidence during the course of the inquest were similarly equivocal.

As a result of considering all of the expert evidence on the issue, I am of the view that excessive body fat may increase the risk of decompression sickness and should be discussed with a prospective deep diver during a dive medical examination. However by and of itself, it is not a factor that would warrant a prospective diver being refused a clearance to dive.

Conn's Syndrome and hypertension

Dr Mitchell suggests that a history of controlled hypertension is tolerated by most dive medical examiners. This proposition seems uncontroversial although there is some doubt in this case over the extent to which Dr Broe's hypertension was controlled. As noted by Dr Emerson, the main concern with hypertension is the potential long term cardiac ramifications.

Obstructive sleep apnoea

In their reports both Dr Mitchell and Dr Fock, a diving physician and anaesthetist based at the Hyperbaric Unit of the Alfred Hospital in Melbourne, highlighted the potential serious complications that may arise from obstructive sleep apnoea and the risk this represents in a diving context. Dr Mitchell noted the potential for pulmonary hypertension which could exist asymptomatically. A consequence could be to reduce the capacity of the lungs to filter nitrogen bubbles from the veins. He stated that a particular concern was the potential for subsequent right heart failure. Dr Fock also noted the association between OSA and pulmonary hypertension indicating that this could also lead to an induced atrial arrhythmia or arterial gas embolism.

Dr Chris Acott, a diving medical specialist at the Hyperbaric Unit of the Royal Adelaide Hospital outlined at some length the potential problems OSA can cause in a diving context including cardiac related concerns, increased susceptibility to oxygen and carbon-dioxide toxicity and the dangers of daytime somnolence.

All three doctors were of the view they would have required further investigations or questioning of Dr Broe before recommending him as fit to undertake technical diving.

Dr Edmonds and Professor Gorman expressed less concern. In the case of the latter, one basis for not being inclined to recommend further testing was that, in his view, the risk emanating from the potential problems is relatively minor in the context of an already risky activity. This is related to the more philosophical issue of the dive medical practitioner's role, authority and responsibility discussed below.

Phenytoin

Those experts who commented on Dr Broe's use of this medication were unanimous in saying they would not have recommended it in conjunction with diving. I accept its use was not disclosed to Dr Emerson although it is also unlikely that Dr Emerson specifically asked Dr Broe what medication he was taking for sea-sickness. There is no suggestion that its use contributed to Dr Broe's death.

Role of the dive medical practitioner

Professor Gorman, Head of the School of Medicine at Auckland University and a well regarded expert in dive medicine, considers the role of the dive medical examiner is to alert the prospective diver to any increased risks his or her condition(s) may add to the envisaged activity. This view of the role of the doctor as an adviser, rather than a screener of unsuitable candidates seems only to apply to some conditions; others are said to clearly make diving untenable and should result in the issuing of a certificate to this effect.

Professor Gorman expanded on this point when giving evidence and supported it with a suggestion based on experience in New Zealand that the role of doctor as '*policeman*' has the propensity to promote non-disclosure (or even less disclosure than usual). He referred to evidence suggesting the New Zealand practice of explaining the risk associated with various medical conditions and, in the case of occupational diving, moving that risk directly on to the candidate and their employer, had resulted in a significant increase in disclosure of medical conditions. Professor Gorman was not the only expert to refer to the phenomena of candidates who are refused a dive medical certificate simply approaching another practitioner and, not disclosing the relevant problem.

In my view, the position advocated by Professor Gorman faces a number of difficulties, at least in the context of a dive medical practitioner conducting an assessment using AS/NZS 2299[5]:-

- Dr Emerson was aware the dive medical recommendation would be relied on by Prodive when determining whether Dr Broe could participate in the technical diving course;

- The form is worded in an unambiguous fashion and clearly gave Dr Emerson the opportunity to either postpone his assessment until further tests were conducted or to pass Dr Broe, but with certain provisos;

[5] Professor Gorman, although having assisted in creating this form, was highly critical of it. In particular his criticism concerned its tendency to require the channelling of a spectrum of candidates into bipolar pass/fail categories.

- The theory of the diver as risk acceptor does not adequately have regard to the risk that a medically unfit diver poses to their dive buddy or instructor. Those parties are not privy to the explanation of risk provided by the doctor and can not have regard to it when electing to dive with the examinee; and

- As the dive operator's submissions point out, by signing the certificate, the medical examiner makes a representation to the diver operator that the patient is fit to dive. I accept the submission made on behalf of Dr Emerson that it is the operator who must explain the risks of the diving course to the student, but the operator can not be expected to have regard to medical information provided only to the medical examiner.

Having regard to these matters, I am of the view that when he examined Dr Broe, Dr Emerson was required to make an objective assessment of whether any of his physical or medical conditions increased the risk of his suffering any adverse outcome when undertaking technical diving, as compared to a person who did not have any of those conditions. I consider it incumbent on Dr Emerson to make any inquiries or investigations necessary to enable him to make a properly informed assessment of any relevant matters that were reasonably raised by his examination or by what he was told by Dr Broe.

Conclusion as to adequacy of the diving examination

Having regard to the uncertainty surrounding the precise impact of advancing age and excessive weight on the risk to a diver, Dr Emerson could reasonably have concluded Dr Broe's age and weight were not sufficiently concerning of themselves to stop him from undertaking the technical diving course. They were however matters that should have been discussed with Dr Broe and weighed in the mix of factors when Dr Emerson was making the final determination as to his fitness to undertake the course. It seems likely that this occurred.

The evidence concerning Dr Emerson's response to Dr Broe's disclosure of OSA is more problematic. I accept the expert evidence that the condition had the potential to increase the risk of decompression sickness that could not be discounted merely because Dr Broe successfully managed a demanding medical practice and had completed many dives without incident. These compensatory factors relied on by Dr Emerson were not, in my view, sufficient to conclude Dr Broe was not susceptible to the possible consequences of OSA as described by Doctors Mitchell, Fock and Acott.

The risks OSA posed were more significant the longer it went unresolved and the deeper Dr Broe dived.

