The Analysis of a Boiler Safety Valve Recovered from SS *Xantho* (1848–1872) and its Historical, Social, and Engineering Ramifications

ALEX KILPA

The work in this project was undertaken to partially fulfil the requirements of Flinders University for the degree of Master of Arts (Maritime Archaeology).

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Student Supervisor Dr Wendy Van Duivenvoorde

Report—Department of Maritime Archaeology, Western Australian Museum, No. 312

Declaration

I certify that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

Alex Kilpa

November 2012

Style Guide

This thesis complies with the editorial policy and style guidelines as recommended by the Society for American Archaeology. All measurements of distance, area, pressure, and weight are expressed in the metric system unless reporting excavated materials, in which case the English equivalent is followed by the metric in parentheses.

Alex Kilpa

November 2012

Abstract

Only limited archaeological research has been conducted on boiler safety valves of mid nineteenth-century steamships. As a result, this lack of knowledge has led to assumptions that spring-loaded valves were used in this era because they were more suitable for the task, i.e. the rolling and pitching at sea had no effect on the force applied by the valve. Noted Maritime Historian Denis Griffiths (1997:58), for example, states that "initially safety valves were of the deadweight type, but spring-loaded safety valves became normal in the 1850s following their general adoption on railway locomotive boilers."

This study examines and reconstructs a safety valve, of a type once believed obsolete by the late 1850s, that archaeologists recovered from close proximity to the boiler of SS *Xantho* (1848–1872). An alternative perspective is presented which demonstrates that these devices were used at sea well into the 1870s, even though spring-loaded safety valves were preferred over deadweight and lever-weighted mechanisms. It was only at the end of the nineteenth century that improvements in the engineering and metallurgy of spring and pop safety valves had advanced to a point where their installation on steamships had the confidence of engineers, and government regulatory agencies such as the Board of Trade.

Acknowledgements

Maritime archaeological investigation of shipwreck sites can span many years and many generations of archaeologists. This study therefore is an accumulation of work by a great number of people who have contributed to the study of steamship technology and specifically *Xantho* itself. Some of these people I have had the privilege to work with on a day-to-day basis, others I have never met but have enjoyed the literature and documents they have forwarded.

In particular, I would like to thank Dr Michael McCarthy for his tolerance, understanding, and support for this study and my interest in the field of maritime archaeology. I practically visited his office every day over the past two years to discuss steamship technology and, in particular, that of *Xantho*—he always had time to assist me. Also, Colin Cockram for his outstanding diagrams of the *Xantho* safety valve and in transcribing my data to a scaled architectural drawing of *Xantho*'s propulsion system, Don Cockrell for developing an adequate support for the safety valve, so it can be displayed in the '*Xantho* to Suffragettes Gallery' at the Western Australian Museum, and all those members of the Maritime Archaeological Association of Western Australia who offered support and accompanied me to Port Gregory for the May 2012 fieldwork.

A special thanks is also given to Eric Coates for the restoration of the Bourdon Pressure gauge featured in this thesis and maritime archaeological conservator Jon

Carpenter for the de-concretion of the isolating valve and who bore with equanimity my constant presence and commentary as I hovered around the de-concreting table and caustic bath.

Special thanks also to the Visitor Services Officers who regularly brought the public in to see what I was doing, to Dick Garcia who was always generous with his advice, and to Kalle Kasi who operated the XRF and FTIR analytical equipment. I also would like to thank Dr Wendy Duivenvoorde and Dr Jennifer McKinnon for running a great course at Flinders University and finally Mum and Dad for sponsoring my academic studies and seemingly dropping me off at the airport every few weeks.

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FOREWORD: SS *XANTHO*, A PRÉCIS OF EVENTS TO 2010

In 1871, the 23-year-old iron-hulled schooner-rigged paddle steamer SS *Xantho* was sold to Glasgow scrap metal merchant Robert Stewart, who fitted the vessel with a second-hand 10-year old ex-RN screw engine, pumps, and a new boiler manufactured locally by David Davidson. He then sold it to visiting colonial entrepreneur Charles Edward Broadhurst who intended to use it in the northwestern Australian pearling industry to transport shell, carry 'Malay' pearl divers, and pick up passengers and cargoes as a 'tramp steamer' on its voyages from Fremantle to Batavia via intervening ports and pearling havens.

With a worn-out hull overloaded with lead ore from the nearby Geraldine mine, and its decks opened by the heat of the sun, *Xantho* sank near Port Gregory, Western Australia on November 16 1872. Initially, Broadhurst had high hopes of refloating the vessel and brought in a hard-hat diver to examine how this could be achieved however, it proved an impossible task because the ship had filled with sand. All loose objects of value were subsequently salvaged after which it was abandoned. Around the turn of the century, SS *Kurnalpi* called in to Port Gregory and it appears it may have collided with the wreckage, which lay just a few metres beneath the surface.

In 1979, the wreck was re-located and inspected by members of the Maritime Archaeology Association of Western Australia. Later reports of looting, including the removal of a boiler gauge and other objects in 1983, hastened diving conservators and corrosion specialists to join the archaeological team in its investigation. This inspection showed that the ship was fitted with a Crimean War gunboat, non-condensing horizontal trunk engine, designed and built by John Penn of Greenwich incorporating the standard thread of Joseph Whitworth. These were the first mass-produced, high pressure, high revolution marine engines ever made, rendering *Xantho*'s engine of international significance. As a result of its unique status, and based on the advice of corrosion scientists that the engine had a short projected life if it remained on the seabed, the Western Australian Museum's (WAM) Maritime Archaeology Advisory Committee endorsed the project leader's advice that the engine must be recovered. The Museum administration subsequently provided a budget of AUD $7,200 for the entire project.

In 1984 the engine was cut free from its bearers using thermal lance equipment and in 1985 the engine was raised in the context of an excavation of the stern section aft of the boiler. The de-concretion of the engine began in a conservation laboratory soon after it was raised in 1985 and was completed a decade later with the opening of the last of the internal spaces and the freeing of its movable parts. In the interim other objects including what was first thought to be a condenser (but which was later identified as a distilling apparatus) and a boiler safety valve were recovered, de-concreted and sent to the treatment tanks. The many anomalous features surrounding the engine and the initial belief that the safety valve was of an outmoded and inefficient 'deadweight type' led to the assumption that the ship was refitted for use in calm rivers or on inland waters where fresh waters was readily available. Work then began on rebuilding the engine in the exhibition galleries as a 'work-in-progress'. A working model was produced, together with a number of concepts in plan view and in model form for the future exhibition of the raised objects. These were used as aids in understanding how the vessel was engineered and operated. By 2006 the engine had been totally reassembled and could be turned over by hand. It was a conservation triumph, which attracted archaeologists and conservators to an international celebratory conference on iron, steel and steamship archaeology held to mark the occasion.

The investigation into the engineering, the many anomalous features on the seabed in and on the engine, together with the absence of a condenser and the existence of the deadweight safety valve also resulted in a detailed study of Charles Broadhurst, who like *Xantho* had been previously dismissed as a total failure—he as an entrepreneur and his ship as the State's first coastal steamer. As a result Broadhurst is now recognized as one of Western Australia's 100 most influential citizens of all time. Further studies uncovered his remarkably talented wife, the feminist Eliza Broadhurst and their suffragette daughter Katherine one of the founders of the Karakatta Club which helped Western Australian women obtain the vote ahead of most of the world. As a result the museum's exhibition on *Xantho* is entitled 'Steamships to Suffragettes: guano to pearls' focusing as much on the people involved (including the Broadhursts') as it does on the engine and its conservation.

Unfortunately, both the 'distiller' and the boiler safety valve suffered degradation during their conservation treatment and emerged from the treatment tanks in hundreds of pieces. As apparently insolvable three-dimensional jigsaw puzzles they were initially considered hopeless cases, not capable of providing any further useful information. That was until conservation staffer Alex Kilpa volunteered his services in their reconstruction. What has transpired as a result of his research and three-dimensional visualization skills is the total reassessment and presentation of both items into the Western Australian museum's Shipwreck Galleries.

M. McCarthy
Archaeology Director
SS *Xantho* program

CHAPTER I: INTRODUCTION

The use of safety valves as mechanisms to prevent boiler explosions is well documented for land applications (Hewison 1983; McEwen 2010:1–185). Safety valves were, as described in historical record, critical for reducing the incidence of such explosions, which were costly both in terms of human life and material resources. To the knowledge of this author, no archaeological study has been undertaken to investigate the use of safety valves at sea, although there are numerous historical accounts of boiler explosions occurring in such environments including HMS *Thunderer* in 1876 (McEwen 2010:181–183), *Sultana* in 1865 (Potter 1992:3; Voulgaris 2009:7), and *Chattahoochee* in the same year (Watts et al. 1990:17–18; Foenander 2011).

