

CAN FRANCESCO DE MARCHI'S TREATISE BE USED AS EVIDENCE OF A REVOLUTIONARY APPLICATION OF A DIVING BELL VENTILATION SYSTEM AS EARLY AS 1535?

Adam Olejnik¹⁾, Piotr Siermontowski¹⁾, Bartłomiej Jakus¹⁾, Małgorzata Samborska²⁾

¹⁾ Department of Underwater Technology, Polish Naval Academy

²⁾ Polish Society of Hyperbaric Medicine and Technology

ABSTRACT

The material presents an analysis of the treatise by Francesco de Marchi with regard to the use of a diving bell described therein, developed by Guglielmo da Lorena in 1535. The analysis was conducted on the basis of the original 1599 text *Della Architettura Militare*, incorporating contemporary knowledge in the fields of underwater work technology, diving physiology and medicine, and the history of technology.

Based on an estimation of the bell's volume, pressure conditions, and the application of a validated ventilation model for hyperbaric facilities, the theoretical duration of the device's protective function and the time required to reach the critical partial pressure of CO₂ were determined. The results indicate that, without active air exchange, prolonged underwater stay would have been physiologically unlikely.

In light of the conducted analysis, de Marchi's treatise does not provide sufficient grounds to formulate a hypothesis about the existence in 1535 of an advanced ventilation system analogous to solutions known from later constructions.

Keywords: underwater technology, theory of deep-sea technology development.

ARTICLE INFO

PolHypRes 2026 Vol. 94 Issue 1 pp. 7 – 18

ISSN: 1734-7009 **eISSN:** 2084-0535

DOI: 10.2478/phr-2026-0001

Pages: 7, figures: 1, tables: 1

page www of the periodical: www.phr.net.pl

Publisher

Polish Hyperbaric Medicine and Technology Society

Original article

Submission date: 14.12.2025 r.

Acceptance for print: 12.01.2026 r.



INTRODUCTION

The turn of the 15th and 16th centuries was a period when ancient culture was rediscovered in Europe. It was then that the European elite returned to their roots, taking an interest in even the smallest manifestations of culture. It was also the moment when underwater archaeology was born [1]. Guglielmo da Lorena (Master of Lorraine) is considered one of its fathers. In July 1535, together with Francesco de Marchi, he used an open diving bell to explore shipwrecks – palaces built on the orders of Emperor Caligula in the 1st century AD and sunk immediately after the end of his short reign in Lake Nemi, located about 30 kilometers southeast of Rome in the Castella Romania region [2].

Joseph Eliav's article published in *The International Journal for the History of Engineering & Technology* in 2015 describing this event is based on an analysis of the text contained in Francesco de Marchi's book entitled „*Architectura militare*” [3]. In the conclusion of his article, Eliav puts forward a bold hypothesis, assuming that de Marchi's text is based on facts, that Guglielmo da Lorena, many years before Edmund Halley, invented a mechanism for effective ventilation of a diving bell based on pressure differences. Eliav's hypothesis is based on the following premises [3]:

1. Da Lorena's bell must have had some kind of air exchange mechanism, otherwise the diver would have drowned at a shallow depth, while de Marchi writes, based on his own experience of diving in this bell, that it could last up to two hours and be carried out at depths of 5 to 12 meters.
2. Francesco de Marchi categorically rules out the use of a tube connecting the de Loren bell to the surface.
3. Da Lorena's bell used an undisclosed air exchange mechanism that allowed the pressure and volume of air to be maintained so that the water level in the bell did not change.
4. The method developed by Edmund Halley in 1791 allows the above conditions to be met.
5. According to J. Eliav, Guglielmo da Lorena had access in 1535 to technology that allowed him to build the same solution as Edmund Halley in 1791.

Therefore, based on his own analysis of the source text developed by Francesco de Marchi, Joseph Eliav hypothesizes that two engineers who encountered a similar technical problem solved it in a very similar way, despite the centuries of scientific and technical progress that separated them. Eliav points out that this is a bold hypothesis, based on the credibility of de Marchi's book. However, in the opinion of the authors of this study, this hypothesis is too far-fetched, as we will attempt to prove below.