I accept Dr Emerson was entitled to place a higher degree of reliance on Dr Broe disclosing relevant medical information than would be expected of a non medically trained candidate, and indeed Dr Broe did disclose his sleep apnoea. There is no evidence of any suppression of information by Dr Broe. Contrary to the submissions of Dr Emerson, Dr Broe's denial of severe or frequent headaches and chest pain on exertion were not false. The

headaches had been resolved years earlier, and the chest pains first reported by Dr Broe in 2000, were very different to those the subject of inquiry on the medical questionnaire. In his case, the chest pains atypically were relieved by exertion. Nor is there any evidence Dr Broe did not answer any of Dr Emerson's inquiries about his OSA truthfully. It seems likely that he did not know of the extent of the effects the condition may have had on pulmonary hypertension.

It seems from his evidence, Dr Emerson was not fully aware of the intricacies of this esoteric area of medicine either. Further, the tests that may have revealed relevant pulmonary hypertension had never been undertaken. Nor had the scans that may have revealed the cardiac abnormalities to which Dr Fock referred.

I do not accept the submissions made on behalf of Dr Emerson that he did not know Dr Broe's full medical history and therefore can not be criticised for failing to appreciate the significance of his OSA. In my view it was Dr Emerson's responsibility to make all necessary inquiries. Having been told Dr Broe suffered from OSA, Dr Emerson had an obligation to fully research the possible adverse effects of the condition on a diver engaging in deep, mixed gas, decompression dives. Only when he could be reasonably confident that none of these created an unacceptable risk to Dr Broe, could he have reasonably made the recommendation that Dr Broe was fit for all occupational diving. In my view he failed to do this.

It is pertinent to observe that it is far from certain that any of these risk factors either in isolation or combination actually precipitated Dr Broe's death. As will become obvious, the uncertainties surrounding the onset of decompression illness make it impossible to find that Dr Broe's weight, age, borderline high blood pressure or OSA contributed to his death.

The DSAT Tec Deep Dive Course

The course consists of a theoretical component and a number of pool and ocean dives. During the theoretical phase significant focus is placed on the basis for and calculation of decompression schedules. The practical element of the course consists of 12 dives; 4 in a pool and 8 in open water. The dives, as a general rule gradually increase in complexity and depth as the course proceeds such that by the final dive, students have scoured a depth of at least 44 metres using a mixture of decompression gases.

Informed consent

The DSAT Tec Deep Diver Manual is intentionally confronting in its description of the risks associated with technical diving. Among a myriad of warnings it states:

> "*In technical diving, even if you do everything right, there is still a higher inherent potential for an accident leading to permanent injury and death.*"

The experts who gave evidence referred to the extreme or inherently risky nature of technical diving. One described it as the diving equivalent to base

jumping. The prospective student on a DSAT designed course is adequately informed that by undertaking the course they are accepting this high degree of risk.

Dr Broe had been heavily involved with diving, diving courses and diving trips for a number of years. I have no doubt he had researched aspects of technical diving before undertaking the course and he almost certainly discussed it with other experienced divers. I have no doubt Dr Broe understood and accepted the unavoidable risks involved in the activity.

Prodive

The course undertaken by Dr Broe was offered by Prodive Brisbane, a trading name of Billionaires in Business Pty Limited which purchased the business in 2004. It was operated and managed by a director of the company, Mr Mark Thomas. He made it clear Prodive relied entirely on PADI (and through them DSAT) for the design of the technical diving course it offered. Mr Thomas confirmed in evidence that PADI were periodically paid fees for the use of their trademark and intellectual property. This reliance extended to the adequacy of the qualifications of staff employed by Prodive. Although of course they could undertake their own assessments, it was clear from Mr Thomas' evidence that qualifications via the PADI system of accreditation were taken at face value.

The course which Dr Broe undertook was the second technical diving course offered and run by Prodive. The first had apparently proceeded without incident. No further technical diving courses were run under the ownership of Billionaires in Business Pty Ltd, which sold Prodive Brisbane in November 2005.

Progress through course

Dr Broe enrolled for the course on 19 January 2005 and attended lectures and demonstrations on most weekends thereafter. Pool dives were conducted on 12 and 13 February. The first four open water dives were conducted over the weekend of 19 and 20 February 2005. The final four open water dives were conducted on the Sunday and Monday of the Easter Weekend, 27 and 28 March 2005.

There were only two students on the course, Dr Broe and Adam Kamine. The instructor was Rodney Bartlett, an IT specialist who had worked on a casual basis for Prodive for a number of years. Mr Bartlett held the appropriate PADI instructors qualification and had conducted the earlier technical diving course offered by Prodive. At the inquest Mr Bartlett and Mr Kamine stated that the course had been successful and without incident over the first two weekends and that Dr Broe had conducted himself in his usual confident and competent manner.

The incident weekend

The dive platform for the final weekend was the *MV Esperance Star*, a vessel familiar to Dr Broe and used many times previously by Prodive. In addition to the three technical divers, on board were eight recreational divers, two 'dive supervisors' or 'surface watch' personnel employed by Prodive and the

captain of the vessel, Trevor Jackson. Mr Jackson sourced the oxygen and compressed air that was to be used by divers to refill their tanks during the trip. This vessel was fitted with a gas mixing panel enabling the mixing to take place on board.

The original intention to depart on the evening of Saturday 26 March and anchor in Moreton Bay was thwarted by weather. Most participants on the trip spent Saturday night on board the vessel at Scarborough and the boat sailed early the following morning.

The dive supervisor assigned to the three technical divers was Owen Lloyd. As part of ensuring the safety and integrity of the above water aspects of the dive, he was responsible for maintaining the dive safety logs.

The planned dives

The table below outlines the planned and actual characteristics of the 4 technical dives conducted over the weekend.