Research Question

In 1871, scrap metal merchant Robert Stewart (1820–1881) of Glasgow (County of Lanark 1881), fitted a former Royal Navy gunboat engine, a new boiler, and other ancillary machinery including a weighted boiler safety valve to *Xantho*, in order to convert the 23-year old paddle steamer to screw propulsion. The research question around which this thesis hinges is "what can the safety valve recovered from SS *Xantho* (1872) reveal about the development of safety features on nineteenth-century steamships?" In order to answer this question, this thesis was developed in two stages with sub-sets of secondary questions relating to this research theme.

Stage one Initial research questions relating to the identification and functionality of the safety valve. In this first stage, a particularist approach for generating research questions relating to the nature of this artefact was considered critical because it was not understood and subject to misrepresentation. As Jeremy Green (1990:235) suggests, it is important, to build a clear understanding of the nature of the material before constructing a deeper hypothesis. In order to do so, the following four questions will be addressed:

- What was the purpose of this object?
- What was its material composition?
- How did this device function?
- Where was it located on the boiler?

Stage two Propose comparative questions relating to safety valve options for boilers in the mid nineteenth century. These included:

- How did the mechanism recovered from *Xantho* compare in terms of composition, safety rating, and design to other types of safety valves, (i.e. lever-weighted and spring-loaded valves) available in the mid nineteenth century?
- Under what environmental circumstances would these mechanisms be best suited, i.e. at sea, land, rivers, lakes?
- Were there guidelines, legislation, or regulations for the installation of such mechanisms?

The Absence of Historical Records

Although *Xantho,* built in 1848, may be considered a relatively modern vessel, much of the technical information relating to its construction and service modifications no longer exist. Keith Muckelroy (1980:10) is well-known for his rejection of nineteenth-century shipwrecks for archaeological investigation on the basis that historical documentation reveals more about such ships than their archaeological remains. The absence of a substantial body of historical data for *Xantho* demonstrates Muckelroy's rejection can no longer be considered a valid position (McCarthy 1998:99).

Ships during their lifespan typically undergo changes including outfitting with new technology, and repair or replacement of obsolete or damaged equipment. Often, in absence of documentation, it becomes unclear as to what were original fittings and what subsequently were added. One such example is the paddle steamer *Medway Queen,* built in 1924 (Brouwer 1993:162), where its owners the Medway Restoration and Preservation Society believe it had a deadweight safety valve. Yet, it is now impossible to verify their assertion because the entire boiler was discarded when the original ship was broken up prior to the rebuilding of its hull (Bob Stokes, Project Manager Medway Queen Restoration Project, personal communication 2011).

With the exception of official inquiries and related media reports into the causes of boiler explosions on steamships, such as that of HMS *Thunderer*, information on boiler safety mechanisms installed on specific ships is recorded infrequently in historical accounts (*The New York Times*, July 26 1876; *The Illustrated London News*, September 2, 1876). Most maritime historians have emphasized the general characteristics of steamship propulsion systems but have paid little attention to the types of safety valves used on particular vessels (for example, Chesneau and Kolesnik 1979).

Justification for Archaeological Research

Archaeological studies of safety valves used in nautical applications have rarely been undertaken. Propeller ship *Indiana* (1848) is one of the few examples, but even in this case its highly detailed report was conducted as part of an overall plan to examine the vessel's propulsion system and not to study the functionality of the safety valve itself (Appendix A) (Johnston and Robinson 1993; Robinson 1999). A plausible explanation for the lack of research in this field in Australia may relate to the difficulty of obtaining data for interpretation from maritime archaeological sites.

A statistical examination of the *Australian National Shipwreck Database* (Department of Sustainability, Environment, Water, Population and Communities 2011) demonstrates that of the 8005 shipwreck sites located in Australia, both on land and under water, only 1077 were of screw-driven vessels and paddle steamers. Potentially a substantial resource for investigation, these statistics are somewhat deceptive because the exact location of many of these shipwreck sites is unknown and a significant number of them date to the twentieth century and are, thus, beyond the scope of this investigation.

Known steamship sites include the ship graveyards located at Homebush Bay (New South Wales), Port Phillip Heads (Victoria) North Arm Port Adelaide (South Australia), and Rottnest Island (Western Australia). In most cases these ships were totally gutted of their machinery in the salvaging process leaving nothing more than remnants of the hull or just the keelson (Green 2004:71, 2011; Richards 1997, 2008; and Western Australian Museum 2012a). It is, therefore, unlikely that such sites can yield archaeological evidence applicable to this study.

Of those steamships classified as shipwrecks, i.e. wrecked as a result of an unplanned catastrophe, geographical location and depth of the wreck site are significant factors that influence the post-depositional process and the transformation of the site. In cases where the shipwreck site is located in shallow waters, historical and archaeological records suggest that their owners or agents recovered as much as possible from them directly after their wrecking. Salvage practises were common, not only to save cargo but also to recover valuable metals, such as copper, associated with the ship itself. Examples of this practice are *Brisbane* (1881) (Steinberg 2008:25), *Killarney* (1928) (Richards 1997), and *Silver Star* (1942) (Western Australian Museum 2012b) (Figures 1-1 and 1-2).

Figure 1-1. SS *Killarney* (1928) and its marine boiler located at the Garden Island ship graveyard, South Australia. This vessel was stripped of all its precious metals (Richards 1997:48).

Figure 1-2. The remains of *Silver Star* (1942). The salvaging of this vessel removed all precious metals including the copper steam pipes and brass safety gauges. Only the base of the safety valve remains (C. Cockram, 2012).

In what could be described as a second phase of salvaging, many of these sites have become vulnerable to treasure hunters and looters, as seen in other parts of the world, particularly in the waters of developing nations where legislative protection for historic wreck sites is limited or non-existent (Parthesius et al. 2003:4–5; Parthesius 2007:17–18; Tripati et al. 2010:185). Figures 1-3 and 1-4 show two sites where modern-day trophy hunting is known to have occurred.

Figure 1-3. Boiler from *Nightingale* (1933), a fishing boat wrecked at Glenmore/Munster in KwaZulu-Natal, South Africa. Although the boiler is intact, all precious metals such as the copper pipes have been removed (J. Sharfman 2012, reproduced with permission).

Figure 1-4. Tugboat *Alice G* (1927) located in ca. 10 meters of water that sank as a result of a severe storm in Little Tub Harbor in Tobermory, Ontario. Visible are the boiler and the base of the safety valve. The rest of the valve appears to have been salvaged, possibly as a trophy (*ScubaQ* 2012).

In other cases where a ship wrecked in deeper waters or an inaccessible geographical location, such as *Tasman* (1883) (Nash 2002), they are better protected from salvage and treasure hunting activities. By the same token, this also makes it difficult for archaeologists wanting to study a wreck site. As Michael Nash suggests "there is no detailed archaeological information on the equipment of the SS *Tasman* (1883) as the wreck lies at 70 m and could only be surveyed to get the broad details of the site" (personal communication 2011).

It is evident that the number of wreck sites yielding possible information about pre-1870 era steamships and their boiler safety valves is quite limited. This research, therefore, provides an invaluable case-study on an aspect of marine technology that to date has been overlooked or in some cases misinterpreted in maritime archaeology.

CHAPTER II: METHODOLOGY

Introduction

James Delgado (1997:259) states that maritime archaeology is:

> The study of human interaction with the sea, lakes, and rivers through the archaeological study of material manifestations of maritime culture, including vessels, shore side facilities, cargoes, and even human remains.

Any study in archaeology, therefore, necessitates research and the acquisition of data. The type of methodology developed to achieve this aim, however, is highly dependent on the nature of the research question being asked. This chapter provides an overview of four approaches that have been used historically to obtain, assess, and interpret maritime archaeological data. They include area excavation, site sampling, non-destructive data collection, and partial excavation. This chapter also outlines the objectives of this study and presents an outline of the research methodology.

Area Excavation as a Data Collection Methodology

Traditionally, excavation as a method for accumulating data was seen as a "quintessential activity in archaeological recording" (Gould 2000:51). In the early days of maritime archaeology, i.e. the 1960s and 1970s, the methodology associated with the study of submerged archaeological artefacts was heavily influenced by the practices and techniques developed for terrestrial archaeology. More often than not, this involved excavations where large sections of a site or even entire ships and their contents were removed from the seabed and taken to a museum or archaeological research facility. At these sites the material was catalogued, conserved and studied in a laboratory type environment. This resulted in an accumulation of resources for generations of archaeologists to study and for the general public to enjoy and understand. The successful integration of maritime archaeological material from the Kyrenia ship (295–280 B.C.), *Mary Rose* (1545), *Vasa* (1628), and *Batavia* (1629) into museum environments are testimony to that fact.

To some there was also an element of orthodoxy about this type of approach. George Bass for example suggests that only through total excavation can a true understanding of the nature of a ship and its cargo be understood. From Bass's (2011:10) perspective the archaeological remains of a ship should be looked upon as a "singular burial site". The logistic requirements to excavate an entire shipwreck are quite different from a proposal to excavate the entire remains of a sprawling Roman city, for example, which most archaeologists would consider unrealistic. However, to remove only part of a ship or its cargo would be akin to an archaeologist "excavating only part of a skeleton and leaving the rest" (Bass 2011:10).

