CHAPTER 8

Hannes Keller and His Secret Mixtures

On December 3 1962, one month after Dan Wilson's 400-foot dive, the Swiss mathematician Hannes Keller reached the astonishing depth of 1,000 feet in the open ocean off Catalina Island. Keller was outside his diving bell *Atlantis* for no more than two minutes and his companion died during the ascent, but the fact remained that an inspired amateur from a land-locked country had demonstrated that the limits to human exploration and exploitation of the sea lay much deeper than all but a few specialists suspected. And that was not all. Had things gone according to plan, after five minutes at 1,000 feet the divers would have decompressed in only four and a half hours: a schedule they had followed without incident on a chamber dive a month earlier. What was the secret?

Keller had started diving in 1958 in the Swiss lakes, making his own regulator out of wood because he lacked the tools to machine metal. It quickly dawned on him that unlike space exploration, diving was a field where an individual carrying out his own research could have a big impact, and that the way to do that was to break the world depth record. Not wanting to settle for half measures, he set himself a goal of 1,000 feet, four times as deep as any oil company was then drilling. First, however, Keller had to find someone who could help him on the physiology side. That man was Dr Albert Bühlmann, chief of the cardio-pulmonary laboratories in the department of medicine at the University Hospital, Zürich. Bühlmann's field was diseases of the lung. He was also involved with aviation medicine—but about diving he knew nothing whatever.

With Keller's knowledge of mathematics and limited experience of diving, and Bühlmann's knowledge of physiology, they started work. Clearly, to get anywhere near as deep as 1,000 feet it was going to be necessary to breathe a helium-oxygen mixture (in an April 1975 interview in *Skin Diver* Keller said he originally wanted to use hydrogen because he was looking for a cheap method; Bühlmann refuted this).

But they saw difficulties. The US Navy, in its original work, had found that for short duration dives to medium depths a longer decompression was needed for helium than

for air. From this, it was concluded that the saturation of the body, and of some tissues in particular, occurred faster with helium than with nitrogen: a hypothesis that Keller and Bühlmann confirmed in the laboratory, establishing the saturation rate for all tissues as 2.65 times faster with helium than with nitrogen. Therefore if helium-oxygen alone were used, the decompression required for a very deep, very short dive would be out of all proportion to the time spent on the bottom.

The procedure devised by Keller and Bühlmann was to compress rapidly with a series of mixtures containing high concentrations of oxygen and a maximum of nitrogen, switching to straight helium-oxygen only towards the bottom, then reintroduce nitrogen as deep as possible in the decompression, with subsequent complete substitution of nitrogen for helium, to accelerate the elimination of helium from the tissues. Decompression was a continuous ascent rather than being done in stages. This combination of switching inert gases and breathing high partial pressures of oxygen throughout the dive (always greater than 2.0 atmospheres) to shorten decompression was naturally kept under wraps and remained the object of intense speculation for several years. The same went for the new method Keller and Bühlmann developed for calculating decompression, with which they formulated some 400 tables for depths to 1,312 feet with the help of a computer at the IBM Centre in Zürich.

In November 1959, Keller descended to 400 feet in the Lake of Zürich in an upturned 50-gallon oil drum weighted down with large stones. Most of the equipment, such as it was, was borrowed, and his emergency ascent device was an old car tyre. It was, Keller admitted, a terrifying experience. The following year he progressed to less hair-raising methods when the French navy, with some prodding from Cousteau, put the chambers of the Groupe d'Etudes et Recherches Sous-Marines (GERS) in Toulon at his disposal.

The first dive, to 820 feet, went off in November 1960, and a further two dives, to 1,000 feet and 700 feet, followed in April 1961. During the compression phase of the 1,000-foot dive Keller went from 300 feet to bottom pressure in two minutes (a compression rate of 350 feet per minute!), which he reported produced dizziness and tremors.

At the time little was made of this. In fact, Keller was exhibiting mild symptoms of HPNS. What Keller and Bühlmann did not know (and neither did anyone else at the time) was that nitrogen, which they were using purely to shorten decompression, also, fortuitously, counteracted HPNS—and Keller was compressing with a maximum of nitrogen most of the way, which conferred maximum protection. It may well be that Keller was minimally susceptible to HPNS anyway, but it is certain that had he tried to duplicate the 1,000-foot GERS dive on helium-oxygen alone he would assuredly have exhibited severe symptoms, including possibly vomiting, with the consequence that the physiological difficulties of rapid descent to great depths would have been confronted many years earlier than they in fact were.