	Dive 1	**Dive 2**	**Dive 3**	**Dive 4**
Date	27/3/05	27/3/05	28/3/05	28/3/05
Start time	9.01am	2.32pm	6.46am	11.04am
Finish time	9.45am	3.47pm	7.40am	12.03pm
Total dive time (mins)	44	75	54	59
Bottom time (mins)	15	25	25	25
Planned depth (metres)	42	42	50	50
Recorded depth (metres) on Dive Safety Log	42	40	43	50

Calculation of decompression schedules

Technical deep diving necessarily requires participants to undertake a process of decompression as they rise to the surface. The longer and deeper a dive, the more nitrogen is absorbed into the blood and other body tissue. As the diver ascends and the pressure decreases, there is a propensity for the nitrogen to form bubbles in the blood and tissues. Unchecked, this can have catastrophic effects. The length of time necessary for the process of ascent in order to prevent or limit the formation of nitrogen bubbles is a function of the characteristics of the dive. In other words it varies according to the depth of the dive, the total time spent at those depths and the type of gas being breathed. The last one hundred years has seen the ongoing development of theories and mathematical formulas which attempt to prescribe appropriate ascent times depending on these characteristics. The practical effect of these is that the diver conducts a series of stops at varying depths during the ascent and for varying periods of time.

Recreational divers conducting decompression dives using compressed air have long had access to tables designed by the US Navy and the Canadian

military. The latter have designed tables known as the DCIEM tables which are the most widely used and considered the more conservative in approach.

Technical divers use gas mixtures other than air including Nitrox (with oxygen contents higher than air) and 100% oxygen during the ascent phase. This allows for nitrogen built up in blood and body tissue to be more readily expired from the body via the lungs during ascent. In theory it allows for decompression times to be significantly reduced.

The addition of different gas mixes makes the use of decompression tables problematic and in the last 10-15 years a number of algorithms have been developed which purport to factor in the relevant dive characteristics, including the gas mix to be used, and recommend an appropriate process of ascent.

The diver's descent, total time spent at maximum depth and process of ascent is collectively known as the "dive profile". The term "decompression schedule" applies to the stops made by a diver on their ascent including the depth and time of those stops and the mixture of gas used on each.

Different theories support various algorithms. None have been scientifically validated. One school of algorithms is based on a theory known as the "Reduced Gradient Bubble Model" (RGBM) which accepts bubbles will form, but puts forward decompression schedules which minimise their number and size to a sufficient degree. In part, this is done by the diver conducting more decompression stops in the early part of the ascent.

Anyone can develop an algorithm based on one of these theories (or indeed their own). The algorithm is presented to the diver in the form of a software program allowing the diver to input the characteristics of the dive. In practice, the evidence at the inquest gave a strong indication that certain specific software programs are recognised amongst the technical diving community as being appropriate for use.

However, there is no regulation or even recommendations from either government or diving organisations such as PADI to guide a technical diver on which model or particular brand of software is to be preferred.

The DSAT Manual for technical deep diving issued by PADI makes note of the potential risk in the use of decompression software due to the potential for a diver's individual characteristics to fall outside of the assumptions on which the algorithm is based. It nonetheless suggests that desktop decompression software has an excellent track record.[6] It refers students to their PADI representative for recommendations on appropriate software.

The dive schedules used for the four dives were calculated by a software program know as GAP and were based on the RGBM. GAP was, and is, apparently a well-known, widely used brand of software.

Mr Bartlett gave evidence he had downloaded a free version of the GAP software (a version with more features is available for a fee). Decompression

[6] DSAT Manual page 99.

schedules included among the documents provided to Workplace Health and Safety by Prodive suggested that Dr Broe also had access to the program.[7]

There was some inconsistency in the evidence of Mr Kamine and Mr Bartlett in relation to the way in which the decompression schedules for the weekend were calculated. Mr Kamine was adamant he had relied on decompression schedules given to him by Mr Bartlett and he had simply trusted in their reliability. Mr Bartlett asserted the calculation of decompression schedules and the use of software formed part of the theoretical aspect of the course. He stated that Mr Kamine and Dr Broe calculated the decompression schedules and he checked those proposed schedules against the GAP software to ensure they were appropriately conservative. I accept Mr Bartlett's evidence on this issue.

Dr Edmonds was critical of dive software such as the GAP program used in this case. He noted in the second of his two reports that such decompression software is often variable in its acceptance of risk and the variables included in the algorithms are often untested in operational conditions. He developed on this theme in his evidence at the inquest, critiquing the reliability of databases being compiled by some dive software manufacturers in order to assess the reliability of their algorithms.

Conclusion as to use of dive profile software

Having regard to the widespread acceptance by technical divers of the software used by Mr Bartlett and the absence of any evidence it contributed to the death of Dr Broe, I consider it was reasonable for Mr Bartlett to use this particular program and to recommend it to his students.

Sunday 27 March 2005

The two dives conducted on Sunday 27 March 2005 were conducted in the shipping channel west of Cowan Cowan in Moreton Bay and went to depths of 42 and 40 metres respectively according to the dive safety logs. The dives were conducted as planned, with Mr Bartlett taking the two students through various drills while at maximum depth. The decompression schedules followed for these two dives were notably longer than those calculated by the GAP software. Mr Bartlett explained this was because the divers had created a decompression schedule as though they only had access to air rather than Nitrox or oxygen. He explained this was one way in which a decompression schedule could be made more conservative. The rationale being that by using these gases, the level of nitrogen "offload" would be faster than presumed by the algorithm and the ascent safer.

On the Sunday evening Mr Bartlett refilled the decompression gas tanks for various people on board including himself and Dr Broe.

During the course of the evening the divers dined together. The issue of how much, if any, alcohol was drunk by those on board and, in particular, Dr Broe, was explored at inquest.

[7] Exhibit WHST1

The presence of alcohol on the vessel was not an issue addressed with any of the witnesses in the initial investigation and understandably those who gave evidence had a limited recollection of such matters four years later. There was certainly no rule against alcohol being drunk by students of an evening. There is some evidence that Dr Broe drank a small quantity of wine when the boat was in port. There is no evidence he drank on the night before his death. This issue came into focus as a result of the finding at autopsy of a low level of alcohol in Dr Broe's blood. For the reasons outlined in the discussion of the autopsy results, below, it is not necessary for this issue to be explored further. I am satisfied Dr Broe was not affected by alcohol when conducting any of the four dives that weekend.

