

# Limits for underwater noise exposure of human divers and swimmers

Steve Parvin

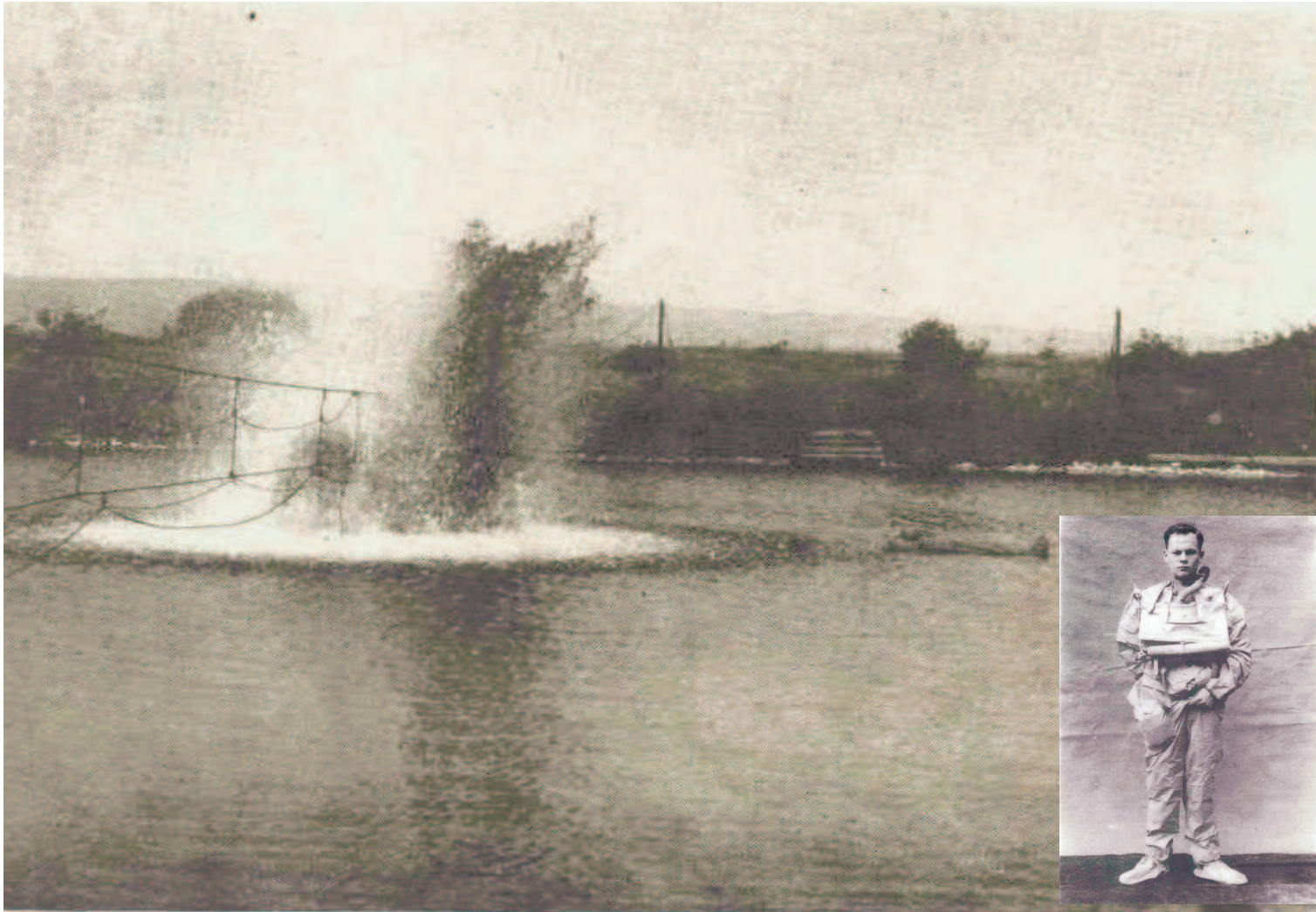
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# Introduction

- Historic Blast Data
- Underwater Hearing Threshold Levels
- Diver Aversion Response Levels
- Tolerance Levels
- Auditory Injury Levels
- Guidance levels for recreational and military divers