METHOD

The evidence was based on an analysis of the same passages from Francesco de Marchi's work used by Joseph Eliav, namely passages from chapter 82 of the book, between pages 356 and 366, as well as chapter 84. These

passages had been translated by expert Italian translators. The analysis was based on the translated text.

The analysis was carried out on the basis of contemporary information in the fields of underwater technology, human physiology and medicine, as well as general history and the history of technology.

ELEMENTS OF DE MARCHI'S DESCRIPTION THAT ARE CONFIRMED BY CONTEMPORARY KNOWLEDGE

The description contained in de Marchi's work [4] certainly refers to an event that took place and is intended to document it. Some of the information contained therein is uncontroversial and confirms the credibility of the authors.

An example is the description of the need to leave the water due to the cold. This is confirmed by data from limnology and meteorology. The water temperature of the thermocline zone of Lake Nemi at the time described was most likely 23–25°C, while below the thermocline it was as low as 20°C, which at a depth described as „*no deeper than six Roman canne*,” or about 13 meters, could have been a shock to an unclothed human body.

The description of underwater visibility conditions is also confirmed by today's research. The date of the operation coincides with the time of best insolation and the lowest average cloud cover [5].

A very important piece of evidence is that de Marchi was actually underwater and observed fish through a layer of air (inside the device), the glass of the illuminator and the layer of water. This optical system causes light rays to refract, making the objects viewed appear 1/3 larger. And indeed they were described as larger, although in his description de Marchi overestimated the magnification; the smallest finger of the hand – a human arm. The author of the treatise could not have drawn these facts from another source, as the first scientific description of the phenomenon was written almost 50 years after his death [6]. This means that he described what he actually saw. The disproportion between the actual magnification by a simple optical system and what de Marchi described can possibly be explained by the use of a lens, and not a simple piece of glass, as an illuminator in the device, which lens was a magnifying lens.

Another physical phenomenon unknown to de Marchi and his contemporaries, and which came as a surprise, was the problem with voice communication. He described being underwater at a depth of about 13 meters and not hearing someone calling him loudly. At that time, the phenomenon of sound wave reflection at the boundary between media of different densities (air - water and upper and lower water layer) had not yet been described, which prevented the sound from reaching de Marchi's ears.

His second impression concerning audibility, that he could hear the tools working underwater very well, is also a result of the laws of physics: the speed of sound is three times faster underwater and the incompressibility of water causes the sound wave to lose energy more slowly. This was not researched until the early 18th century, hence de Marchi could not have known the scientific basis for this phenomenon [6].

Another impression described by de Marchi concerns the behaviour of fish during his stay underwater. He took with him to the bell, as he writes, four loaves of not very fresh bread and a piece of cheese. These supplies crumbled, attracting fish, which is nothing new. However,

the fish were also attracted by the researcher's own body, which, as he writes, „*being without pants*” was exposed to „*stabbing into that part...*”. The behaviour of the fish (currently observed during so-called „fish peeling” treatments) was caused by the hygiene rules of the time, or rather the complete lack thereof. Due to the lack of bathing or even washing, exfoliating skin remained on the surface of the skin, stuck together with sweat and sebum, providing excellent food for fish and attracting them with a strong smell, which in interpersonal contacts was suppressed at that time by the excessive use of perfume.

Medical evidence of diving underwater to a depth of more than a few meters is provided by his description of ear discomfort. He wrote that „*I experienced such great pain in my ears... as if a steel rod had pierced me from ear to ear.*” Today's divers describe it in similar terms when they have problems equalizing the pressure in the middle ear as the surrounding pressure increases. This pressure bulges the painfully innervated eardrum, and with further immersion, if the pressure is not equalized, the eardrum ruptures. Fortunately, as the further description shows, the eardrum did not perforate, as there is no mention of hearing loss, even unilateral, in the treatise. De Marchi probably swallowed saliva during the dive, unconsciously partially equalizing the pressure. However, this was certainly not a conscious action, as the mechanisms allowing pressure equalization were not described in medical literature until the 19th century [7].

He also described profuse nosebleeds, which he mistakenly associated with ear problems. In accordance with the laws of physiology, the bleeding stopped when he swam in the (cold) water of the lake and rinsed his nose.