Monday 28 March 2008 – the third Dive

The divers aboard the *Esperance Star* awoke to exceptionally good diving conditions on the Monday with perfect weather, no current and excellent water visibility.

At 4.00am the boat upped anchor and proceeded to the wreck of the *St Paul*, north of Moreton Island. The wreck sits in water ranging in depth from 38 to 44 metres. The original plan was for only the recreational divers to dive at that location. However, because of the exceptional conditions the three technical divers decided to dive on the wreck as well. They adhered to the dive profile designed for their intended depth of 50 metres except their bottom time was at a slightly shallower depth of 43 metres.

The rationale of Mr Bartlett was that by following that decompression schedule, in circumstances where the actual depth was in fact less, the divers would be conducting themselves conservatively.

There is no evidence from any of the parties on the boat that in the period between surfacing from this third dive and commencing his final dive Dr Broe exhibited any signs of difficulty or, in particular, any of the symptoms of decompression illness.

Reverse dive profiles

Reverse dive profiles, or as Mr Caney suggested they should more accurately be referred to, "reverse depth profiles", describe two dives conducted on the same day, where the second dive descends deeper than the first.

Over a long period the practice had developed a reputation as being unsafe and it is habitually avoided. However, a 1999 workshop of experts at the Smithsonian Institute suggested the basis for this belief could not be traced to any compelling evidence or diving experience that indicates an increased risk of decompression sickness. The workshop found no reason for diving communities to prohibit reverse dive profiles for non decompression dives of less than 40 metres and depth differentials of less than 12 metres

However, the dives conducted on the Monday clearly exceeded the recommendation of the 1999 workshop both in depth and by virtue of being decompression dives.

In deciding to complete the third dive to a depth of only 43 metres Mr Bartlett caused the dives conducted that day to have a reverse depth profile. It was not clear whether Mr Bartlett was cognisant of this at the time. If he was then his evidence was that the practice could be justified by the fact the decompression schedules actually conducted were not in a reverse profile.

The practice of conducting reverse depth profile dives was criticised particularly by Dr Edmonds. His criticism was set in similar terms to that which he afforded to decompression algorithms; namely that the practice was untested and the level of risk unknown. The remaining expert evidence on this point indicated less concern with the practice.

Mr Bartlett rationalised the safety of the dives on the basis that, although the first dive had been shallower than the second, a decompression schedule that presumed a depth of 50 metres meant that the theoretical concerns around the concept of reverse depth profiles would be alleviated. This rationale did not attract as much support among the expert witnesses as one might have expected. Dr Acott expressed a view that, despite the nature of the decompression schedule followed on dive three, it would have been prudent to recalculate the decompression schedule for the final dive.

Conclusion as to reverse dive profiles

The findings of the Smithsonian workshop remain the highpoint of analysis on this issue. Although casting doubt on concerns about the undertaking of reverse depth profile diving, it did not come to the converse position and suggest the practice should be undertaken. The rationale on which Mr Bartlett's decision was based, if in fact he turned his mind to it at the time, was not unreasonable in my view. Given the confusion among experts as to the theoretical basis for the critique of the practice, it was open to Mr Bartlett to assume that by following the 50 metre decompression schedule in dive 3 he was acting prudently. I conclude Mr Bartlett should not be criticised for permitting the students to undertake reverse depth profile dives.

Spacing of the dives

Mr Bartlett factored in a presumption when calculating the decompression schedules that there would be two hours of surface time between dives 1 and 2 and between dives 3 and 4. Twelve hours of surface time was allowed between dives 2 and 3.

The actual surface times all exceeded these periods.

Dr Edmonds expressed some concern in relation to this issue as part of his wider criticism of the decompression schedules put forward by the GAP software. In framing his critique he drew comparison with the decompression schedules and surface times suggested by the DCIEM tables. On this basis he suggested the schedules and surface times actually conducted over the weekend were "provocative".

This drew criticism from both Dr Mitchell and Dr Fock. They pointed out that the DCIEM tables are based on the diver using air rather than oxygen enriched gases and suggest that any comparison is meaningless. However

Dr Edmonds was using the comparison to highlight the large discrepancy in suggested decompression times between different decompression models when it comes to repetitive diving. To that end it is consistent with his overall concerns about the lack of scientific testing of the various computer based models.

Conclusion concerning dive schedules

I am satisfied the surface time between the four dives did not pose any risk to the divers.

Filling of air and decompression gas cylinders

Mr Bartlett gave evidence that on the Sunday evening he filled the decompression cylinder carried by Dr Broe on his fourth and final dive. The intended gas mix for that cylinder was 50% oxygen and 50% nitrogen.

Testing commissioned by Workplace Health and Safety Queensland showed the gas in that cylinder to consist of 59% oxygen and 41% nitrogen. This increased the risk of oxygen toxicity which can lead to a diver suffering seizures underwater which will usually be fatal.

The GAP software had been configured on the basis that Dr Broe was carrying 50% oxygen. As a result decompression stops were scheduled for 21 and 18 metres during ascent. At these depths 50% oxygen is considered safe. 59% oxygen should only be used to a maximum depth of 17 metres if one is to adhere to the accepted "partial pressure" limits used to decrease the likelihood of oxygen toxicity.

The expert evidence was unanimous in finding this anomaly did not contribute to Dr Broe's death. The increased level of oxygen, while dangerous for the reasons outlined above, would have in fact reduced the likelihood of Dr Broe suffering from decompression illness.

Mr Bartlett outlined to the Court three layers of checks which he says are common to all diving trips. All three would have had to have been breached or failed for the level of oxygen in Dr Broe's tanks to have been so inaccurate:-

- The gas mix is combined from tanks of compressed air and compressed oxygen using tables which require the gas mixer to calculate how much of each should be added to a tank when the existing gas mix and pressure is taken into account. An experienced gas mixer, Mr Bartlett would have had to make a mistake in his calculations.