# Historic Blast Data



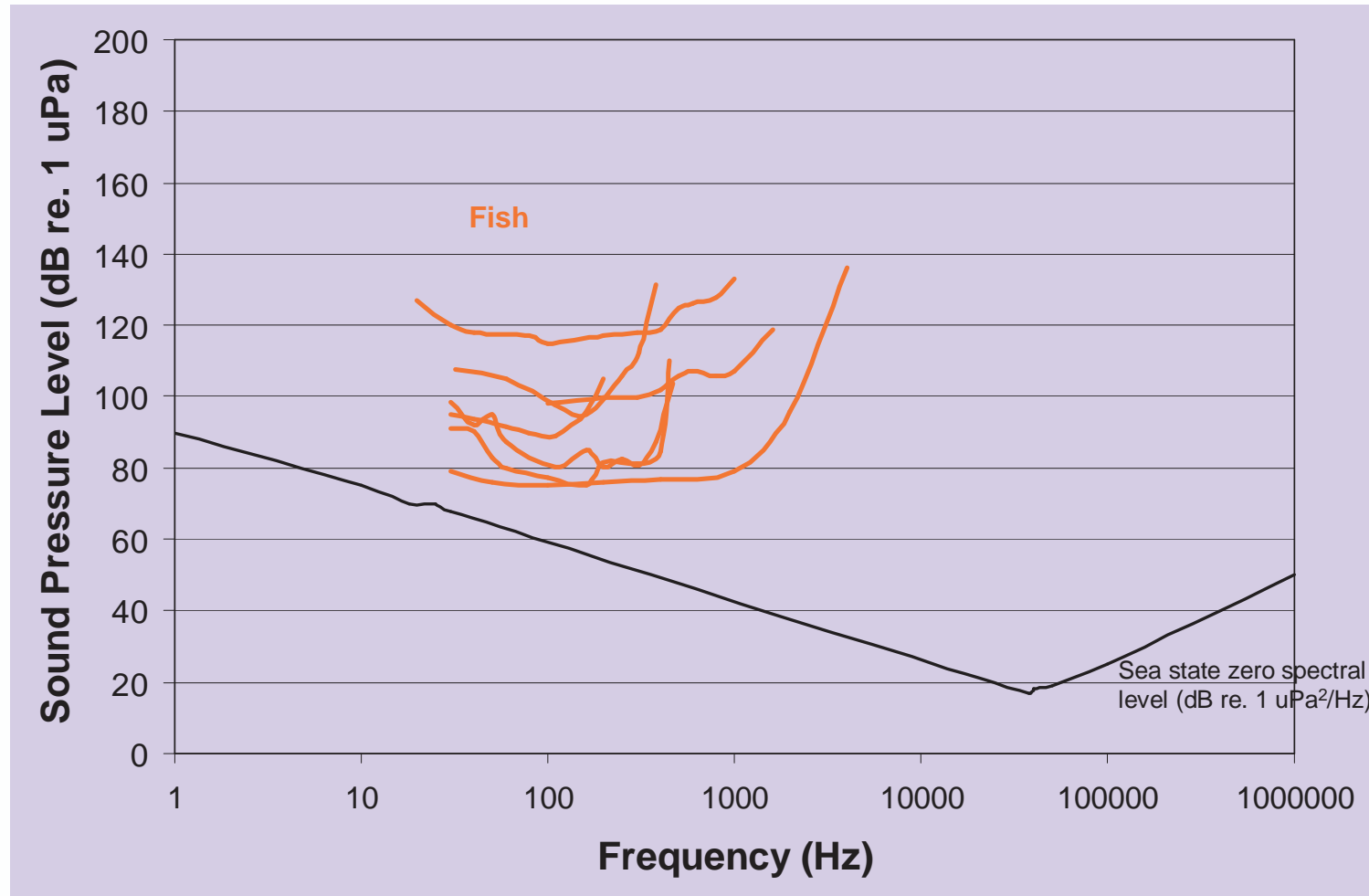
# Historic Blast Data

Subjective comment from a diver exposed to a 5 lb (2.27 kg) charge of TNT)

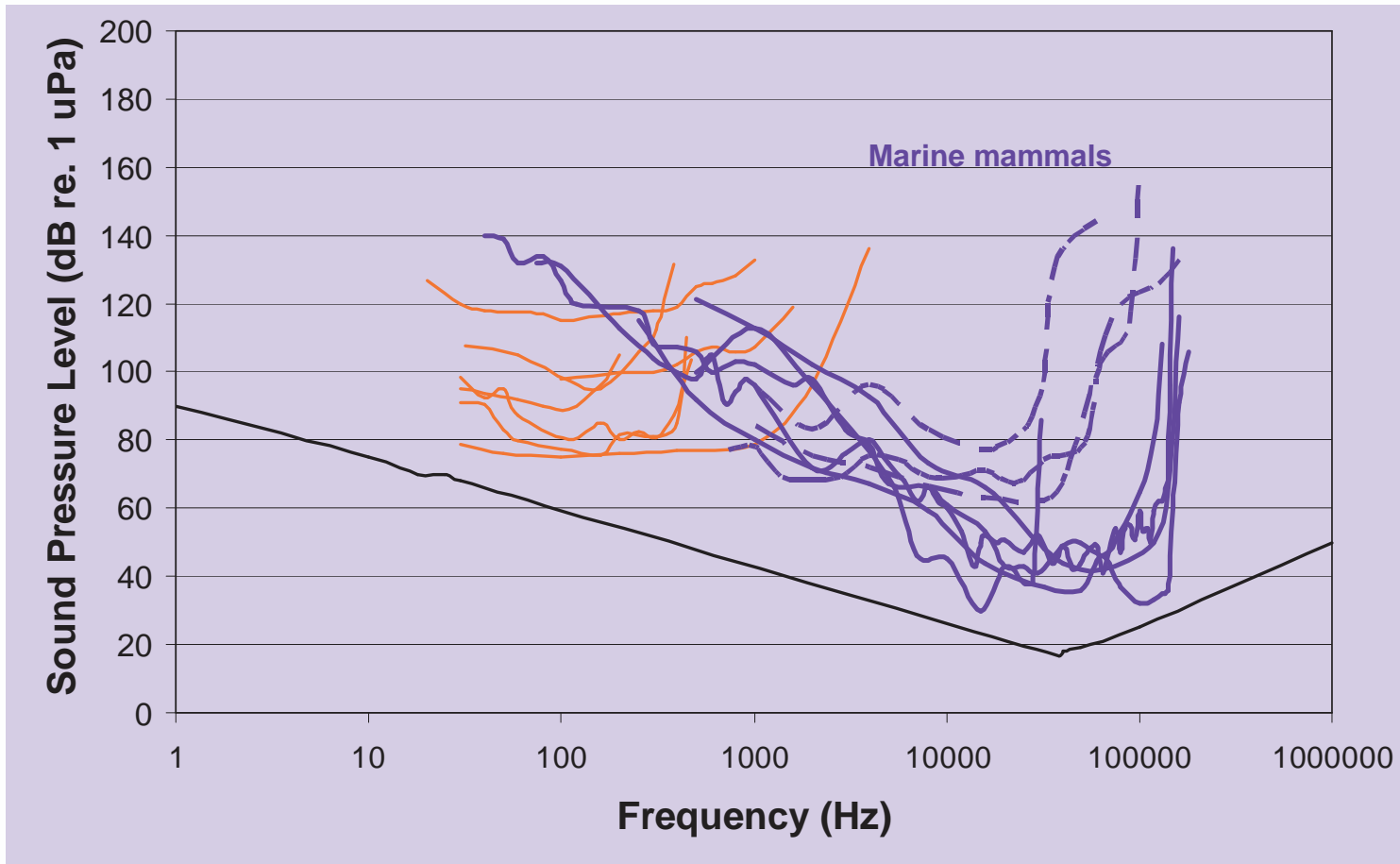
Range		Sensations	Estimated Shock Levels			
feet	metres		P psi	P MPa	I psi-msec	I Pa.s
110	33.5	Sound of intense bang.	160	1.1	75	516
100	30.5	Intense bang. Mild blow on chest.	175	1.2	85	585
90	27.4	Severe blow on chest.	195	1.3	95	654
80	24.4	Blow on head and torso. Body shaken. Brief paralysis of arms and legs.	220	1.5	105	720
75	22.9	Violent blow. Brief paralysis of limbs. Substernal pain for 1/2 to 1 hour.	240	1.65	110	760
70	21.3	Violent blow. Temporary paralysis of limbs. Substernal pain lasting several hours. Aural damage. Tongue lacerated. Mask blown off. Mild concussion.	260	1.8	115	790