By the time Keller completed the dives at GERS, the news that a wonder boy out of nowhere was diving to great depths with God-knows-what exotic gas mixtures—and returning to the surface with seemingly ridiculously short decompressions—was reverberating throughout the professional diving community. As Dr Val Hempleman, then Superintendent of the Royal Naval Physiological Laboratory (RNPL) at Alverstoke, put it:

'He was making all us conventional diving groups—USN, RN and French navy—look like a group of yesterday's men with no real grasp of the correct diving physiology necessary

for safe, but rapid, decompression. The interested scientists and diving physicians began to take sides in the debate about how Keller was succeeding to apparently make fools of us all.'

Nowhere was the debate more bitter than in the USA. Captain George Bond, later credited as the father of saturation diving, was convinced that Keller had hit upon a successful technique that should be acquired by the US Navy. Captain Robert Workman was equally convinced there was nothing to be gained. In the end, it was agreed that since as far as they knew Keller had only made deep dives with a few seconds at bottom pressure, the navy should offer him a contract to demonstrate a dive to 700 feet with ten minutes at maximum depth.

Further controversy ensued when Keller and Bühlmann, who thoroughly distrusted the US Navy, demanded complete control of the chambers at NEDU in Washington, where the dive was to take place. This was unheard of. The US Navy was not accustomed to handing over its facilities to foreigners, still worse to those from a country with no coastline.

Keller being suited up at the US Navy Experimental Diving Unit (*US Navy*)

Eventually a compromise was worked out and the dive went ahead on May 10 1961, with Keller decompressing in the mind-boggling time of approximately 100 minutes. Hempleman, who was present at the demonstration, was so astonished by Keller's performance that he followed him around for several hours afterwards, expecting to see some adverse reaction; but Keller was totally unaffected. Looking back some 30 years later, Hempleman recalled:

'This was apparently a victory for the Keller approach and it caused a tremendous rise in support for deep diving in the US and Europe. The USN could not be told how

to conduct deep diving by Swiss amateurs: pride was at stake and research on decompression received support in all interested countries. It was as if circumstances had conspired to focus attention on deep diving research at a time when the knowledge gained in this burst of activity would be very useful shortly afterwards for the exploitation of offshore resources. All credit to Hannes Keller for disturbing the peace, gaining amazing publicity, and thereby provoking systematic deep diving work!'

Nonetheless, the general reaction at NEDU to Keller's demonstration dive was that he was a physiological freak, and there was considerable doubt whether the procedure would work with anyone else. Keller decided the only way he was going to prove that his method was valid, and persuade the US Navy to give him a research contract, was to take someone else with him on a deep dive.

Having a flair for publicity, Keller went to see Kenneth MacLeish, an editor at *Life*, and proposed that he buy a round-trip ticket to 700 feet. The price: $2,000. *Life* would get a dramatic and unusual story, and Keller would show the navy and everybody else that an ordinary human being could make such a dive and return to surface pressure without incident, just as he had. Understandably, MacLeish wanted to know what he was letting himself in for. How dangerous was it? Very dangerous, replied Keller, adding that he himself was frightened. Such an honest admission satisfied MacLeish that he was not dealing with a lunatic, and he agreed to go.

The dive took place on June 28 1961 off Locarno, at the Swiss end of Lake Maggiore, in the presence of Lieutenant Commander Charles Aquadro, the official US Navy observer. There was no diving bell. The divers were lowered from a raft, on a platform that Keller and his assistants had built specially for the dive, breathing through mouthpieces from onboard cylinders of premixed gas. Earlier on, convinced—correctly—that everyone was trying to find out the composition of his gas mixtures, Keller had planned on diving with a home-made closed-circuit breathing apparatus. On a visit to Keller's workshop in Winterthur, Hempleman and others from RNPL, seeing he was barely aware of the difficulties involved, persuaded him to go to open-circuit, even though it would be more costly in gas usage and was also liable to donate free gas samples of his secret mixtures.

Keller, in the constant-volume dry suit, before the dive in Lake Maggiore

There were four changes of gas on the way down and four on the way up, starting and ending with pure oxygen and preceded at the surface by one hour of oxygen to flush the nitrogen out of the tissues. Both divers wore Spirotechnique constant-volume dry suits, with two bottles of 'universal mixture' on their backs in case of an emergency ascent. MacLeish received three days of training, and then it was straight to a new world record of 728 feet. Whereas the Royal Navy had taken almost 12 hours to decompress George Wookey from his five-minute stay at 600 feet—which admittedly included

treatment for a minor bend—Keller and MacLeish went from the surface to 720 feet and back in one hour.

Having thus shown the sceptics that their approach was indeed applicable to the average man, Keller and Bühlmann got two research contracts with the US Navy for a series of deep dives, using different subjects, to 500 feet, 650 feet, 820 feet and 1,000 feet. The dives took place in 1962 at the University Hospital, Zürich, in a two-place chamber designed by Keller and built by the Swiss firm Sulzer. Those dives led up to the 1,000-foot dive at Catalina Island.