- After mixing the gas Mr Bartlett says he used an analyser to measure the relative levels of oxygen and nitrogen.

- It is common practice as confirmed by Messrs Bartlett, Lloyd and Kamine, that it is the responsibility of the individual diver to test the gas mix prior to diving. In his evidence at inquest Mr Lloyd said that he is certain he would have asked Dr Broe to confirm the gas mix notwithstanding that it was not ultimately written on the dive safety

log as required. Dr Broe had completed a gas mixing course and was familiar with the use of the relevant equipment.

Conclusion as to gas mixing

It is unclear how the gas mix in one of the sling tanks came to be different to what had been planned. An undetected failure in the gas analyser on board the boat can not be ruled out, although it is difficult to understand why it was not detected before or after this incident. In the circumstances no findings can be made against any individual with respect to the error. There is no evidence to suggest that this is a common problem in the industry and on its face the process of multiple checks appears appropriate.

The final dive

At 11:04am Dr Broe commenced his final dive along with Mr Bartlett and Mr Kamine. The *Esperance Star* had moved to a spot just off Flinders Reef, several kilometres north of Moreton Island. As with his previous dive Dr Broe was carrying on his back twin cylinders containing compressed air along with two decompression 'sling' tanks. One of these contained the Nitrox mix while the other contained 100% oxygen.

The planned dive profile

Mr Lloyd the dive supervisor and lookout had been provided with a handwritten outline of the proposed decompression stops by Mr Bartlett. After a bottom time of 25 minutes at 50 metres, the divers would proceed to 27 metres for their first decompression stop on air. After another air stop, the divers changed to Nitrox at 21 metres and undertook another series of stops at 3 metre intervals until they were 6 metres from the surface. At this level the 100% oxygen was utilised with the divers spending 4 minutes at 6 metres and then 9 minutes at 3 metres.

It is the usual course for divers to prepare contingency decompression tables. These factor in either the loss of an air or decompression tank or a change in maximum depth.

Contingency tables were found with Dr Broe's diving equipment some months after his death. They had been prepared for the possibility of descending to various depths; going as deep as 52m. Tables had also been prepared for the various possibilities of losing either air, Nitrox or oxygen tanks.

For the reasons set out in counsel assisting's submissions, I accept that these tables were created by Dr Broe for use in dive 3. Had he noticed on his last dive that he had exceeded the maximum depth planned and wished to revert to contingency decompression schedules he would not have had one available to him that was appropriate for that dive.

Adherence to the planned dive profile

The dive plan produced by the GAP software provided for the divers would take 5 minutes to reach a depth of 50 metres. In fact, they only took between 2 and 2.5 minutes to do so.

Mr Caney agreed that in theory this meant that a further period of decompression would have been required to take account of the extra two to three minutes spent at significant depth. Dr Fock also agreed with this proposition although he suspected the difference to the decompression schedule would be minimal.

The evidence from Mr Kamine and Mr Bartlett was to the effect that the original decompression schedule was followed. A print out of the dive profile recorded on Dr Broe's Suunto dive computer corroborates this.

Dr Fock undertook an exercise in overlaying the actual dive profile carried out by Dr Broe with a profile generated on his own GAP software. He was unable to obtain a match but by "forcing" in the actual stops carried out by Dr Broe during ascent the program suggested that the dive fell just inside what was deemed acceptable. The evidence of Dr Fock was that the ascent actually carried out by Dr Broe involved too many stops at deep levels. This practice of course underpins RGBM modelling, however, as Dr Fock points out, the assumption that further stops at deep levels adds to conservatism can be erroneous. It fails to acknowledge the propensity for further nitrogen to be absorbed at those levels.

The GAP software allows the user to make a choice between more and less conservative dive profiles. It is significant Dr Fock found the actual dive profile carried out by Dr Broe was on the limits of acceptability even without any allowance for conservatism.[8]

Depth

Dr Broe was carrying two dive computers with him during the course of the weekend. They recorded maximum depths for his final dive of 52.4 metres and 53.2 metres respectively.

During the course of the inquest Mr Bartlett produced a copy of the readout from his dive computer which showed a maximum depth for that dive of 50.1 metres. Mr Kamine recalls that for most of the dive he was hovering only a metre or two from the bottom and that he clearly recalls his depth gauge showing 48 metres. There was no procedure for calibration or comparison of the dive gauges over the course of the weekend. Mr Bartlett indicated that he adhered to a practice whereby as instructor, he would be the one to carry out the most aggressive dive plan. This would ensure, as a matter of practice, that no student went deeper than he. He was adamant Dr Broe did not dive to a depth significantly deeper than he did.

There is no adequate explanation for how Dr Broe could have descended to a depth some three to four metres deeper than the others. It is perhaps significant that on the first dive of the weekend Dr Broe's gauges also recorded depths of around two metres deeper than that recorded on the dive safety log. The depths recorded for his second dive of the weekend though

[8] Dr Fock said that instead of putting in an artificial option for conservatism, he applied a theoretical barrier of a 90 degree gradient as being the limit of what might be deemed safe. In order to cater for the actual dive plan followed by Dr Broe it was necessary for him to postulate a plan carrying a relatively high 85 degree gradient.

were two metres shallower than that recorded on the dive safety log, which contradicts the suggestion that both of Dr Broe's depth gauges were consistently reading too deep.

I also accept the evidence of the charts and the statement of Trevor Jackson, the skipper, that the *Esperance Star* was anchored in very close to 50 metres of water at the point where Dr Broe's final dive was conducted.

The dive safety log showed a maximum depth for Dr Broe's fourth dive as 50 metres. Mr Lloyd accepted he cannot be sure whether he in fact asked Dr Broe the maximum depth of his final dive. He agreed the 50 metre figure recorded may have been adopted from the depth of other divers. I expect this was in fact the case. It was apparent that he did not have a practice of requesting the depths until the divers had completed boarding the vessel. Mr Bartlett also stated that he had no practice of checking the depth gauges of his students.