Wright H C, Davidson W M and Silvester H G. *The effects of underwater explosions on shallow divers submerged in 100 feet of water*. Royal Navy Physiological Laboratory report RNP 50/639, October 1950.

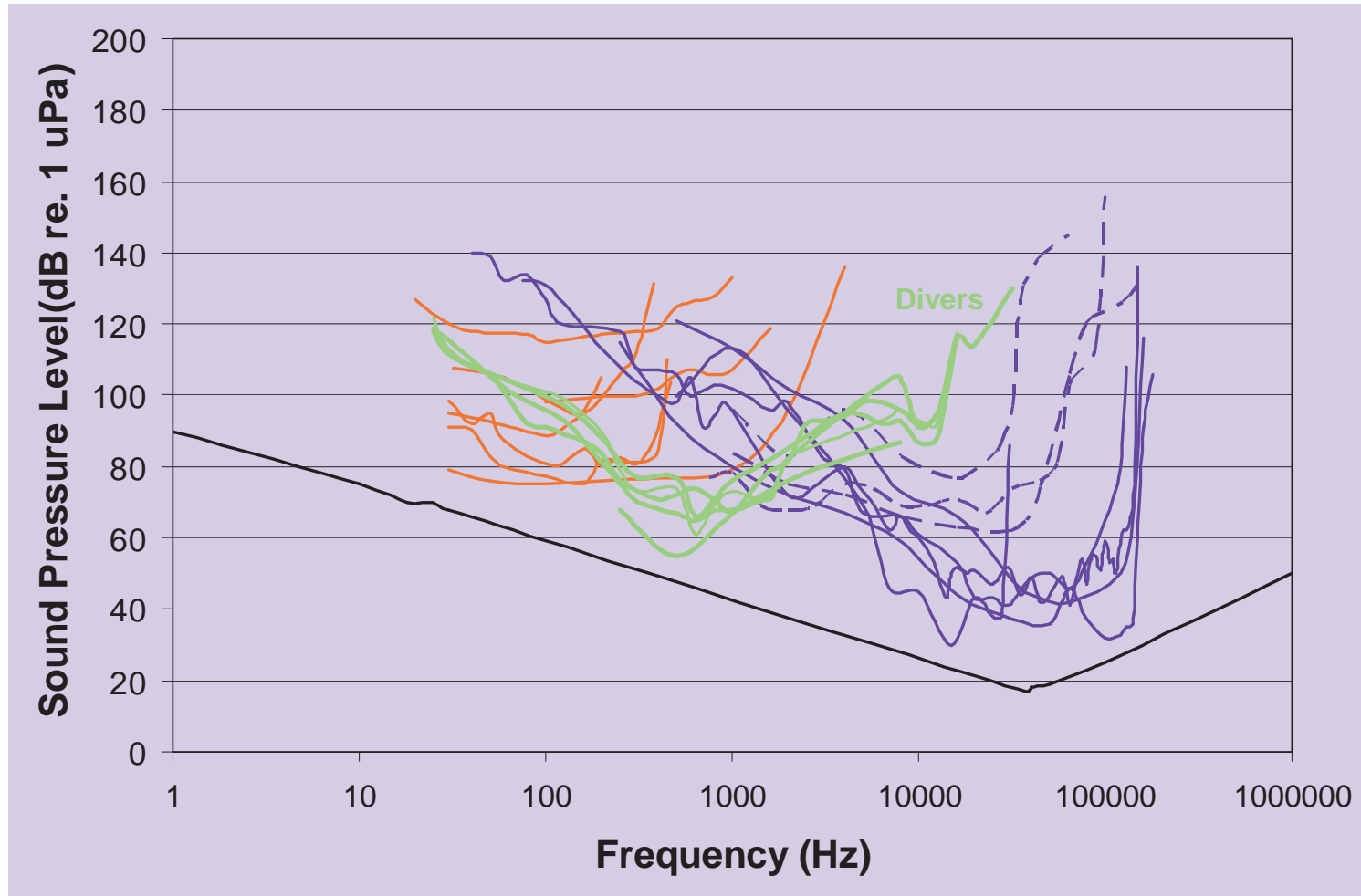
# Underwater Hearing Threshold

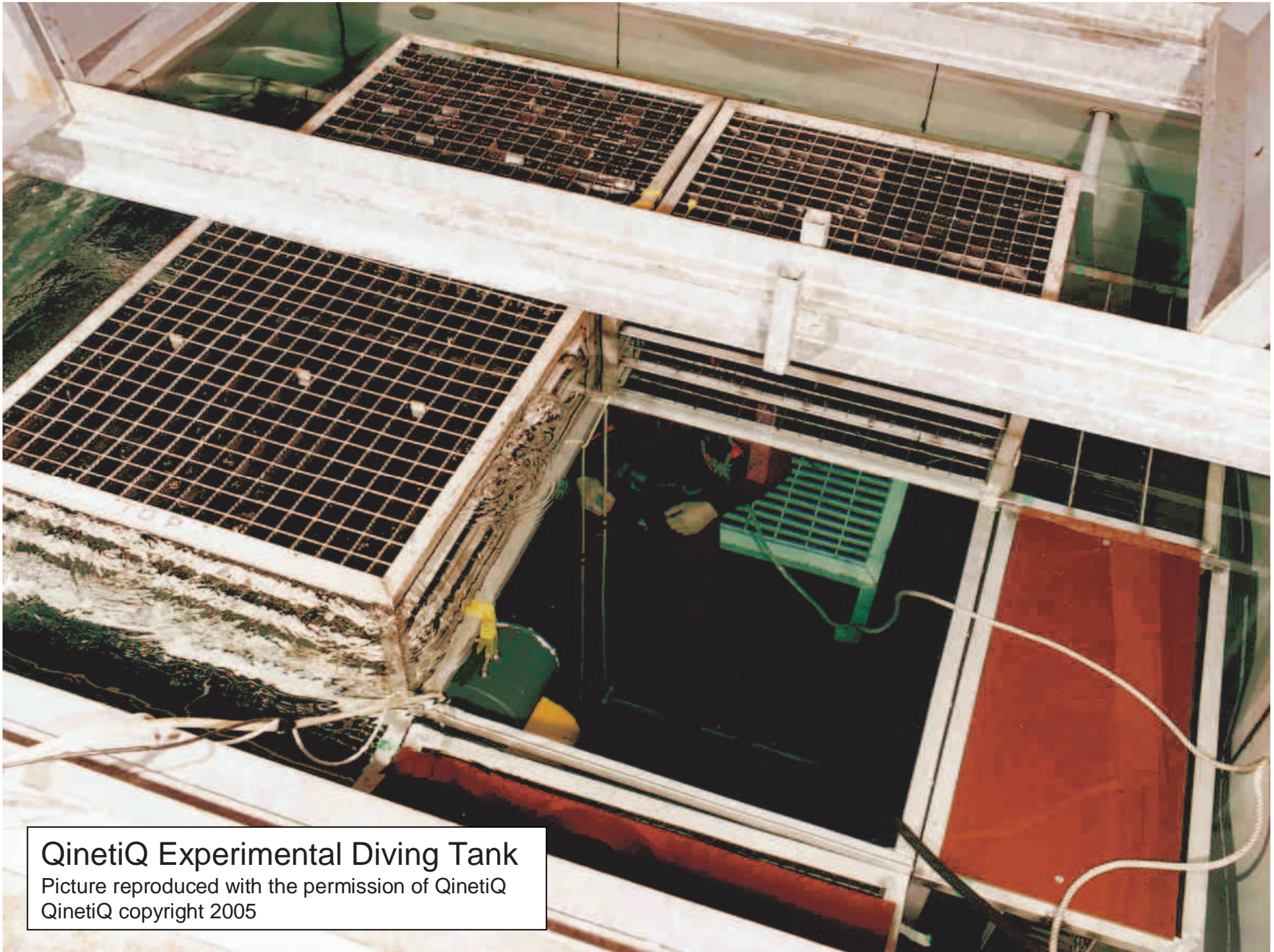


# Underwater Hearing Threshold



# Underwater