Thanks to Captain Francesco de Marchi's light pen, we can be absolutely certain that he experienced everything he described, but also that he did not understand these phenomena, as the level of science of the time did not allow for their explanation.

ELEMENTS OF DE MARCHI'S DESCRIPTION REQUIRING PHYSIOLOGICAL AND TECHNICAL VERIFICATION

The first thing that raises doubts is the „effective” way to prevent ear pain during diving. Certainly, pushing musk-soaked cotton wool into the ear canal was not an effective method. Such a „dressing” would most likely become soggy and fall out of the ear, and even if it remained there, the pressure would simply push it towards the eardrum. This would not prevent water from affecting the structures of the ear in front of, behind, and inside the tampon.

The second issue that raises doubts is the protective effect of da Lorena's bell. The report (chapter 82 of the treatise) states the following about the protective effect of the bell designed by the Master of Lorraine (Guglielmo da Lorena): „*(...) in which [da Lorena] stayed for about an hour (...)*” „*(...) having spent half an hour underwater, as I read on the clock that was brought to me (...)*” „*(...) I stayed there for an hour (...)*”. Then, in chapter 84, he confirmed this information by writing: „*(...) The device was useful for use underwater for one or two hours (...)*”. Assuming that de Marchi did indeed use a phrase that can be unambiguously translated as an „hour”, the question arises: what did Francesco understand by this term? And also, what kind of „orologio” clock was brought to him?

The answer to the second question can be found in historical sources. At that time, small mechanical watches that could be worn on the person already existed;

they can be seen in paintings from that period, such as *Tobias and the Angel* by Andrea de Verocchio, and are also described as products manufactured by Henlein [8,9]. However, due to the fact that these were „luxury” items, a larger home or travel clock was probably used to measure time, which was „brought” to him.

However, the issue of time is a bigger problem. In 1535, Italy used a system known as „Italian hours.” The first hour began at sunset or at the end of twilight, or about 30 minutes (by today's standards) after sunset – which in fact depended on local custom. This means that the length of an hour depended on the season and geographical location. However, it is important to note that the end of the day was always at 24 o'clock. This allows us, despite the division into „time zones,” to assume that the hour at that time can be equated with the modern hour [9].

Thus, knowing the actual time interval de Marchi was writing about, one has to wonder whether the protective effect of the bell designed by the Master of Lorraine was in fact that long.

When diving in de Marchi's open bell, he was chest-deep in water and above an air cushion that allowed him to breathe. The description indicates that the bell was not connected to the surface in any way, „*(...) no pipe connected to the surface (...)*”. Thus, the air that had accumulated in this part of the bell at the moment of immersion was the entire supply for breathing during the stay underwater. Knowing how much air there was, it is possible to calculate the theoretical time for which it was sufficient, or, as we would call it today, the protective action time of the bell.

In addition, the calculation requires the pressure at the diving depth, atmospheric pressure, and knowledge of the minute ventilation of the lungs, i.e., the volume of air consumed per unit of time. This value is identical underwater and on the surface in terms of volume, but in diving conditions it refers to compressed air. For these reasons, the pressure at the diving depth and atmospheric pressure must be taken into account.

The town of Nemi is located at an altitude of 521 meters above sea level. The standard pressure drop with increasing altitude is 11.34 hPa per 100 meters. This means that the atmospheric pressure in Nemi will be 59.08 hPa lower than the standard atmospheric pressure (1013.25 hPa) and amount to 954.17 hPa.

De Marchi writes that during the dive he performed simple tasks: he walked, tied ropes, and generally moved around. He was certainly a little stressed and definitely excited, so his oxygen demand and, consequently, his minute ventilation were greater than at rest, if only because of the greater resistance of the denser aquatic environment.

Assuming an average minute ventilation value, in accordance with the principles used in diving technology [7,10], it can be assumed that his minute ventilation was up to 0.04 cubic meters per minute. This means that at the atmospheric pressure prevailing in Nemi, the minute air demand was 0.038 m³.

We do not know exactly what shape the bell was, although De Marchi writes „*(...) the round bell was like a barrel (...)*”. A barrel is not a perfect cylinder, but assuming that it was a cylinder, we will overestimate the volume of the instrument, but the error will not be significant.