Bass (2011:10) states that "partial excavation and sampling techniques can only lead to a misinterpretation of materials". While reflecting on a study of an eleventh-century shipwreck located at Serçe Limani, Turkey, he added:

> At the end of the first excavation season, there was pressure to publish both scholarly and popular articles on the site. These publications are now embarrassing. Almost every conclusion was wrong. Because we had raised mainly the ship's Near Eastern cargo of glass vessels and glazed terra-cotta bowls during the initial campaign, I concluded that they were evidence of a Muslim merchant venture. In the following campaign, however, we found the pork bones, lead seals with Christian images, fishing weights decorated with crosses and the name Jesus, and graffiti that proved the merchants on board were Hellenized Christian Bulgarians who lived on the north shore of the Sea of Marmara near Constantinople, which is slowly leading into even more detailed contributions to medieval history.

In another example, anthropological studies of *Mary Rose* (1545) revealed a high predominance of religious artefacts known as paternosters. These were found on all decks of the ship and are known to be closely linked to those who affiliate themselves with the Roman Catholic Church (Redknap 2005:5). This was initially interpreted as an example of religious tolerance on board naval vessels during a time when Catholicism was persecuted by King Henry VIII. However, subsequent research of the enamel taken from the teeth of the deceased has since presented additional evidence that perhaps up to 60% of the crew may have been of Southern

European descent, possibly Spanish. This suggests an alternate explanation for the high incidence of Catholic related religious artefacts on board the vessel (Foote 2005a; 2005b).

Although instances like these tend to validate Bass's research methodology, in Australia, financial support and sponsorship of institutions conducting maritime archaeological research was more forthcoming in the 1960s and 1970s than it has been in more recent times when the novelty of raising shipwrecks had worn off and the realities of the long-term costs of conservation had become more apparent.

Additionally there have been growing concerns relating to the techniques used to excavate materials. Although seldom mentioned in academic journals, the process of excavating materials from a wreck site often involves drastic measures that are potentially destructive not only to the objects being raised but to surrounding materials. For example the removal of *Xantho*'s engine from its bedding required the use of a thermal lance (Figure 2-1). Likewise the removal of the stern section of *Batavia* required the use of a chain saw to cut the timbers. Even though the end result for these projects has been impressive, it is important to recognise that excavation in itself is a destructive process (Figures 2-1 and 2-2).

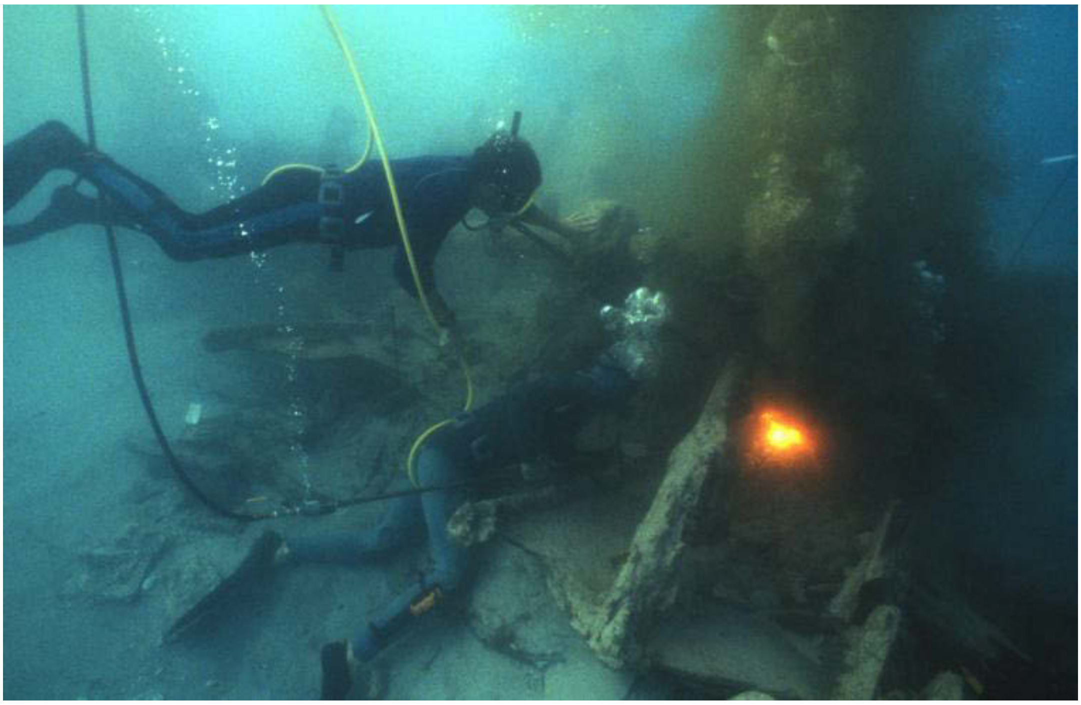


Figure 2-1. Diver Geoff Kempton assisted by Michael McCarthy removing *Xantho*'s engine via the use of a thermal lance (P. Baker, 1985).

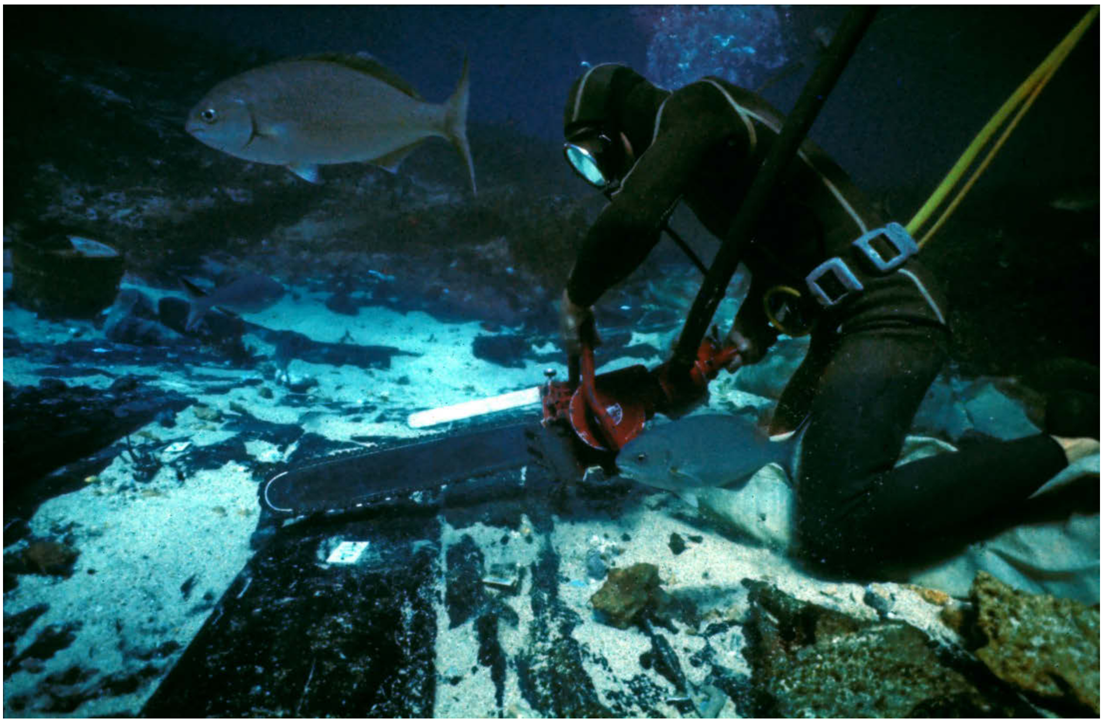


Figure 2-2. Diver sawing *Batavia* hull planking with a pneumatic chainsaw. (J. Green, 1974).

Non-Intrusive Archaeological Studies

A second means of obtaining archaeological data that has come into vogue in recent times has been non-intrusive archaeological studies, where sites are studied in situ with minimal disturbance to materials. This approach is the United Nations Education and Scientific Organisation's (UNESCO) preferred option for managing cultural materials under the sea as stipulated in its *Convention on the Protection of the Underwater Cultural Heritage Under the Sea* (2001).

However, the use of in situ practices for archaeological investigation is not universally accepted. In a questionnaire sent to 210 individuals in 12 countries respondents to this survey raised concerns regarding the use of in situ techniques as a blanket methodology for undertaking archaeological studies. Five major conflicting themes were identified:

1. Practitioners point to the lack of convincing research into methods and a shortfall of quantitative data demonstrating the success of in situ preservation and storage.
2. The ease with which some agencies approach in situ preservation and storage, which can be misread as an 'out of sight, out of mind' attitude, raises concern among practitioners.
3. The idea that in situ preservation and storage is meant to curtail any and all excavation and the implications that mentality has on the discipline of maritime archaeology concerns archaeologists in particular.