Hearing Threshold

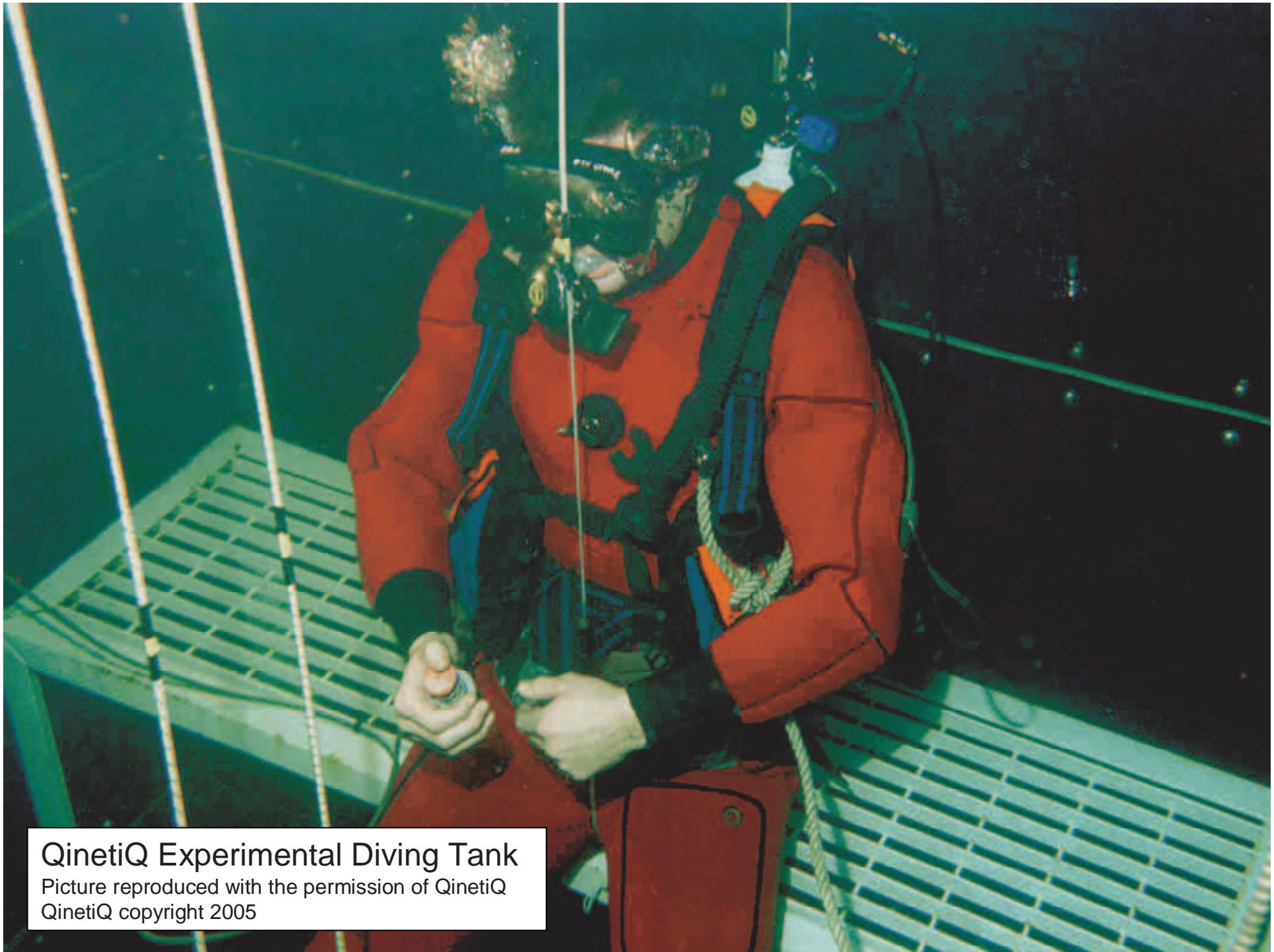




## QinetiQ Experimental Diving Tank

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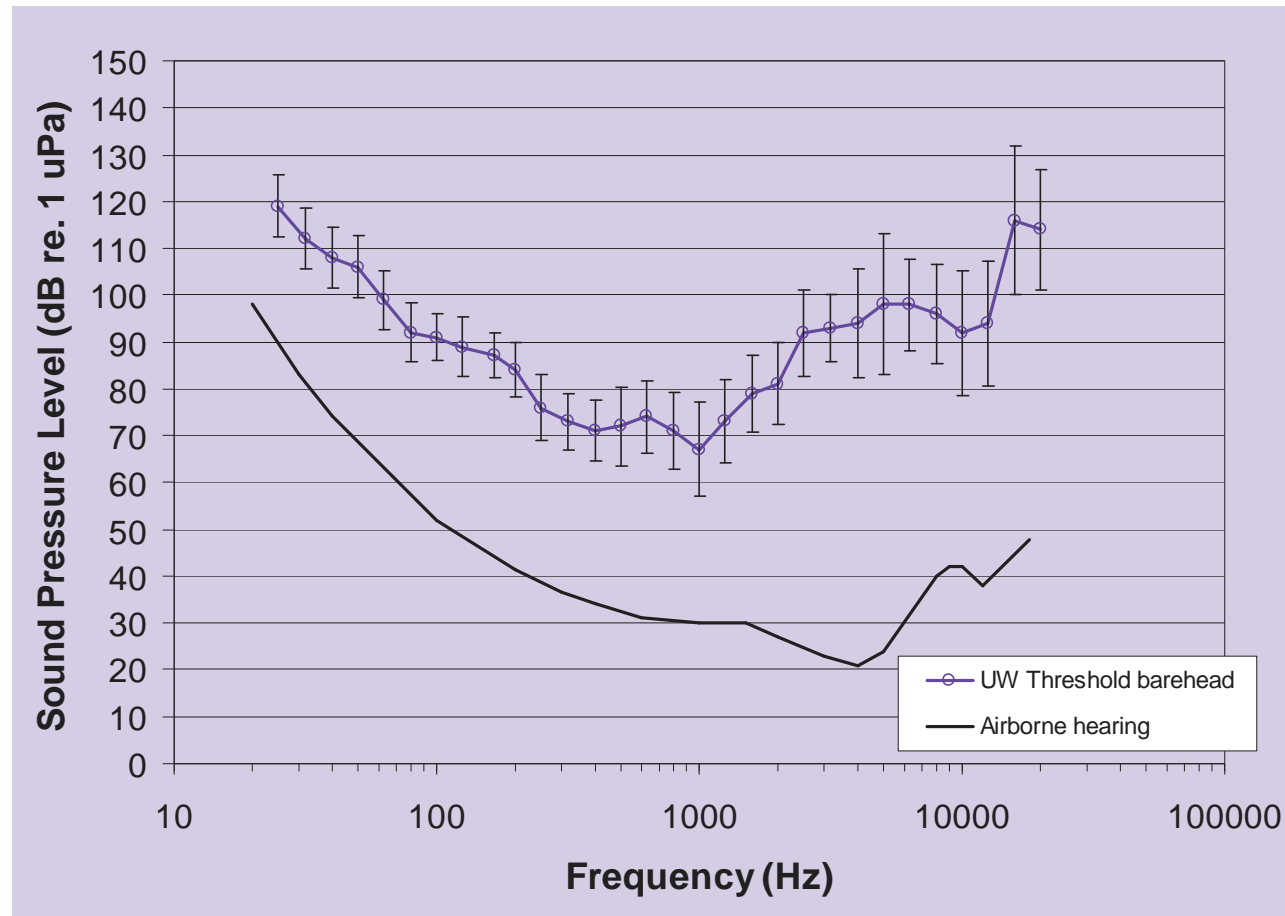