The description indicates that the bell was about 125 centimeters high and 75 centimeters wide – „*(...) about*”

five hands long and about three hands wide (...)” – assuming that an adult male’s hand is about 25 centimeters. Then the volume of the device is about 0.55 m³.

It is not certain whether the dimensions given by Franchesco de Marchi refer to the external or the internal dimensions of the bell. However, based on the wording of the description, it should be assumed that these were the dimensions of the device as seen from the outside. De Marchi then states that the barrel was made of oak wood, two fingers thick (approx. 4.5 cm). Subtracting 9 cm and 4.5 cm (taking into account the thickness of the lid) from the width and height of the bell, respectively, and recalculating the volume, we obtain 0.41 m³.

This is the actual total internal volume of the bell. However, it is not the volume of air available to de Marchi. There was a man in the device and filled part of its volume, including the air cushion. The description that *„(...) below his elbows he felt piercing cold (...)”* allows us to assume that his head, part of his chest, and his arms up to his elbows were in the air space.

Assuming that the diver in the bell was up to 1.70 m tall [11] and had a normal build, the total volume of his body can be calculated. With a weight ranging from 53.5 kg to 72.0 kg, his volume was between 0.05 and 0.07 m³. Assuming that the part submerged in water constituted approx. 80% of this volume, the volume of the diver in the air pocket is approx. 0.01 m³.

Subtracting this value from the total volume of the bell, we obtain the effective volume of da Lorena’s bell at 0.4 m³. During the descent to a depth of 13 meters, this volume decreased due to the increase in ambient pressure, while at the same time water entered the space. This process was halted after the dive was completed, when the pressure in the bell equalized with the ambient pressure.

At a depth of 13 meters, the volume of the air cushion was therefore approximately 0.17 cubic meters. Now, taking into account the altitude above sea level at which Lake Nemi is located and calculating the pressure at a depth of 13 meters, i.e., 2229.02 hPa, we can determine the effective air supply: 0.39 m³.

De Marchi’s minute air requirement was 0.038 m³ and the effective air supply in the bell is 0.39 m³. How many minutes of breathing was this enough for? Dividing these values by each other, we obtain 10 minutes and 18 seconds. After this time in the bell, the diver begins to run out of air. Or rather, this is the time when the entire volume of air contained in the bell will be passed through the respiratory tract of the person inside it.

However, breathing is not only the movement of air in the respiratory tract, but above all gas exchange, i.e. the intake of oxygen and the excretion of carbon dioxide.

During breathing in a confined space, the concentration of carbon dioxide increased. Physiologically, it is assumed that the first symptoms of carbon dioxide poisoning may appear at a partial pressure of this gas of 1.5 kPa [7,12]. This means that at atmospheric pressure, its content cannot exceed 1.48%. As the ambient pressure increases, the numerical value of the percentage at which carbon dioxide reaches its maximum allowable partial pressure relative to sea level pressure decreases.

At a depth of 13 meters, the limiting pressure of carbon dioxide (1.5 kPa) is already reached at a content of 0.67%. This is more than twice less than under normal conditions, assuming that initially there was about 0.03% carbon dioxide in the bell’s atmosphere. At the depth reached by the bell, it was 0.07 kPa.

After starting the dive, De Marchi inhaled air from the bell’s air cushion and exhaled used air, including carbon dioxide.

It is possible to calculate the time it takes for the percentage of carbon dioxide to reach a level at which symptoms of carbon dioxide poisoning appear. The volume of the bell, the diver’s minute ventilation and carbon dioxide emission, atmospheric pressure, and the initial carbon dioxide content and its limit pressure must be taken into account. For the purposes of this material, the calculations were performed using a verified ventilation model for hyperbaric facilities, the assumptions and verification results of which are described in detail in [10]. It was calculated that the atmosphere in the bell becomes dangerous 39 seconds into the fourth minute of stay at depth. This means that at this point, ventilation of the bell with fresh breathing gas should begin (Fig. 1). This is sometimes referred to as the time until first ventilation.