4. The idea that in situ preservation and storage is the ‘best’ form of conservation for underwater cultural heritage concerns a broad range of practitioners.
5. Practitioners are concerned that in situ methods and techniques limit access for both researchers and the general public (Ortmann et al. 2010:33).

Most respondents did agree that in situ archaeological studies “are but one tool to be considered” and its use should be dependent upon the significance of the site, the environment, the materials involved, access to long-term funding, and the development of a clear and well-constructed research plan (Ortmann et al 2010:36).

Although non-intrusive archaeological studies may appear to be somewhat limiting in some instances, they may be far more appropriate and cost effective, depending on the nature of the proposed research questions. Broad-based research questions such as those posed in Richards’ (1997) study of the Garden Island ships’ graveyard, for example, are more than adequately addressed with an in situ methodology. In this particular case, area-based excavations would not necessarily have yielded any further significant data.

Selective Sampling Techniques for the Accumulation of Archaeological Data

By the 1980s excavation was still undertaken in Australia, but had moved away from the concept of area excavation to more targeted approaches where only certain artefacts were removed. Furthermore, Federal and State legislation in Australia stipulated materials could only be removed from a protected site by applying for a permit, and that their removal had to be justifiable and not undertaken merely to satisfy curiosity.

The excavation of materials through sampling is similar to the non-intrusive archaeological techniques described above but includes the excavation or removal of materials with the aim of addressing a specific research question. Cheryl Ward and Rachel Horling's (2008: 148–173) remote exploration and archaeological survey of four Byzantine ships in the Black Sea could be seen as an example of a research methodology that would fit this criteria as only a small number of amphorae were recovered from the wreck sites and only for comparative purposes.

Partial Excavation

This type of archaeological approach is a compromise between area excavation and a non-intrusive archaeological study. It is based on practicality where only materials that are needed to answer a specific research question are excavated. By this method material, not directly related to the research question, are left in situ for other researchers to explore and assess.

The recovery of materials from *Xantho* was undertaken by the Western Australian Museum under the direction of Dr Michael McCarthy from 1985 to 1995. The original intent was to focus on the study of the horizontal trunk engine, a unique machine, and to save the associated precious metals from treasure hunters. The removal of the horizontal trunk engine was the last major recovery operation undertaken by the Western Australian Museum. However, the methodology used was different from the area excavation technique applied to *Batavia.* Furthermore, *Xantho* had tremendous research potential and was intimately associated with Western Australia's colonial history but did not receive the funding and resources associated with the seventeenth-century and eighteenth-century Dutch East Indiamen wrecked along the Western Australian coast.

Objectives of this Study

The general research design for this study has been developed in accordance with the principles outlined by Colin Renfrew and Paul Bahn (1991:61), which led to the following objectives:

- The formulation of a research strategy to resolve a particular question or idea;
- The collection and recording of evidence against which to test that idea;
- The processing and analysis of that evidence and its interpretation in the light of the original idea to be tested; and
- The publication of the results in journal articles, and books.

The basic aims for this research followed these principles but with one additional objective—the quest to have this work available for public access through display of these materials in a museum. Although the dissemination of archaeological findings through publication is undoubtedly an important step in gaining scholarly recognition, the effectiveness of archaeologists employed by museums or other public institutions, is often tied to community interest, government funding, and the generosity of philanthropists. They, therefore, have a responsibility to the general public for the justification of continuing research.

The exhibition of conserved materials is an important adjunct to the documentation, conservation, and analysis processes that follow archaeological field studies. As Graeme Henderson (1986:9) suggests "museums can be an excellent resource to draw upon ideas about aspects of ship construction". The research and reconstruction of the safety valve in this study generates a platform for future studies of steamship technology and provide a visual representation of its relationship with the engine and boiler. This study will make an important contribution to the reconstruction of *Xantho*'s propulsion system, which is to be displayed in the Western Australian Museum's 'Steamships to Suffragettes Gallery'.

The Research Methodology

To answer the research question 'what can the safety valve recovered from SS *Xantho* (1872) reveal about the development of safety on nineteenth-century steamships?' this study adopted a holistic research approach that draws upon six sets of data, including:

- Socio-economic factors that influenced the development of nineteenth-century safety valves;
- Historical documentation (including photography) that provides evidence of mounting types associated with mid to late nineteenth century horizontal boilers;
- Information derived from the reconstruction of the safety valve;

- Associated archaeological materials, such as the boiler, still present at the shipwreck site;
- Materials previously removed from shipwreck site such as its engine and associated pipework; and
- Literature, diagrams, and manufacturer's catalogues of marine propulsion machinery to aid in the development of a hypothetical model of *Xantho*'s propulsion system.

These six data sets are represented schematically in the Figure 2-3. The conclusions obtained from these datasets form a cultural interpretation of the value of safety valves to society in the nineteenth century.

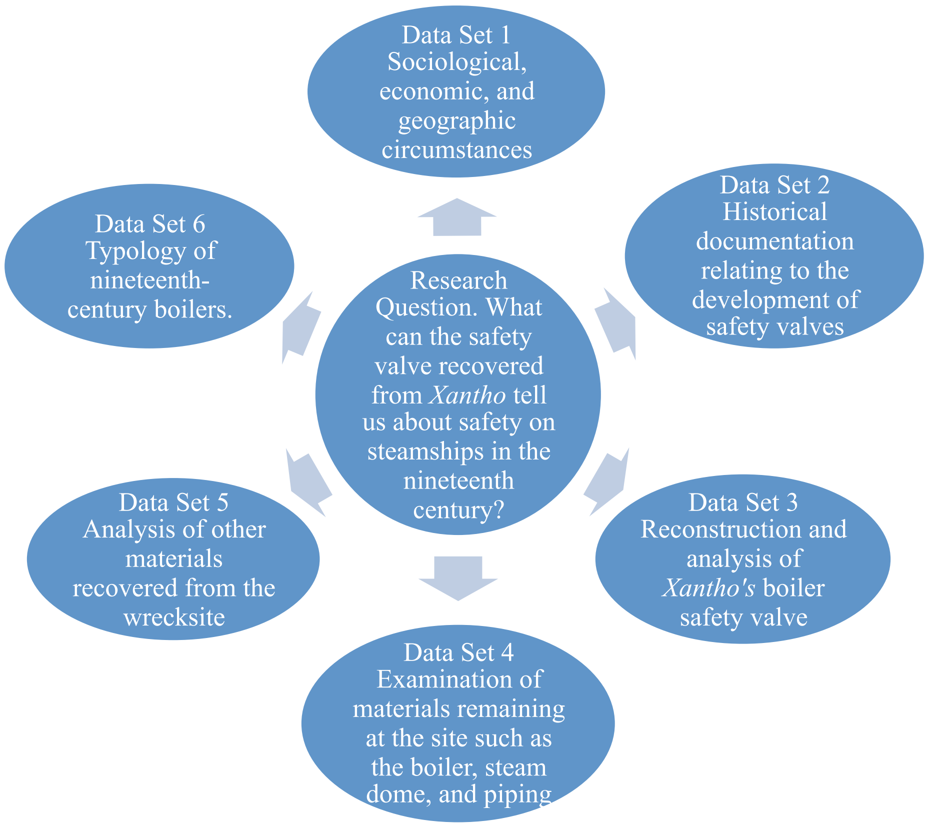


Figure 2-3. Mind map of data sets used to answer the thesis research question (A. Kilpa, 2012).

Conclusion

There are many ways archaeologists can obtain data. Traditional approaches have placed great emphasis on full-scale archaeological excavation, whereas more recent trends have moved towards partial excavation and in situ studies. The success of any research is dependent upon developing a research methodology that is feasible and appropriate to the research question being asked. As Jeremy Green (1990:124) states: "excavation alone is not archaeology, but part of a process whereby information is obtained which allows archaeological interpretation." The methodology applied to this study draws upon data from a variety of sources and is not solely dependent on further excavation of materials from the wreck site.

CHAPTER III: BOILER EXPLOSIONS IN THE NINETEENTH CENTURY—A SOCIO-ECONOMIC PROBLEM

Introduction

The nineteenth century witnessed remarkable advancements in technological engineering. The steam engine, coupled with its powerhouse the boiler, were harnessed to undertake complex engineering tasks with greater efficiency and fewer personnel. The adoption of steam engines and boilers for maritime applications allowed vessels to move through the water in the absence of wind, thus allowing travel to be accomplished more predictably. Human life, however, was put in jeopardy in the quest to extract more output from this developing technology.

The tendency to run boilers beyond their maximum designed pressures, often quite deliberately, resulted in faster steam engines and serious explosions both in the United Kingdom and abroad (Voulgaris 2009; Langlois et al. 1994:11). In some cases, it was ignorance of steam's physical properties and not exclusively the fault of the operators. Numerous anecdotes however tell us of safety valves and those who tampered with them, including "the one about the passenger who, feeling the cold, betook himself to the warmth of the area above the boiler and made himself a comfortable seat on the safety valve (Richards 1987:71).