## QinetiQ Experimental Diving Tank

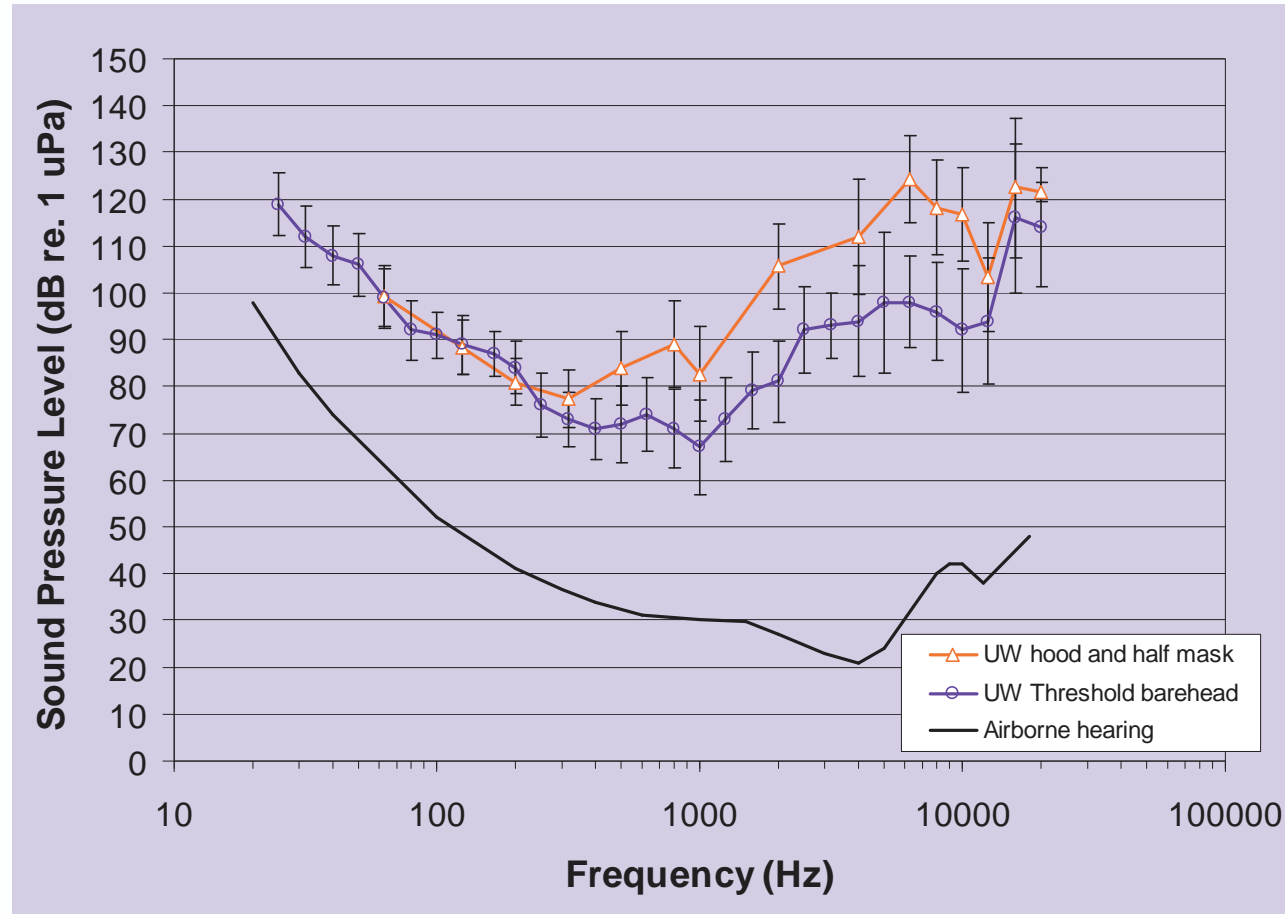
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# Underwater Hearing Threshold