On this basis, we can assume that in the sixth/seventh minute of the Captain’s stay, he would start to experience a headache. This would be followed by a decrease in performance and sweating, an increase in heart rate, and rapid breathing. Hypothetically, in the 40th minute, convulsions and cyanosis would appear, and after an hour he would lose consciousness and then die. Hypothetically, because as indicated earlier, the oxygen supply in the bell would be exhausted at minute 11.

De Marchi writes that his head hurt underwater, but he identifies this with what we have identified as pressure injury to the ear. However, carbon dioxide poisoning was probably more significant. The pain in his ears was so intense that the Captain did not even notice it. He also did not know that there was such a thing as carbon dioxide, so how could he have known that he was being poisoned by it? This phenomenon was only described after De Marchi’s death.

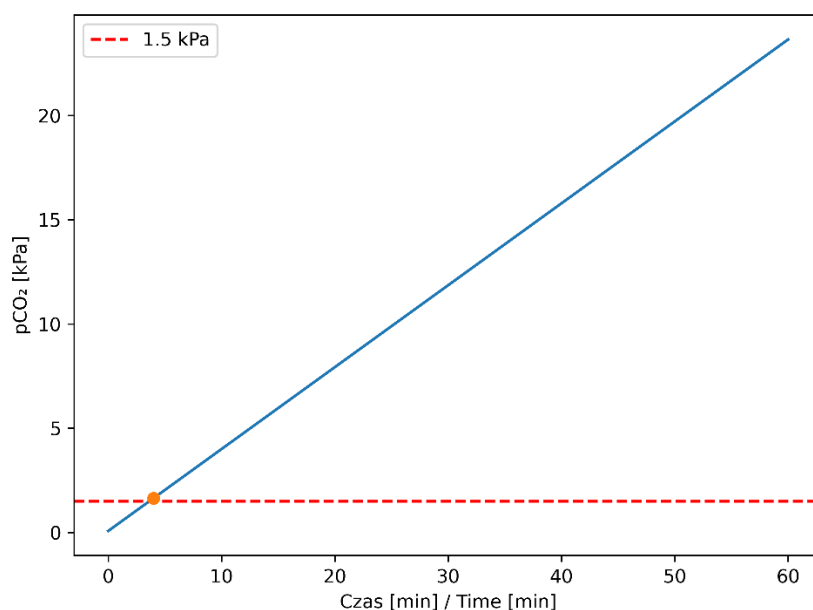


Fig. 1 Theoretical increase in partial pressure in da Lorena's bell.

The analysis indicates that the description of the dive is not fully consistent with the physiological and technical limitations resulting from the parameters assumed. The air supply stored in the bell did not allow for a long stay underwater. A long stay was also associated with carbon dioxide poisoning. Based on the assumed

parameters and calculation results, the limit parameters for staying in da Lorena's bell, as shown in Table 1.

Tab. 1

No.	Parameter	Value	Unit
1.	Effective volume of the bell	0.39	[m ³]
2.	Minute ventilation of the lungs	0.038	[m ³ /min]
3.	Protective action time of the bell	10	[min]
4.	Time until first ventilation	4-5	[min]

These results indicate that without active air exchange, a prolonged stay (of one hour or more) would be physiologically extremely unlikely. Paradoxically, this conclusion may reinforce Eliav's hypothesis about the ventilation system of this device.

THE VENTILATION SYSTEM OF DA LORENA'S BELL

Eliav assumes that there must have been some mechanism for air exchange in the da Lorena's bell, especially since Francesco De Marchi categorically rules out the use of a pipe connecting da Lorena's bell to the surface [3]. Furthermore, according to Eliav, the undisclosed air exchange mechanism allowed the bell to maintain the correct pressure and air volume so that the water level inside the bell remained unchanged.

In Joseph Eliava's opinion, the only solution that meets these requirements is the open bell ventilation method developed by Edmund Halley in 1791. Thus, according to this opinion, Guglielmo da Lorena in 1535 had access to technology that allowed him to build the same solution as Edmund Halley more than two hundred and fifty years later. Eliav draws his conclusions based on an analysis of the content of De Marchi's treatise discussed here, but from a later edition, i.e. 1810. In short, based on his analysis of the source text, J. Eliav hypothesizes that two engineers who encountered the same technical problem solved it in a very similar way, despite the centuries of scientific and technical progress that separated them. The author of that article himself points out that this is a bold hypothesis, based on the credibility of De Marchi's book.