This chapter provides a statistical analysis of the factors responsible for boiler explosions in the United Kingdom during the nineteenth century. Also described in this section is the impact of legislation and the effectiveness of inspection agencies in reducing the incidence of boiler explosions.

Boiler Explosions and Loss of Life

Today, when steam boiler explosions are rare, it is difficult perhaps to imagine the terror associated with such occurrences. There are few photographs showing the consequence of boiler explosions on steamships in the nineteenth century (see Figure 3-1) and many of the illustrations that have tried to portray their occurrence such as the ones presented in Figures 3-2 and 3-3 may seem fanciful if they were not accompanied by eye witness accounts.

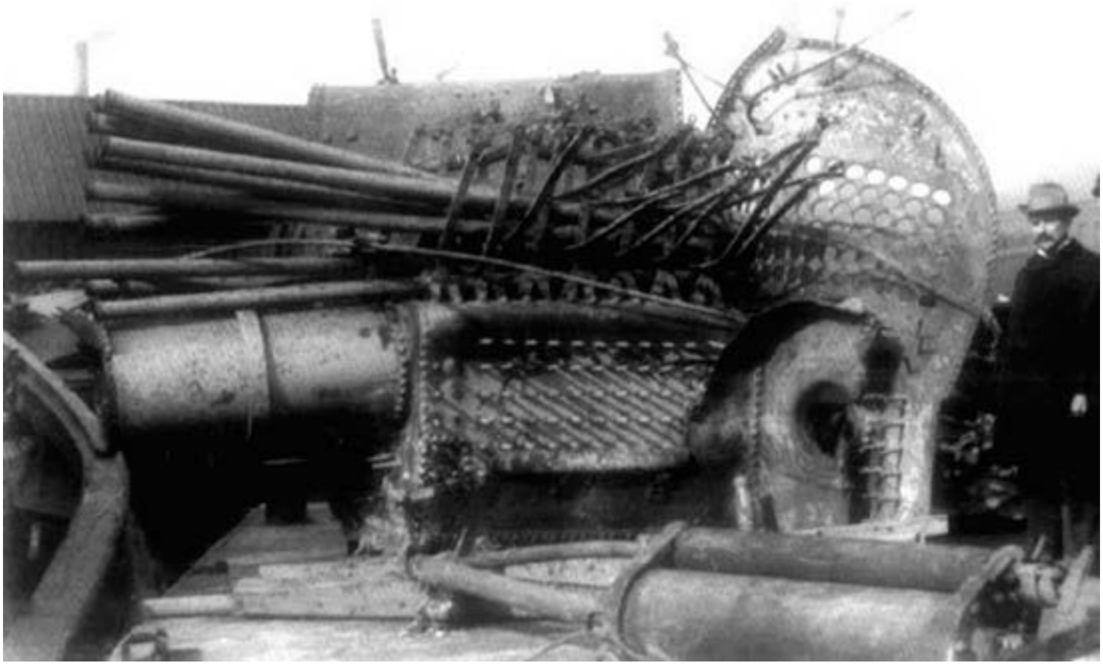


Figure 3-1. Aftermath of a nineteenth-century steamship explosion. This 1895 photograph shows the remains of *Morford*'s boiler under examination at a pier in Chicago. Despite the violence of the explosion, this vessel was rebuilt and returned to service (*Twaintimes* 2012).

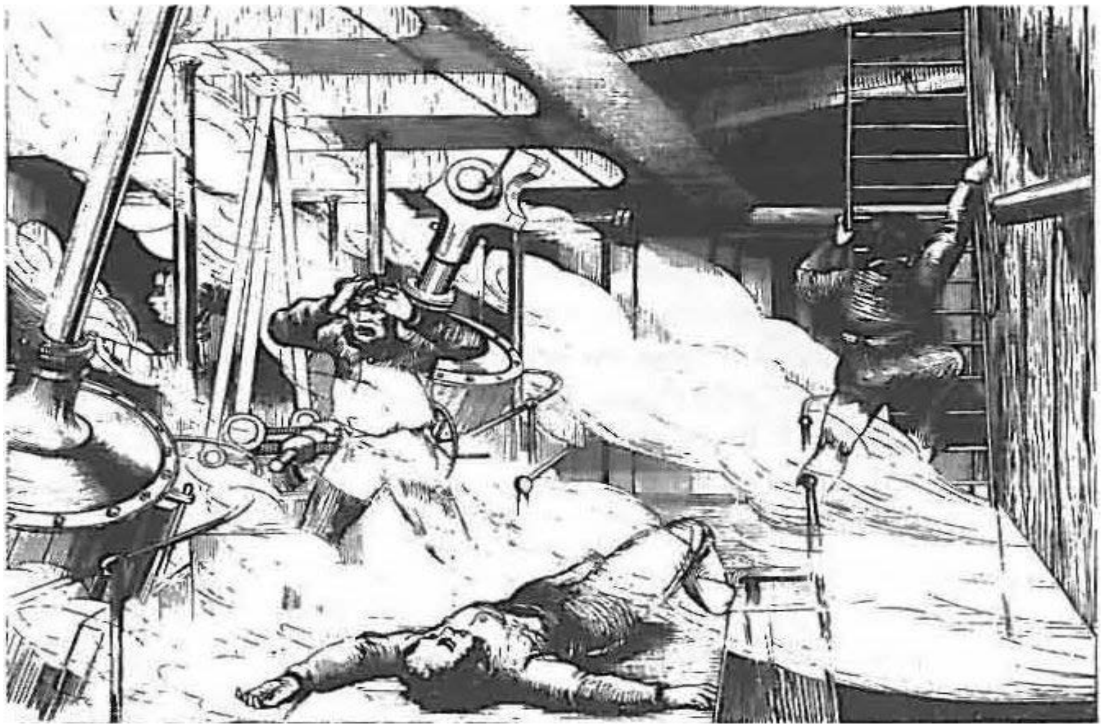


Figure 3-2. Boiler explosion aboard SS *Agnes Irving* in October 1865 (Richards 1987:72).

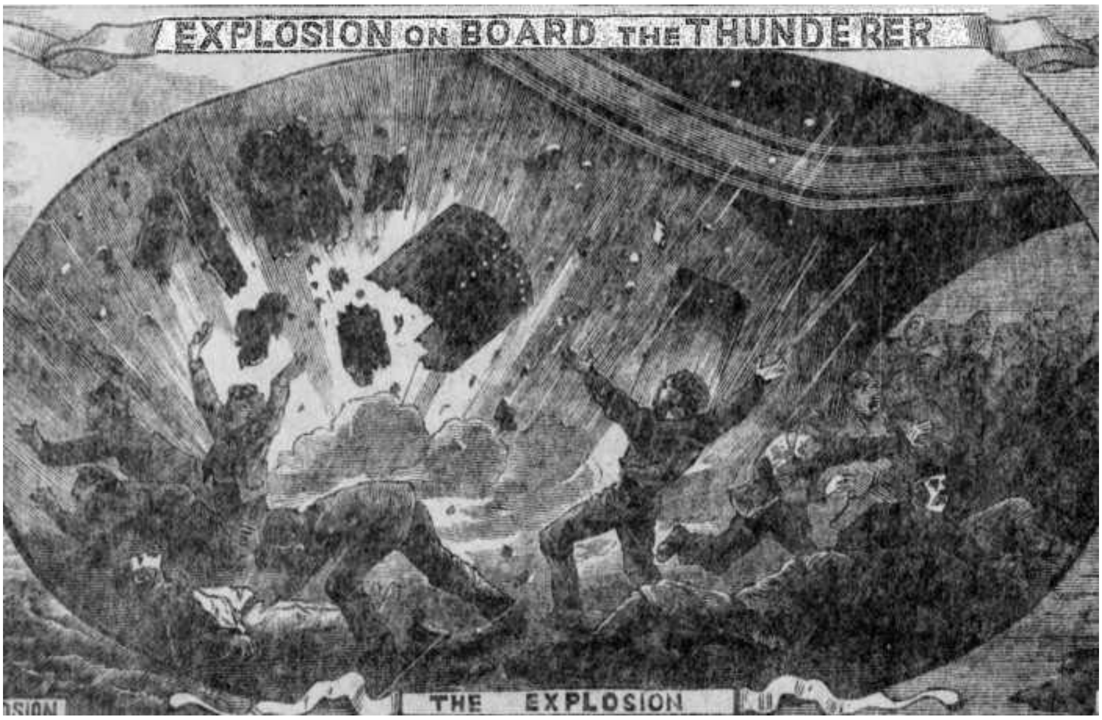


Figure 3-3. Boiler explosion aboard HMS *Thunderer* (*Illustrated Police News*, 29 July 1876).

Although death as a consequence of a boiler explosion could be instantaneous, in many cases it was prolonged and agonising. Lieutenant Augustus McLaughlin (1863:869–870) vividly recalls the tragic death of midshipman Charles K Mallory on board the CSS *Chattahoochee* (1864) on May 27, 1863 (Foenander 2011).