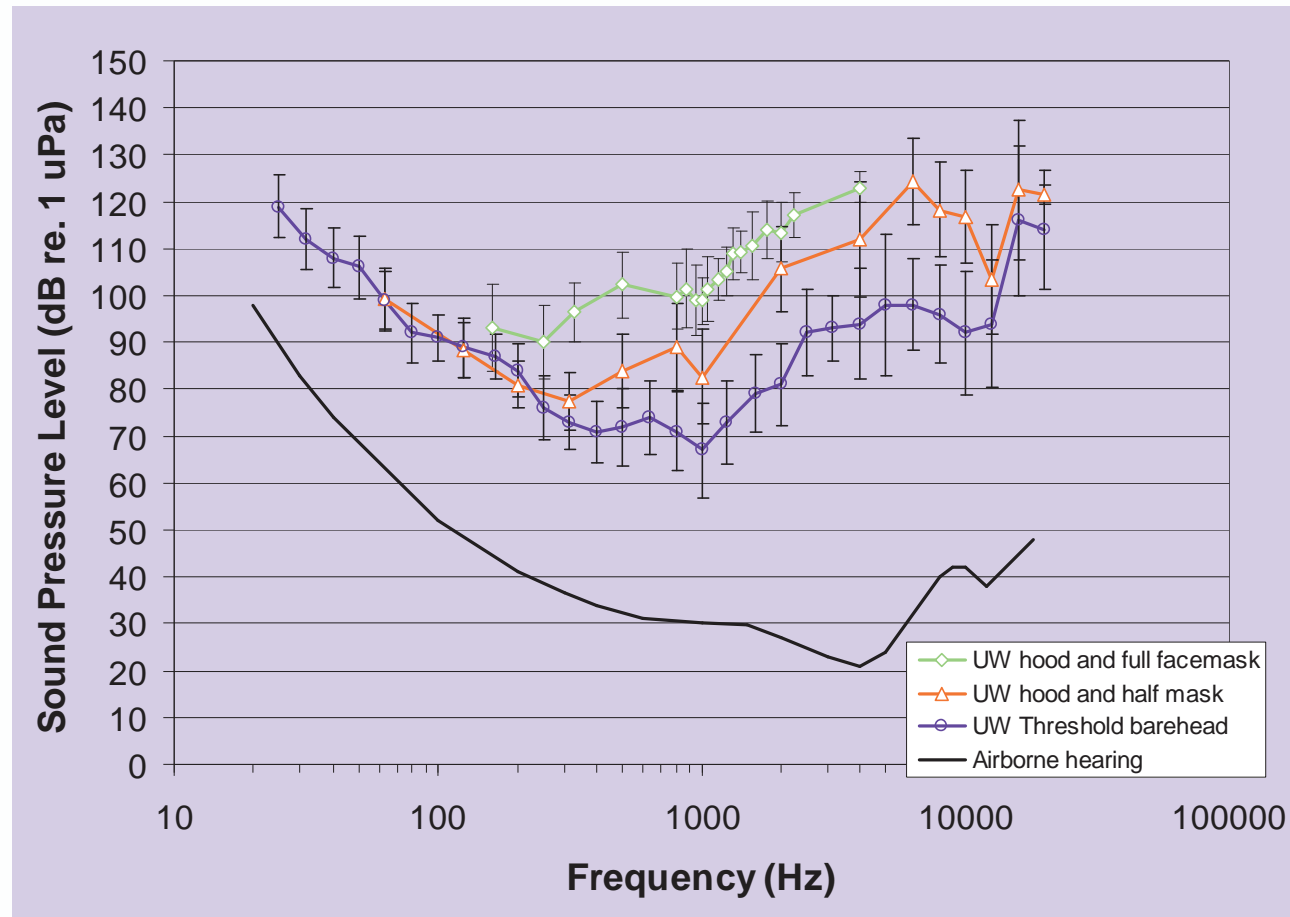
Parvin S J. *The effects of low frequency underwater sound on divers*. Proceedings of Undersea Defence Technology, pp227-232, Wembley, 1998.