Based on Daniela Lamberini's work, this can be estimated [13]. The version of Captain De Marchi's treatise published in 1810, i.e., the edition used by J. Eliav, is a publication based on a copy of the 1599 edition and copies of manuscripts and drawings made between 1788 and 1793, which came from the collection of the last female descendant of the De Marchi family. However, according to Lamberini, this edition is less complete than it could be, because the publisher ignored part of a content of the manuscript copies. The edition we analyzed, on the other hand, is based on a manuscript that is not the only manuscript of De Marchi's work [4].

As it turns out, the work was created over several decades. The manuscripts multiplied because De Marchi wrote his treatise „in his own way,” then updated the text and had it transcribed and translated into „proper Italian” by various copyists. This is confirmed by the Captain's letters to the secretary of Prince Octavian, which have survived to this day and show that De Marchi had problems with the Italian language, his vocabulary had many dialectal influences and was rough. Lamberini describes this style as „hard-working” – which would suggest that the author of the treatise had problems with writing [13].

The Captain compiled the descriptions of the drawings and chapters, as well as the comments on the architectural ideas contained in the treatise, after completing the drawings, first in the form of copperplate engravings. Usually after some time had passed. According to Lamberini, the texts are largely inspired by thought patterns and quotations taken from common classics, but they abound in digressions on current events and valuable (nonetheless) references to modern military architecture. The work was published more than twenty years after the author's death, and by the time it was published, it was already outdated.

The work, which we so carefully analyze as source material, is in fact the work of its editor—it was published on the basis of copperplate engravings and various texts (manuscripts) found years later, which the editor combined as best he could with drawings and published as a whole. Some copies even included a letter stating that it was the fruit of the latest discoveries.

The author of De Marchi's biography points out that he was self-taught and traveled extensively – sometimes on a mission, sometimes simply as a courtier – but always took elaborate notes, probably with some difficulty. She assesses the drawings in his treatise as amateurish at the level of a self-taught person, but indicating a good assimilation of theoretical knowledge. Interestingly, De Marchi, known to us as a specialist in military architecture, had several achievements during his lifetime, but he was not known as an architect. He was simply a professional courtier, an inventive organizer of parties and games, a talented dancer, a riding instructor for court ladies, and a chronicler of social events at the court where he was currently staying.

Thus, De Marchi's work is not a reliable source for proving hypotheses regarding the bell's ventilation system. There is also another piece of circumstantial evidence that supports the possibility that the Master from Lorraine is doubtful.

The method of ventilating a diving bell developed by Halley, from today's point of view, works on the simple principle of pressure difference. A barrel of air submerged deeper than the bell with the diver, connected to the bell by a suitable hose, due to the pressure difference resulting from the difference in depth between the barrel and the bell, became a reservoir of fresh air for the diver. Air

spontaneously flowed from the barrel into the bell, where the pressure was lower, if the barrel was deeper than the bell.

One can make the mistake of presentism – that is, perceiving past times and the reasons for decisions made at that time from the perspective of current knowledge. For what is simple for us, was it also simple and easy for da Lorena? To build the bell ventilation system in question, da Lorena would have had to use the pressure difference. So he would have had to know that such a thing occurs when there is a difference in depth.

To know this, he would first have to know and understand the concept of pressure. In addition, he would have to understand that in a gravitational field, water molecules are affected by surface forces (resulting from atmospheric pressure) and volume forces resulting from the total mass of molecules at a shallower depth. Then, the pressure at a given point in the liquid can be defined as the pressure resulting from the mass of the liquid column with a height corresponding to the depth of that point and the pressure of the surface force acting on the free surface of the liquid above that point.

In the first half of the 16th century, people did not know the concept of atmospheric pressure, let alone its development, i.e., the concept of hydrostatic pressure. This knowledge simply did not exist at that time. The first person to correctly define the problem and break away from the prevailing paradigm was Giovanii Battista Balliani [6]. This was later proven by Evangelista Torricelli. The first person to describe it scientifically in 1647 was an Italian monk living in Poland, Valeriano Magni. Blaise Pascal then hypothesized that since there is a vacuum, atmospheric pressure would depend on the height above the earth's surface.