For the dive in the Pacific, there was no question of descending and ascending exposed to the water as in Lake Maggiore. This time Keller drew up a plan for a cylindrical diving bell 7.5 feet high and 4 feet in diameter, which Sulzer then manufactured. Financial support for the venture came from the US Navy, with Shell Oil, as observers, providing the coring vessel *Eureka* as the support ship. According to the *Life* article that appeared after the event, MacLeish had intended accompanying Keller again. For whatever reason, that did not happen; and the second diver was the English journalist Peter Small, a co-founder of the British Sub-Aqua Club who had recently left Fleet Street to take on the club's new magazine *Triton*.

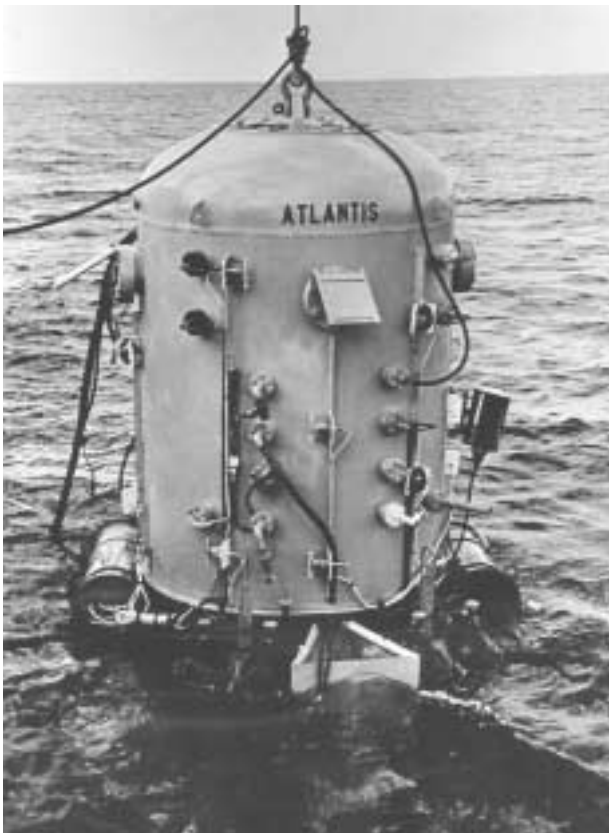
On October 30 1962 in the last dive of the US Navy series, Keller and Small spent five minutes at 1,000 feet in the University Hospital chamber. Decompression lasted 270 minutes with the divers breathing the following mixtures through mouthpieces:

Bottom	8% oxygen, 92% helium
500 feet	15% oxygen, 60% helium, 25% nitrogen
165 feet	30% oxygen, 70% nitrogen
133 feet	50% oxygen, 50% nitrogen
50 feet	100% oxygen

This was a dry run for the open-ocean attempt and went off without any decompression sickness or other difficulties.

On December 1st, after arriving in California, Keller and Small made a 60-minute dive in the *Atlantis*, swimming out of the bell in turn at 330 feet. Decompression was 126 minutes, again without any symptoms of decompression sickness. *Newsweek* later reported, however, that Small had had the bends several times before the 1,000-foot dive and that this had led the US Navy to try to persuade Keller to replace him, but without success. Given that there was a good deal of inaccurate information circulating after the dive, the report may have been incorrect.

As before, the divers wore constant-volume dry suits. Since it has a bearing on subsequent events, it is important to understand that in the constant-volume suit the face mask and mouthpiece are built into the hood, which clamps to the neck of the suit. By exhaling into the suit instead of through the mouthpiece, the diver can adjust his buoyancy, thereby maintaining a constant volume at any depth. Valves at the head and feet prevent over-pressuring. On the surface, the detachable face mask glass is left open, hanging on a retaining chain. Although they were in the dry, Keller and Small kept their faceplates closed throughout the dive—as on the chamber runs, to save money the bell was filled with air not helium—breathing the various gases from cylinders outside the bell by way of a semi-closed system that scrubbed the carbon dioxide.



Atlantis **off Catalina Island** (*Paul Tzimoulis*)

The dive was started and stopped twice because of bad weather. On the third attempt the bell reached the target depth in 16 minutes as planned, with Keller, in contact with Bühlmann by telephone, pressurising the bell as it descended. Pressurisation could not be done on the bottom because the *Atlantis* had an internal hatch but no external hatch, and therefore relied on pressurisation to keep the water out during descent. Down to 600 feet, the divers breathed a maximum of nitrogen, then switched to helium-oxygen. The bottom mix, as on the chamber dive in Zürich, was 92% helium, 8% oxygen.