> Poor Mallory! I shall never forget his appearance. I would not have known him had he not spoken. His face, hands, and feet were scalded in the most terrible manner; he pleads piteously to have his wounds attended to. I urged the doctor, who, by the way, was almost used up himself, to pay Mallory some attention. He then told me that he would have to wait for some assistance. He then said that Mallory could not live. You would have thought differently had you seen him. I could not make up my mind that he would die. When they first commenced to remove the cloths he was talking cheerfully, but the nervous system could not stand the shock. He commenced sinking and was a corpse before they had gotten half through. Duffy, the fireman, expired on the next day.

Statistical Evaluation of Boiler Explosions in the United Kingdom 1801–1870

Historical documentation based on eye witness accounts and the reports of investigative agencies suggest that nineteenth-century boiler explosions were frequently caused by the deliberate overloading or failure of safety valves. However, an examination of statistical data from 1870 (Figures 3-4 and 3-5) as submitted to the Institution of Mechanical Engineers indicates that safety valve failure was just one of a multitude of factors that could be attributed to the cause of boiler explosions. Other factors being: corrosion, faulty design and inadequate water level (Fairbairn 1851:15; 1864:350–353; Hutton 1911:232; Marten 1868; 1870:191–195; 1872).

Number	**Boiler Explosions in the United Kingdom (1801–1866) by Cause**
247	Too uncertain to identify a specific cause
92	Boilers being worn out, from corrosion, or the deterioration of plates or rivets
132	Overpressure, safety valves being wedged or overweighted, acts of carelessness
136	Faulty construction of boiler fittings, want of stays, neglect of timely repairs
106	Shortness of water, formation of scale or mud or external flues set too high
6	Extraneous causes, lightning, fire, gas

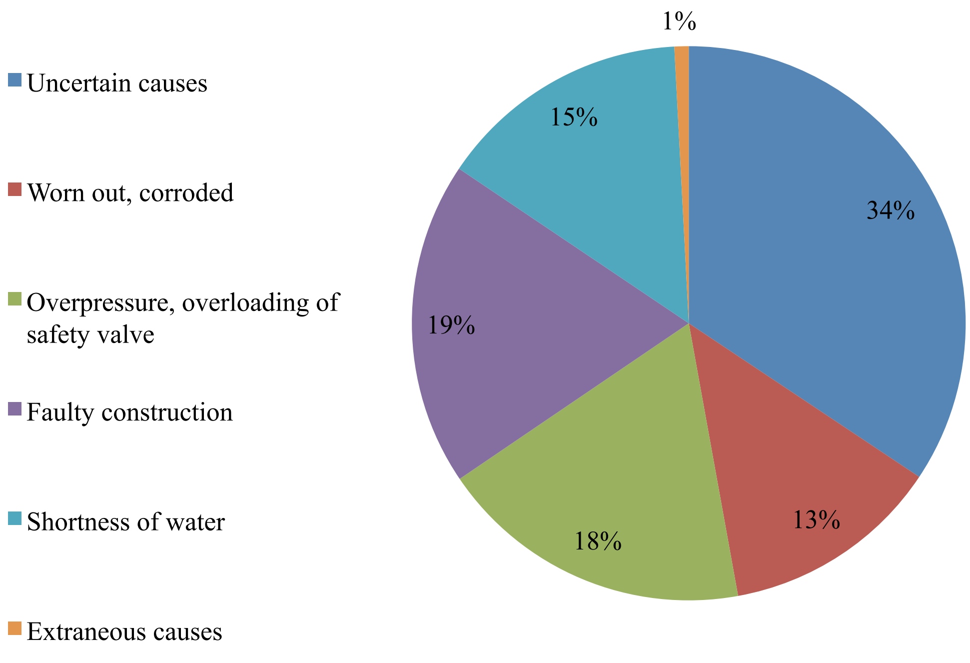


Figure 3-4. Percentage breakdown of causes relating to boiler explosions in the United Kingdom from 1801–1866. Based on statistics presented in Marten (1870:195).

Number	Boiler Explosions in the United Kingdom (1801–1866) by Type
203	Boiler type insufficiently described
57	Marine boilers
140	Cornish, Lancashire, or other boilers internally fired
91	Locomotive, or other multi-tubular boilers
114	Plain cylindrical boilers, externally fired
62	Balloon or haystack, wagon, Butterley, British-tube, elephant or Trevithick
28	Portable, agricultural, upright or crane
14	Heating apparatus or kitchen
10	Furnace upright

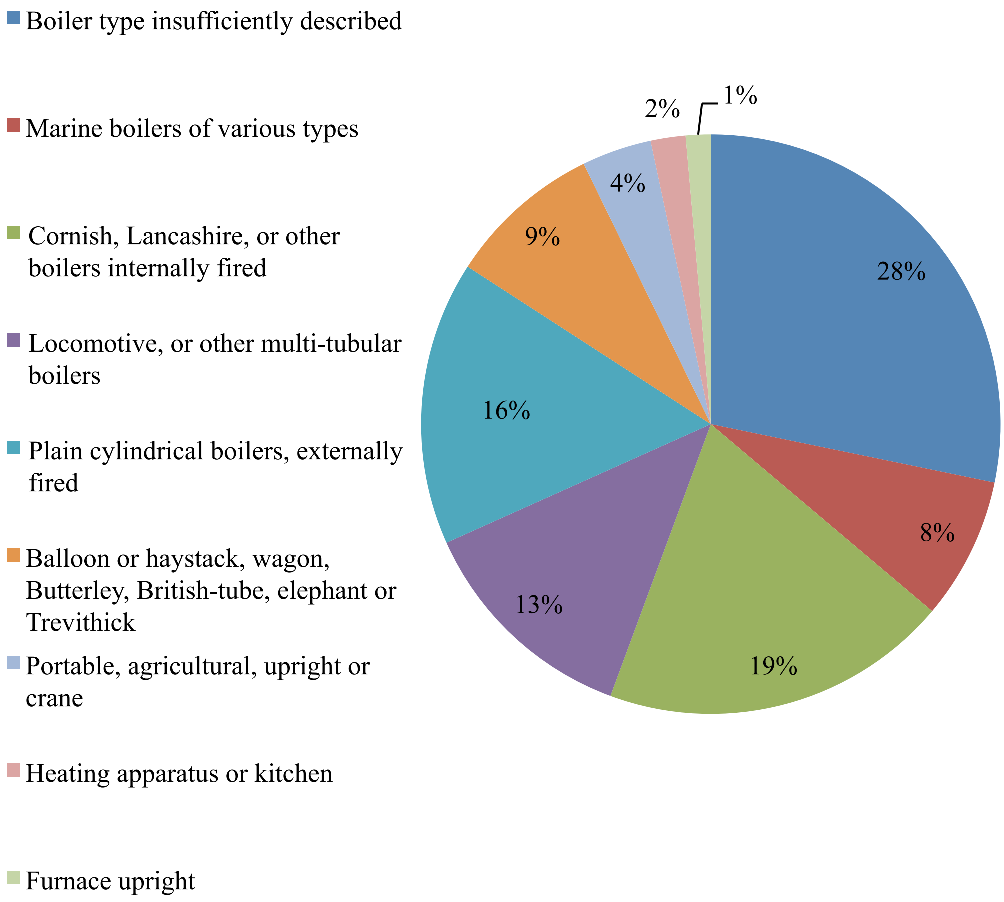


Figure 3-5. Percentage of boiler explosions in the United Kingdom from 1801–June 1866 by boiler type. Based on statistics presented in Marten (1870:194).

Although this data provides a general overview of explosions, its interpretive value is limited because it does not link the cause of the incident to a specific boiler type. It is impossible, for example, to extrapolate the 57 recorded instances of marine boiler explosions that happened during this time period and link them to a specific cause.

In the early years of steamship technology, assessments of boiler explosions were often undertaken by unqualified people with limited knowledge on the subject. Statistical data for the period 1801–1866 indicates that 34% of the 719 reported cases were too uncertain to identify the actual cause. It is also quite possible that cases listed as safety valve failures were, in fact, related to other causes that were poorly understood. These factors led to a strong argument by those advocating for inspection agencies to ensure more accurate assessments of boiler explosions (Robertson and Brooman 1864:90).

Edward Marten (1870:179–218) provided a more detailed analysis that linked the cause of boiler explosions to boiler type (Figures 3-6 and 3-7). Although his statistics cover only a four year period from 1866–1870, they are of interest because they show a significant reduction in the number of cases where the cause of explosion is undetermined. All instances of marine boiler explosions in this time period (Figure 3-8) could be attributed to either: faulty design or construction, corrosion, or shortness of water. Not one was the result of overloading of the safety valve.