Conclusion as to dive profile and depth

As a result of considering all of the expert evidence, I consider the dive profile for the fourth dive designed by the students and approved by Mr Bartlett was in accordance with accepted technical diving practice. I am satisfied the incident dive was conducted with due regard to risk management processes accepted within the industry.

I also find that Dr Broe adhered to this dive profile and did not dive to a greater depth than had been planned.

Exiting the water

At the completion of the dive Dr Broe was the first to exit the water. He passed his decompression tanks to others on the boat while sitting on a submerged duckboard. He then climbed aboard the *Esperance Star* via a small ladder carrying his twin compressed air tanks. It is estimated as a result of tests carried out under the guidance of Workplace Health and Safety that the equipment carried on to the boat would have weighed around 47 kilograms. The submission that this weight was miscalculated because it failed to take into account the weight of the gas consumed during the dive is incorrect. The investigator indicated he weighed the cylinders and harness as they were after the incident dive.

While climbing the ladder, Dr Broe slipped and had to be held momentarily to prevent him falling. He then proceeded to walk to the front of the vessel up an increasingly steep gradient to deposit his equipment at the front of the boat. It was soon clear that Dr Broe was in distress; he had one of his hands across his chest, was having difficulty breathing and soon began to complain of a burning sensation in his chest. He was placed in a prone position and first aid treatment commenced.

First aid

Dr Broe was given oxygen from his decompression cylinder while the crew sought an oxygen mask and another oxygen cylinder. As his condition worsened and the regulator would not stay in his mouth, Mr Kamine held it

close to Dr Broe's mouth and used the purge button in the hope that this would at least increase the percentage of oxygen he would be likely to breathe.

The personnel on the boat were adequately trained in first aid and resuscitation techniques and they soon commenced CPR. Attempts were made to resuscitate Dr Broe for more than one hour utilizing a squeeze bag connected to the oxygen cylinder but, of course sadly, without success.

Despite some criticism by one of the experts, I consider the first aid treatment afforded to Dr Broe was appropriate. The length of time over which attempts to resuscitate him continued indicates a determination by those on the boat to do everything within their power to save him.

Very soon after Dr Broe's predicament manifested, the boat headed for port. It was met by the Coastguard vessel carrying paramedics approximately 1 hour and 20 minutes after Dr Broe collapsed. The Care Flight helicopter arrived shortly after. It was apparent nothing could be done to revive Dr Broe.

The Investigation

Queensland Police Service investigation

Detective Senior Constable Anthony Randolph, who was then performing general duties at Redcliffe Police Station, was dispatched to meet the *Esperance Star* on its return to shore. He initially understood his role to be limited to the lodgement of Dr Broe's body at the John Tonge Centre and it was not until some days later that he was advised he would be investigating the matter on behalf of the Queensland Police Service (QPS).

A memorandum of understanding between Workplace Health and Safety Queensland and the QPS is in place and, in part, is designed to clarify relevant roles during the investigation. As was readily acknowledged by Senior Constable Randolph at the inquest the vast majority of the investigation into the events surrounding Dr Broe's death was undertaken by Mr Brian Marfleet, a principal inspector with Workplace Health and Safety Queensland.

Senior Constable Randolph liaised with the QPS diving squad and through them ensured that Dr Broe's diving equipment underwent thorough testing. The only deficiency of note arising from the initial confusion as to Senior Constable Randolph's role was the failure to seize all the personal items of Dr Broe from the boat.

WH&SQ investigation

Mr Marfleet conducted an extensive investigation on behalf of Workplace Health and Safety Queensland which culminated in a prosecution.

Mr Marfleet conducted records of interview with Mark Thomas, Adam Kamine, Rodney Bartlett and Owen Lloyd. Statements were obtained from the other passengers on the *Esperance Star*. All relevant documentation held by Prodive was provided to the investigator. Ms Egeskov then the Senior

Principal Advisor Ergonomics with the Occupational Health Unit of Workplace Health and Safety Queensland, was engaged to conduct an ergonomic analysis of Dr Broe's equipment. Arrangements were made for Dr Broe's depth gauges to be tested and, in the case of the Suunto dive computer, which was no longer working at the time of testing, information was downloaded from its inbuilt hard drive.

Medical opinion was obtained in relation to the conduct of the dive and the cause of death. The contents of Dr Broe's decompression and compressed air tanks were analysed. The conduct of the course was analysed against the DSAT manual and the industry code of practice.

I am satisfied that Mr Marfleet conducted a thorough and professional investigation. I commend him on his efforts.

The cause of death

The autopsy evidence

An external and full internal autopsy was ordered on 29 March 2005 and carried out on 30 March 2005 by Dr Nathan Milne.

In his initial autopsy report of 26 July 2005 Dr Milne concluded the cause of death to be:

> 1. (a) arterial gas embolism, due to or as a consequence of:
> (b) scuba diving

Dr Milne was asked to reconsider his findings in light of expert reports of Dr Edmonds and Dr Mitchell as well as records of interview with the main participants. On consideration of this further material Dr Milne noted the following: -

> *"At the time of finalising my post mortem report, it was my opinion that arterial gas embolism was the most likely cause of the intravascular and intracardiac gas seen on CT scans and post mortem examination. Therefore, it was also my opinion that this was the cause of death. Arterial gas embolism is the presence of gas in the arterial system, and this can result from pulmonary barotrauma in scuba diving. With pulmonary barotrauma there is expansion of air in the lungs which can result in air being forced into the arterial system and embolising to other parts of the body."*

Dr Milne was then asked whether pulmonary decompression sickness could have been the cause of death, to which he replied:-

> *"Yes. After reviewing all of the above material and my initial post mortem report I am now of the opinion that decompression sickness is the most likely cause of death, rather than arterial gas embolism. This is also the cause of death favoured by Dr Edmonds and Dr Mitchell. Decompression sickness results from the formation of bubbles from gases dissolved in the body during diving. The clinical history is more*

supportive of death from decompression sickness than arterial gas embolism. Decompression sickness is also consistent with the post mortem findings. It could also account for some of the gas seen on CT scans and post mortem examination, as bubbles develop in the venous system."