On arrival, Keller, breathing from bottles on his back, left the bell. Quite what happened next is unclear. Some sources said Keller was outside for two minutes, and that he tried to plant the Swiss and American flags in the bottom. A navy observer who was watching the picture from one of the two external television cameras was reported in *Newsweek* as saying that he saw someone get on the ladder and drop the flags, and that the excursion lasted no more than 30 seconds.

Either way, when Keller returned to the bell and reconnected to the onboard gas supply, he realised that the external cylinder of deep mix was almost empty. Later it was thought that a pressure reduction valve had leaked, although it subsequently proved impossible to reproduce the situation. Knowing he could not continue to breathe from the mouthpiece, Keller opened his faceplate and immediately passed out (breathing air deeper than 600 feet results in loss of consciousness). Small was instructed to do the same, but for some reason did not comply. The bell was then raised to 200 feet in a continuous ascent

lasting 17 minutes as scheduled, at which point Keller regained consciousness and opened Small's faceplate. Keller now closed the hatch to seal the bell so that it could be brought on deck; but it quickly became apparent the *Atlantis* was losing pressure.

The two safety divers, Dick Anderson and Christopher Whittaker, a 19-year-old English friend of Small's, twice swam down to the bell to see what was wrong. On the second dive, they discovered the end of a swim fin stuck in the hatch; as soon as Anderson cut it away the leak stopped. Whittaker, who had appeared fatigued after the first dive, failed to surface from the second descent. His body was never found.

By the time the bell was lifted on board, the internal pressure was at 165 feet. Keller was breathing the 50% oxygen, 50% nitrogen mixture called for at that point in the decompression. At 50 feet, he switched to 100% oxygen. Ninety minutes after Keller opened Small's faceplate, Small recovered enough to be able to talk, after which it appeared to Keller that he fell asleep.

In the meantime the *Eureka* set course for the Long Beach Naval Station, on the assumption that after what had happened both divers might need to be recompressed in a facility equipped for prolonged treatment. During the crossing from Catalina, the decompression was extended from the planned 270 minutes to 410 minutes to hold Keller and Small under pressure until the vessel docked.

When the *Eureka* tied up, the bell was lowered to the quay. Keller emerged in good condition, without any indication of bends; Small, who Keller had thought was asleep, was dead: exactly when he had died is not clear.

Thus a giant leap into the depths ended in tragedy, rendered still more tragic shortly thereafter by the news from England that Small's wife Mary had committed suicide. Not until 1975 would divers again reach such depths in the sea.

After the accident, Keller and Bühlmann continued to maintain a veil of secrecy around their 'magic gases' as far as the press was concerned; but in 1963, as part of their contract with the US Navy, Bühlmann submitted a report to Captain Workman in which he gave complete details of the breathing mixtures and dive profiles. Two years later, for the benefit of their scientific colleagues, Keller and Bühlmann co-authored a paper in the *Journal of Applied Physiology* entitled 'Deep diving and short decompression by breathing mixed gases'. In the circles that counted, the guessing was over.

That was not the end of the story, however. On hearing of the deaths at Catalina Island, the Italian company Micoperi had approached Shell International Petroleum in The Hague. The Italians said that much as they regretted the loss of life, Keller had at least shown that it was possible to go to 1,000 feet and survive, and they urged Shell to fund Keller and Bühlmann to do further research. The persuasion worked.

In 1964, Keller and Bühlmann signed a contract with Shell. A new chamber facility, large enough to allow prolonged experiments, was installed at the University Hospital. Work began with saturation dives to 100 feet to determine the longest half-time values for helium and nitrogen, then progressed in 1965–66 to bounce dives to 720 feet. At the same time, Shell set up a field-testing programme in the Mediterranean with Micoperi, using a large specially designed combination habitat-diving bell, *Capshell*. In August and September 1966 professional divers from Micoperi and sport divers from Switzerland made a 100-foot saturation dive, followed by three bounce dives and one saturation dive to 720 feet. After the dives, Shell and Micoperi formed a 60/40 joint-venture company, Sub Sea Oil Services.

The Shell research contract ended in February 1981. Between 1965 and 1981, Bühlmann conducted some 40 dives to 650 feet and deeper, the last and deepest to 1,650 feet, with an excursion to 1,900 feet. By then, seeing the Swiss and Italian research as too academic, Shell had turned their attention to Norway, to more practical research in support of projects such as the laying of a pipeline across the Norwegian trench.

In November 1990, after 42 years, Bühlmann retired from the University Hospital. Meanwhile Keller was making a great deal of money writing computer software, and playing the piano at public concerts with a German business associate, with whom he recorded on his own CD label—called, aptly enough, 'Vive Les Amateurs'.

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