Number	Boiler Explosions in the United Kingdom (June 1866–June 1870) by Cause
6	Too uncertain to identify a specific cause
89	Boilers being worn out or from corrosion or from deterioration of plates or rivets
25	Overpressure, safety valves being wedged or overweighted, acts of carelessness
69	Faulty construction of boiler fittings, want of stays, neglect of timely repairs
28	Shortness of water, formation of scale or mud or external flues set too high
2	Extraneous causes, lightning, fire, gas

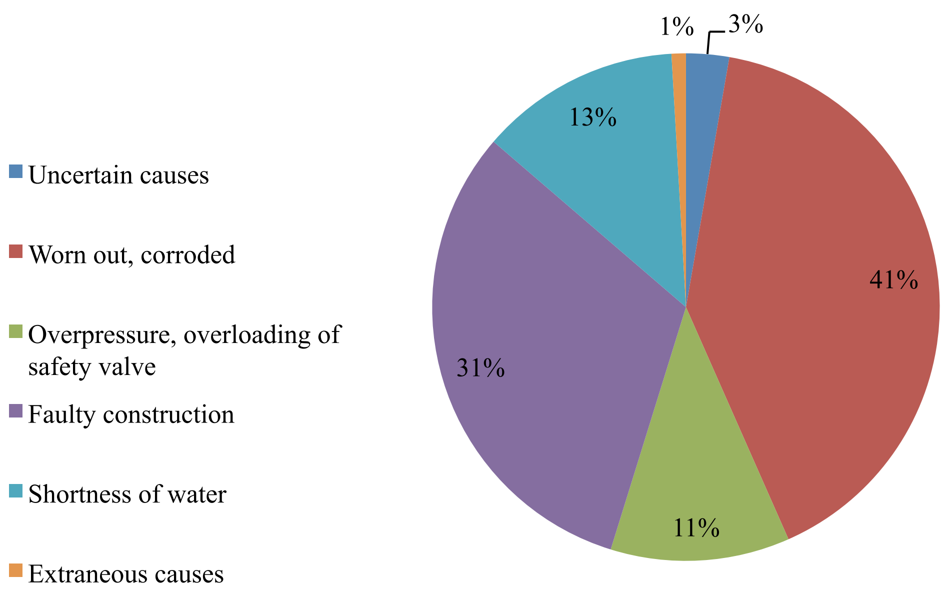


Figure 3-6. Percentage breakdown of causes relating to boiler explosions in the United Kingdom from June 1866–June 1870. Based on statistics presented in Marten (1870:195).

Number	Boiler Explosions in the United Kingdom (June 1866–June 1870) by Type
7	Boiler type insufficiently described
12	Marine boilers
84	Cornish, Lancashire, or other boilers internally fired
10	Locomotive, or other multi-tubular boilers
54	Plain cylindrical boilers, externally fired
5	Balloon or haystack, wagon, Butterley, British-tube, elephant or Trevithick
17	Portable, agricultural, upright or crane
22	Heating apparatus or kitchen
8	Furnace upright

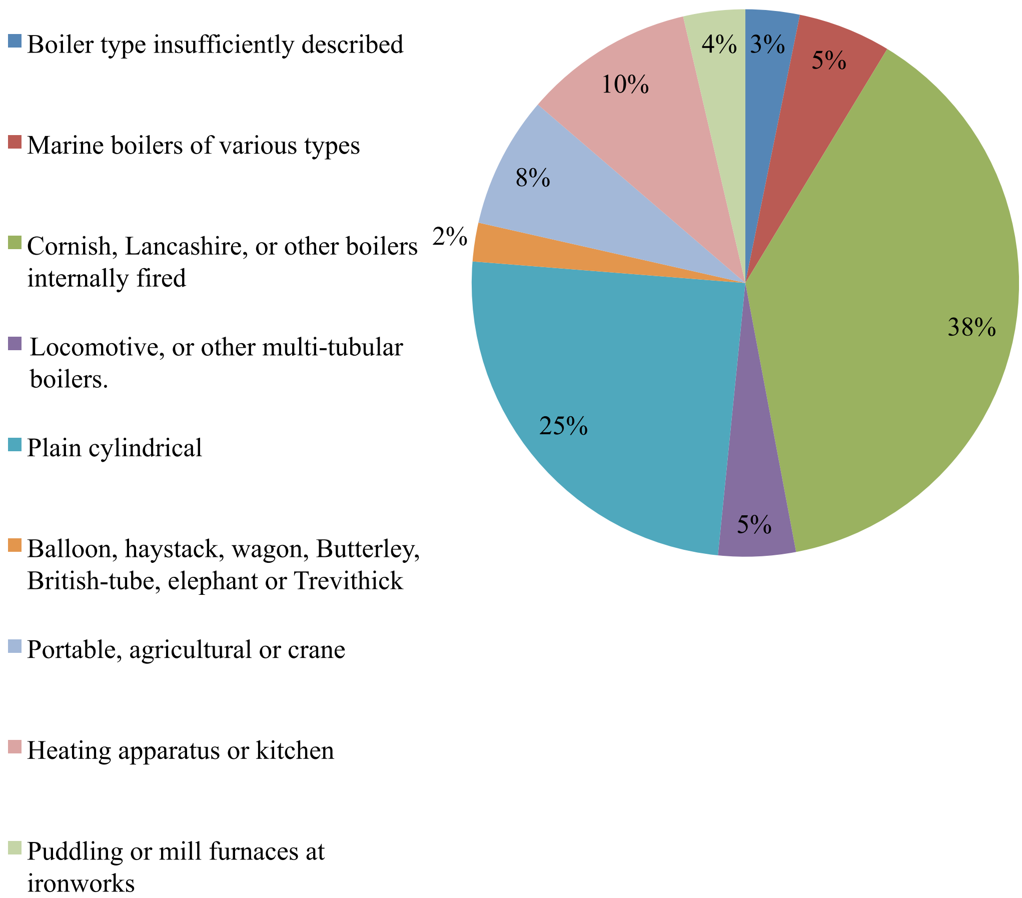


Figure. 3-7. Percentage of boiler explosions by boiler type in the United Kingdom from June 1866 –June 1870. Based on statistics presented in Marten (1870:194).

Number	Cause of Marine Boiler Explosions in the United Kingdom 1866–1870
3	Weak flues
2	Weak ends
1	Bad materials
2	External corrosion
3	Internal corrosion
1	Shortness of water

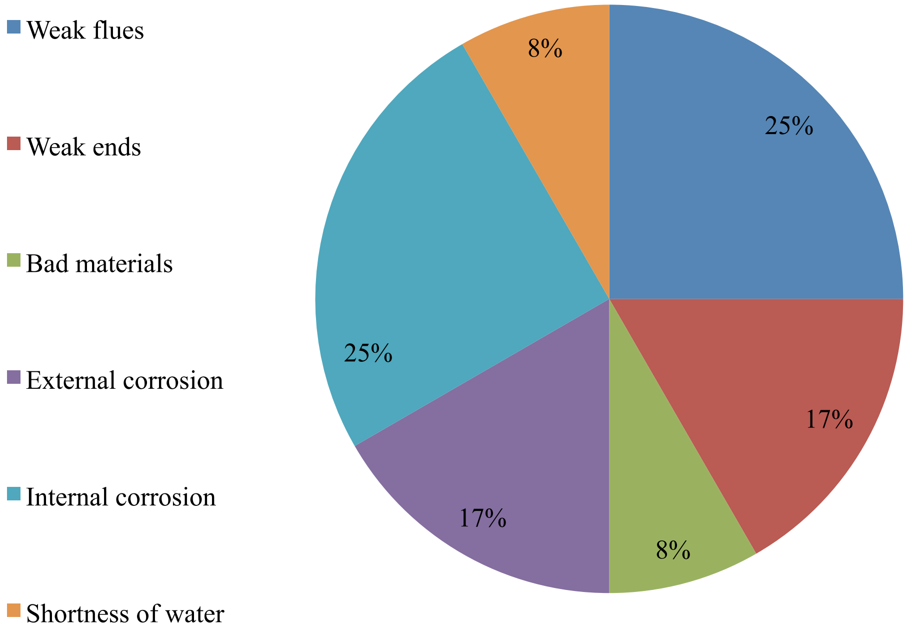


Figure. 3-8. Causes of marine boiler explosions in the United Kingdom from June 1866 –June 1870. Based on statistics presented in Marten (1870:197).

The Development of Legislation and law Enforcement Agencies

Legislation was seen as one method for reducing the incidence of boiler explosions on steamships in the United Kingdom. The first public notice on the subject was the enquiry by a parliamentary committee in 1817 investigating a fatal boiler explosion in London on SS *Richmond*. The committee collected evidence on steamship technology and referred to numerous boiler explosions in their final report. In their summation, the committee recommended that boilers should be made of wrought iron instead of cast iron or copper—the material of choice previously. Furthermore, competent master engineers had to inspect and test boilers twice each year and that there should be two safety valves on each boiler loaded to one third of the test pressure, under penalties for any excess. It also recommended that a certificate regarding the condition of the boiler should be issued, with similar rules applied to the inspection of engines (Guthrie 1971:117–118; Marten 1872:5).