On 22 March 2006 Dr Milne issued an amended autopsy report listing the cause of death as:

1. (a) decompression sickness, due to or as a consequence of
   (b) scuba diving.

A toxicology certificate based on a blood sample taken from Dr Broe revealed a concentration of alcohol at 0.022% as well as traces of Phenytoin. A urine analysis revealed no presence of alcohol.

In his evidence at inquest Dr Milne stated confidently that the alcohol reading was the result of post mortem decomposition. I readily accepted this to be the case.

Dr Milne also expressed a view at inquest that he now considered the arterial gas found in Dr Broe was also formed post mortem. Finally, he responded to a suggestion from other experts that as part of good practice in the conduct of post mortem examinations of individuals who have died while diving, specific note should be made of the presence or otherwise of a patent foramen ovalae (PFO); an atrial septal defect. The significance of a PFO is that it would increase the propensity for nitrogen bubbles in the venous system to cross into the arterial system and thus lead to a variety of problems including arterial gas embolism.

Dr Milne accepted that this was a mistake on his part and was not indicative of any inadequacy in the guidance on dive autopsies available to him. Indeed Dr Milne confirmed by reference to a recent conference he had attended that he was very much cognisant of the protocols for dive autopsies put in place and regularly updated by the Royal College of Pathologists of Australasia.

There was a convergence of views on the issue of best practice in relation to dive autopsies. This was to the effect that the autopsy needs to be done as soon as possible. If the examination can not be undertaken within a few hours of death it is highly desirable for CT scans to be undertaken.

Other expert opinions

The weight of expert medical opinion in this case strongly favours fulminate decompression sickness as the most likely cause of death. This is caused by a massive venous bubble formation of dissolved gas which blocks pulmonary blood flow. It usually presents with chest pain, cough and shortness of breath. It is not associated with the build up of bubbles in the arteries. However, it is now readily accepted there are various other explanations for the build up of arterial gas post mortem. Dr Milne made the salient point that one would expect to see such bubbling in circumstances where there has been post mortem alcohol production as there was here.

As indicated earlier the initial autopsy finding as to cause of death was arterial gas embolism. This is usually a result of pulmonary barotrauma in the context of a diving accident, whereby pressure forces nitrogen through the lungs into the blood stream. There was no evidence of any uncontrolled or unplanned ascent in this case and all of the experts were content to discount this possible cause of death.

Dr Fock noted a second manner in which nitrogen can enter the arterial system, namely, through a PFO or through a process of shunting. This remains a theoretical possibility but was not suggested as a likely cause of death by any of the experts.

After considering the information contained in Dr Broe's medical records, Dr Fock also raised the possibility of a cardiac related cause of death. The scenario put forward by Dr Fock is that Dr Broe's underlying pathology (and in particular possible dehydration suffered as a result of the medication taken for his Conn's syndrome) may have led to hypovolaemia which caused either an arrhythmia and/or relative obstruction of the left ventricular outflow track progressing to cardiac failure and death.

Conclusion as to cause of death

Dr Broe's cause of death has been subject to intense scrutiny by some of the pre-eminent experts in diving medicine. I am appreciative of their willingness to share their knowledge with the court. I accept the majority view that fulminate decompression sickness was the most likely cause of death.

Prosecution arising from WH&S Investigation

Billionaires in Business Pty Ltd and Mark Thomas were charged with breaches of s 24 of the *Workplace Health and Safety Act 1995* in that they failed to ensure other persons were not exposed to risks to their health and safety arising out of the conduct of their business. The particulars of the charge concerned the failure to properly keep the dive safety logs by not recording the Nitrox gas mix to be used by each diver nor the correct maximum depth; the latter particular concerning the entry of 50 metres for Dr Broe's final dive. The charge also encompassed the failure to adequately check and monitor the EANX gas mix used by Dr Broe.

It was further alleged that the breach was aggravated in that it had caused the death of Dr Broe.

On 18 February 2008 both defendants pleaded guilty after WH&SQ agreed to delete the aggravating element from the charge.

Billionaires in Business was fined $15,000 and made to pay legal and investigative costs of $11,000. Mr Thomas was ordered to enter into an $8000 good behaviour recognisance without surety.

Responsibility for the death

It is not the role of a coroner to apportion blame or attribute responsibility for a death. Rather, a coroner is obliged to seek to establish the factual circumstances relevant to understanding how the death occurred. However I have been urged to find the death occurred because the operator did not have sufficient regard to its statutory obligations.

In this case I have found the doctor who undertook the medical examination of Dr Broe did not make all inquiries relevant to determining whether he was fit to dive. The dive operator, quite reasonably, relied on that certification.

Although the operator was prosecuted for failing to adhere to some aspects of appropriate practice, those failings in no way contributed to Dr Broe's death.

I do not consider the operator could reasonably have been expected to refuse to admit Dr Broe to the course and I have found that apart from matters not relevant to Dr Broe's death, they conducted the course in accordance with accepted industry standards and practice.

Abundant evidence persuades me that death can occur in this activity without anybody doing anything blameworthy.

Section 45 findings

A Coroner is required to determine, as far as is possible, who the deceased was, when and where he died, what caused the death and how he came by his death I have already dealt with the last matter, i.e the circumstances of the death. In relation to the other matters I find:-

Identity – The deceased person was Stephen James Broe

Place of death – He died on the vessel *Esperance Star* while it was anchored several kilometres north of Moreton Island in Queensland.

Date of death – Dr Broe died on 28 March 2005.

Cause of death - He died from fulminate cardio-pulmonary decompression sickness incidental to deep water technical diving.