First, his brother-in-law Florian Periera performed the experiment he proposed, which Pascal then repeated himself, confirming his hypothesis. And this is where Edmund Halley comes in, who, based only on the results of Pascal's work and his own calculations, provided a table of pressure dependence on height above sea level. Understanding the inverse relationship, the increase in pressure with increasing measurement depth, posed no major problems for him, and on this basis he developed his diving bell ventilation system.

This does not mean that practical observations of physical phenomena were impossible in de Marchi's time, but the lack of a theoretical concept of pressure significantly limited the possibility of consciously exploiting pressure differences in a systematic way.

CONCLUSIONS

The analysis shows that the description of diving contained in Francesco De Marchi's treatise contains elements consistent with actual physical and physiological phenomena, but does not provide sufficient grounds for formulating a hypothesis about the existence of an advanced diving bell ventilation system in 1535.

Due to source limitations, editorial inconsistencies in the treatise, and the results of the computational analysis, the thesis about the „revolutionary” nature of the solution should be considered unproven. The calculations presented do not rule out the existence of simple, periodic air exchange methods, but the available source material does not allow for an unambiguous identification of the described device with an advanced differential system analogous to the

solution developed by Edmund Halley.

REFERENCES

1. Rackl H.W.: Podróż do milczącego świata. Warszawa: Iskry, 1969. Tłum. E. Werfel.
2. Purtell J.: Projekt Diana, Stowarzyszenie Jezioro Diany-Nemi [online]. <https://web.archive.org/web/20100701192638/http://nemiship.multiservers.com/nemi.htm>. Dostęp: 01.2025.
3. Eliav J.: Guglielmo's secret: The enigma of the first diving bell used in underwater archeology. *The International Journal for the History of Engineering & Technology*, 85(1) (2015).
4. De Marchi F.: *Architettura Militare*, Brescia, 1599 Egzemplarz cyfrowy Ślązka Biblioteka Cyfrowa, s. 60–69. ISSN 1758-1206. DOI: 10.1179/1758120614Z.000000000060.
5. Praca zbiorowa: Analiza statystyczna historycznych raportów pogodowych i rekonstrukcji modeli od 1 stycznia 1980 do 31 grudnia 2016 roku w rejonie miejscowości Nemi; <https://es.weatherspark.com/>. Dostęp 01.2025.
6. Wróblewski A.K.: *Historia fizyki*. Warszawa: Wydawnictwo Naukowe PWN, 2007. ISBN 978-83-01-1435-1.
7. Olszański R., Siermontowski P.: *ABC zdrowia nurka* Wyd. Polskiego Towarzystwa Medycyny i Techniki Hiperbarycznej Gdynia 2000 rok, ISBN 83-88327-21-6.
8. Kula W.: *Miary i ludzie*. Warszawa: Książka i Wiedza, 2004. ISBN 83-05-13336-2.
9. Zajdler L.: *Dzieje zegara*. Warszawa: Wiedza Powszechna, 1977.
10. Olejnik A.: Wentylacja komory dekompresyjnej podczas powietrznych ekspozycji hiperbarycznych. Gdynia: Polskie Towarzystwo Medycyny i Techniki Hiperbarycznej, 2007. ISBN 978-83-924989-3-3.
11. Praca zbiorowa: Milanese people have stayed the same height for millennia; <https://www.scimex.org/newsfeed/milanese-people-have-stayed-the-same-height-for-millennia>. Dostęp 12.2024.
12. Krzyżak J.: *Medycyna nurkowa*. Poznań: KOOPgraf, 2006. ISBN 83-909187-5-7.
13. Lamberini D.: *Dizionario Biografico degli Italiani – Volume 38 (1990): De Marchi Francesco* [online]. [https://www.treccani.it/enciclopedia/francesco-de-marchi_\(Dizionario-Biografico\)](https://www.treccani.it/enciclopedia/francesco-de-marchi_(Dizionario-Biografico)). Dostęp: 01.2025.

dr hab. inż. Adam Olejnik prof. AMW

Akademia Marynarki Wojennej
e-mail: a.olejnik@amw.gdynia.pl
<https://orcid.org/0000-0003-1199-5835>