# Underwater Hearing Threshold



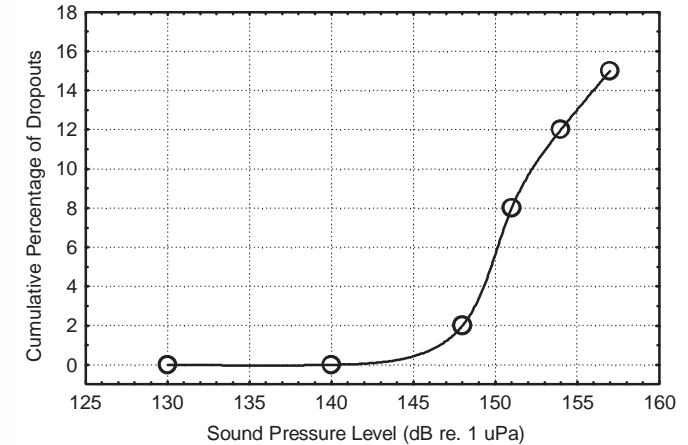
Parvin S J. *The effects of low frequency underwater sound on divers*. Proceedings of Undersea Defence Technology, pp227-232, Wembley, 1998.

# Underwater Hearing Threshold



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# Diver Aversion Response



Significant subject dropouts due to rating of underwater sound as 'very severe'.

- 100 – 500 Hz @ 148 dB re. 1  $\mu$ Pa
- 500 – 2500 Hz @ 157 dB re. 1  $\mu$ Pa

Fothergill D M, M D Waltz, and S.E. Forsythe. *Diver aversion to low frequency underwater sound phase II: 600 – 2500 Hz.* Undersea and Hyperbaric Medicine 27 (Suppl): 18, 2000.

Fothergill D M, J R Sims, and M D Curley. *Recreational SCUBA divers' aversion to low frequency underwater sound.* Undersea and Hyperbaric Medicine 28: 9-18, 2001.

# Tolerance Levels

Summary of minimum SPL causing termination of underwater sound signals in bareheaded divers.

Frequency (Hz)	Termination SPL (dB re.1 $\mu$ Pa)	Reason for Termination
880	182	Sound affected balance, dizziness.
1000	182	Sound affected balance, dizziness.
1400	176	Uncomfortably loud, dizziness
1760	185	Loudness, dizziness
2200	185	Loudness
900 -1250	179	Loudness and dizziness
1400 - 1800	182	Uncomfortably loud. Dizziness at beginning of the sweep
1800 - 2200	185	Loudness

Parvin S J, Searle S L and Gilbert M J. *Exposure of dives to underwater sound in the frequency range from 800 to 2250 Hz.* Undersea and Hyperbaric Medicine, Vol 28 (Suppl): p 44, 2001.

# Auditory Injury Levels


Summary of Sound Pressure Levels causing a 10 dB TTS in bareheaded divers after a 15 minute continuous noise exposure (dB re. 1  $\mu$ Pa)

	500 Hz (n=11)		1000 Hz (n=6)		2000 Hz (n=13)		4000 Hz (n=11)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
SPL in water	174.5	16.6	167.1	8.9	176.2	15.8	179.0	17.4
SPL in air	132.7	12.1	119.9	4.1	123.2	5.1	123.1	8.2
SPL difference	41.8	17.6	47.2	7.3	53.0	15.5	55.9	14.2

Smith P F, Sylvester R, Carpenter S, Ivey L. and Steevens C.C. *Temporary auditory threshold shifts induced by intense tones in air and water.* Undersea and Hyperbaric Medical Society annual scientific meeting, Anchorage, Alaska, 1-5 May 1996.

# Summary

## Bio-effects of low frequency underwater sound (100 to 500 Hz)



SPL dB re.1 $\mu$ Pa	Effect 100 to 500 Hz
184 +	Based on animal models liver haemorrhage and soft tissue damage are likely.
170+	Tolerance limit for divers and swimmers. Sound causes lung and body vibration.
148 -157	The loudness and vibration levels become increasingly aversive. Some divers will contemplate aborting an open water dive.
140 -148	A small number of divers rate the sound as 'very severe'.
136 -140	The sound is clearly audible. The majority of divers tolerate the sound well with only "Slight" aversion.
130	Divers and swimmers able to detect body vibration
80 -100	Auditory Threshold



# Summary

## Bio-effects of underwater sound (500 to 2500 Hz)



SPL dB re.1 $\mu$ Pa	Effect 500 to 2500 Hz
190 +	Hooded diver tolerance limit
167 - 185	Tolerance limit for barehead divers and swimmers. Sound causes dizziness and disorientation. Divers in suit and hood are able to tolerate the sound well.
155 - 166	Divers tolerate these sounds well, although an increasing number of bareheaded divers indicate a 'severe' aversion rating.
140 - 154	Sound is clearly audible to divers. Sound is tolerated well with only slight aversion.
100 - 140	Divers hear underwater sound, but it is masked by exhaust bubble noise.
80	Hearing threshold for hooded divers
65	Hearing threshold for barehead divers

# Guidance

## Recreational divers and swimmers

Frequency range	100 – 500 Hz	501 – 2500 Hz
SPL (dB re. 1 $\mu$ Pa)	145	155

## Military divers

Frequency range	100 – 500 Hz	501 – 1500 Hz	1501 – 2500 Hz
SPL (dB re. 1 $\mu$ Pa)	160	180	190

Parvin S J, Cudahy E A and Fothergill D M. "Guidance for diver exposure to underwater sound in the frequency range from 500 to 2500 Hz. Proceedings of Undersea Defence Technology, La Spezia, Italy, 2002.

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