Section 46 recommendations

Section 46 provides that a coroner may comment on anything connected with a death that relates to public health and safety, the administration of justice or ways to prevent deaths from happening in similar circumstances in the future. That requires the coroner to consider whether the death under investigation was preventable and/or whether other deaths could be avoided in future if changes are made to relevant policies or procedures.

In this case the following matters arise for consideration from that perspective:-

- Investigation of dive deaths;
- Unloading deep divers;
- Dive medicals; and
- Diving death autopsies

Investigating diving deaths

As detailed earlier, there was confusion among the police officers who responded to Dr Broe's death as to who was to investigate the matter. That may have been an isolated incident but it did lead to the loss of some evidence in this case and could in other circumstances have significant adverse impact on an investigation.

QPS has a memorandum of understanding with WH&SQ that seeks to ensure the coordination of investigative effort in all cases where both agencies are involved. WH&SQ have recently created a dedicated unit to investigate adverse diving incidents. The MOU should reference the special responsibilities of that unit. Further, in view of the evidence that an autopsy or at least a CT scan should be undertaken as soon after death as possible, the MOU should also require the early notification of the coroner.

Recommendation 1 – Review of QPS – WH&SQ MOU

I recommend the MOU between the QPS and WH&SQ be reviewed to ensure it facilitates the specialist units in both agencies being expeditiously notified of all diving deaths. The review should also involve the Office of the State Coroner so that procedures can be developed to ensure the early notification of the coroner.

CT scanning of deceased divers

Evidence given at this inquest has highlighted the forensic value of a timely CT scan of a deceased diver. While there is a CT scanner available at the Coopers Plains premises of Queensland Health Forensic and Scientific Services, in other parts of the state these scans will need to be undertaken in the radiology departments of the local hospitals. Recent experience demonstrates this may not be easy to arrange at short notice due to uncertainty among hospital managers. This needs to be resolved.

Recommendation 2 – Protocol for CT scanning of deceased divers

I recommend the Director Forensic and Scientific Services cause to be developed a protocol for the CT scanning of deceased divers in Queensland Health regional hospitals.

Unloading deep divers

Dr Fock notes in his first report the potential link between the levels of exertion required to climb back on to the boat and a significant increase in cardiac output and pulmonary pressures. Ms Roxanne Egeskov, then the Senior Principal Advisor Ergonomics with the Occupational Health Unit of Workplace Health and Safety Queensland, conducted a provisional assessment of the methods of handling equipment on the *Esperance Star*. Ms Egeskov noted that, unsurprisingly, the twin cylinder buoyancy compensator system which

made up the bulk of the 47kg[9] carried by Dr Broe was designed for comfort and balance under water. When worn out of water it sat high on the back distributing the weight to the upper body. Ms Egeskov found that the effect of the weight was exacerbated when climbing the vertical ladder at the rear of the vessel due to the transfer of the centre of gravity.

The Court was fortunate to hear from a number of divers with experience in different countries. It seems the practice adopted by the *Esperance Star* was not unusual but other methods are also adopted on occasions. In particular, it is not unusual for the twin cylinders to be un-harnessed, either while still in the water with the assistance of fellow divers or while the diver sits on the duckboard. I don't accept the suggestion this poses an occupational health and safety danger to those then required to lift the tanks. Further there is capacity for this to be managed with mechanical assistance and, of course, the overriding benefit of such a system is that those exerting themselves would not be susceptible to the aggravation of symptoms of decompression illness.

Recommendation 3 – Review of industry code of practice

I recommend WH&SQ consider amending the Recreational Technical Diving Code of Practice to provide guidance to dive operators on preferable methods by which technical divers may reboard the dive platform and highlighting physical exertion following a dive as a risk factor for the onset of decompression illness.

Dive medicals

The expert evidence revealed considerable divergence of opinion as to the role and responsibilities of a medical practitioner undertaking a dive medical examination. This is not in the interests of divers, their doctors or dive operators.

Recommendation 4 – Review of dive medical forms and guidelines

I recommend the Joint Standards Australia/New Zealand Committees overseeing the relevant standards for both recreational and occupational diving review the dive medical forms contained in the relevant standards in light of the evidence in this inquest. In particular, consideration should be given to explicitly stating the role and responsibility of the medical examiner.

Referral to the Medical Board

The Act provides in s 48(4) that a Coroner may give information about a person's conduct to a disciplinary body for the person's profession if the Coroner believes the information might cause the organisation to take steps in relation to the conduct.

The Medical Board of Queensland considers complaints and information about health care practitioners pursuant to Part 3 of the *Health Practitioners (Professional Standards) Act 1999* ('HP(PS) Act'). When considering whether

[9] There is some uncertainty as to whether this was the weight of the equipment when the twin cylinders were full or their weight after the dive. If it is the former, the load Dr Bore carried onto the boat would have been closer to 40kg.

to take action, the Board considers whether the available information appears to provide grounds for disciplinary action against a practitioner registered under the HP(PS) Act as set out in s 124 of the HP(PS) Act. Such grounds include "*unsatisfactory professional conduct*" which, for the purposes of this matter is defined as: -

> *Professional conduct of a lesser standard than might reasonably be expected of the registrant by the public or registrant's professional peers.*

I have found that Dr Emerson should have made further investigations of Dr Broe's sleep apnoea before certifying him fit for all occupational diving. It could be argued this amounts to unsatisfactory professional conduct on his part, warranting referral to the Medical Board.

There is no doubt that Dr Emerson acted in good faith in his assessment of Dr Broe. There is no evidence he was lax or cavalier. As one witnessed observed, diving doctors rarely come across sufferers of OSA as the condition and the activity very rarely involve the same person.

Dr Emerson impressed me as a conscientious and careful practitioner. I expect he will have learned from the material he has been exposed to as a result of participating in this inquest.

The disciplinary regime created by the HP(PS) Act is not punitive in focus: rather it is designed to maintain public confidence in the medical profession and maintain professional standards. In the circumstances of this case I am of the view that nothing would be served by my making a referral to the Medical Board.

I close this inquest.

Michael Barnes
State Coroner
Brisbane
24 April 2009