Although these recommendations helped to draw attention to the issue of boiler safety, it was only in 1851 that the British Parliament passed the first legislation on the subject. As enacted, the *Steam Navigation Act of 1851* (UK Parliament 2011) read as follows:

> After, the thirty-first day of March one thousand eight hundred and fifty-two it shall not be lawful for any steam boat, of which surveys are required by the provisions of this Act, to go to sea, or to steam upon the

> rivers of the United Kingdom, without having a safety valve upon each boiler, free from the care of the engineer, and out of his control and interference; and such safety valve shall be deemed to be a necessary part of the machinery, upon the sufficiency of which the engineer surveyor is to report as herein provided.

Generally, the introduction of this legislation, enforced by the Board of Trade, was seen as a positive step to reduce the incidence of boiler explosions. However some professional engineering institutions, such as the Institution of Engineers and Shipbuilders in Scotland, believed it gave inspectors too much discretion as to what type of safety valve should be installed (Robson 1874:50– 51).

Despite this perceived shortcoming, the *Steam Navigation Act of 1851* had far reaching consequences internationally. In 1852, for example, the United States Congress introduced legislation that seemingly mirrored the initiatives taken in the United Kingdom. *The Steamboat Act 1852,* as introduced in the United States, required gauges and safety valves to be installed on all steamboats that carried passengers. Strangely freight boats, ferries, and towboats were exempt from these provisions (Twaintimes, 2011; Voulgaris 2009:6–7).

Growth of Inspectorate Bodies in the United Kingdom

Another important development in the United Kingdom that helped to reduce the incidence of boiler explosions was the growth of non-government controlled inspection agencies. One such organization the Association for the Prevention of

Steam Boiler Explosions was established by William Fairbairn (1864:350) in 1855. Known today as the Safety Federation (SAFed), this company is responsible for approving all boiler controls and fittings in the United Kingdom (Spirax Sarco). As an inspectorate, its primary function was to determine the safety of boilers for their operational use. In addition, this agency promoted the importance of boiler maintenance and safe handling practices. The widespread dissemination of literature to its members and their scientific approach for determining the causes of boiler explosions led to behavioural changes by boiler operators and the development of operating manuals for the safe usage of steam vessels. (Her Majesty's Stationery Office 1879; His Majesty's Stationery Office 1901; 1914; Cruickshank 1908).

Reduction of Boiler Explosions

The introduction of legislation and the growth of government and independently controlled boiler inspectorate agencies resulted in safer boiler practices both at sea and on land. Figure 3-9 shows a downward trend in the incidence of boiler explosions in the United Kingdom during the second half of the nineteenth century.

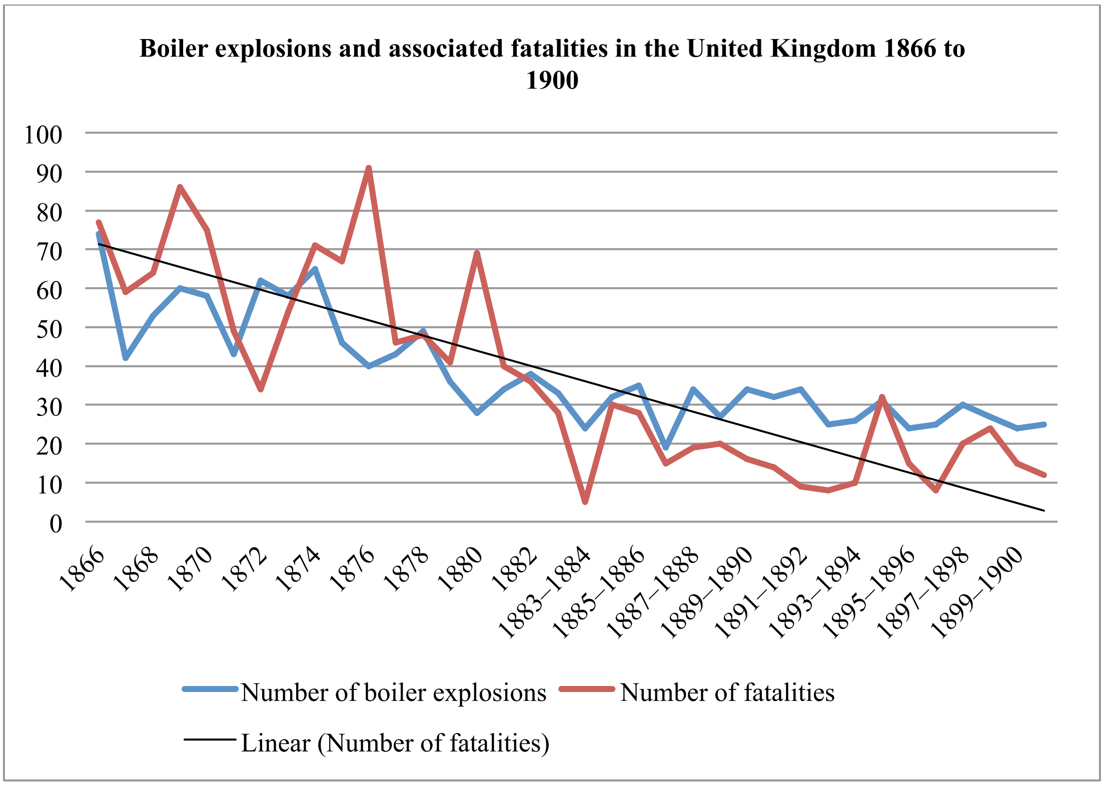


Figure 3-9. Number of fatalities associated with boiler explosions in the United Kingdom during the period 1866–1900. Based on statistical data provided by McEwen (2010: xv).

Conclusion

The development of steam-ship technology in the nineteenth century enabled many engineering and transportation tasks to be accomplished faster and more efficiently than in previous eras. The benefits for industry and transportation led to widespread usage even though there were potential dangers, particularly if the boiler was not maintained or was pushed beyond operational capacity. Boiler explosions were the result of a multitude of factors which extended far beyond defective safety valves or deliberate overloading to increase the steam pressure in a boiler. The passage of legislation in the United Kingdom and the growth of regulatory inspectorate bodies helped to reduce the incidence of boiler explosions.

CHAPTER IV: NINETEENTH CENTURY BOILER SAFETY VALVES

Introduction

This chapter provides an overview of some of the most common weighted and spring loaded safety valve designs developed during the course of the nineteenth century. The general operational characteristics are discussed together with the advantages and drawbacks. Although it was not possible to provide a comprehensive history of boiler safety valves, an expanded listing of patented devices up to 1873 is presented in Appendix B.

Purpose and Types of Safety Valves

The primary purpose of a boiler safety valve is to act as a relief mechanism for excessive pressure. As J.A. Fuller (1985:107) suggests:

> [A] safety valve is a product born of necessity, a result of the recognition that an automatic device was necessary to avoid undesirable results, if, as was bound to arise, sooner or later uncontrolled heat was applied to a closed vessel containing a liquid or gas.

There are four criteria for a good safety valve. They are:

- Pressure under no condition should rise above the load placed on the safety valve;
- The valve should return to its seat with the least possible loss of pressure;
- It should perform its work in the least possible amount of time; and
- It should be perfectly automatic (Adams1874:121; Buel (1875:56).

Safety valves can be divided into two categories: weighted and spring loaded. Most boiler safety valves used on steamships from 1800 to the 1870s tended to be weighted, whereas most boiler safety valves on steamships in the last quarter of the nineteenth century were of the spring loaded variety.

Although by the twentieth century most safety valves attached to steam boilers were the spring-loaded variety, in the nineteenth century the criteria for their installation was determined by several factors, including whether the boiler was stationary or moving, if it was to be used for land or marine applications, and its operating pressure. In his summation of safety valves used in the industry, Richard Buel (1875:90) states that:

> Safety valves for the boilers of locomotives and steamers, and in all instances in which they will be subjected to oscillations and jars, should be loaded with springs. For stationary boilers, either weights or springs can be used at pleasure. In employing spring it is generally considered

> best to arrange it so that it shall be compressed, rather than extended, when the valve is raised.

Other factors that had an influence in determining the type of valve used were reliability, the degree of experience of its operators and the recommendations by boiler inspection agencies, such as the Board of Trade in the United Kingdom.

Deadweight Safety Valves

Deadweight safety valves operate on the principle that the force needed to lift the valve and its weights must exceed the force holding the latter down. There are many variations to this type of valve. Some were "pendulously weighted" where the "preponderance of weights" was located below the valve seat as in the Cockburn Safety Valve shown in Figure 4-1. The advantage of such an arrangement was that it was less likely to jump off its seat when discharging steam and re-seating was more effective once the pressure fell. Other variations had the weights located above the seat as shown in Figure 4-2 (Fuller 1985:110). Most dead-weights found in historical literature appear as circular discs that have been manufactured to a specific loading weight. An example of this arrangement is shown in Figure 4-3.

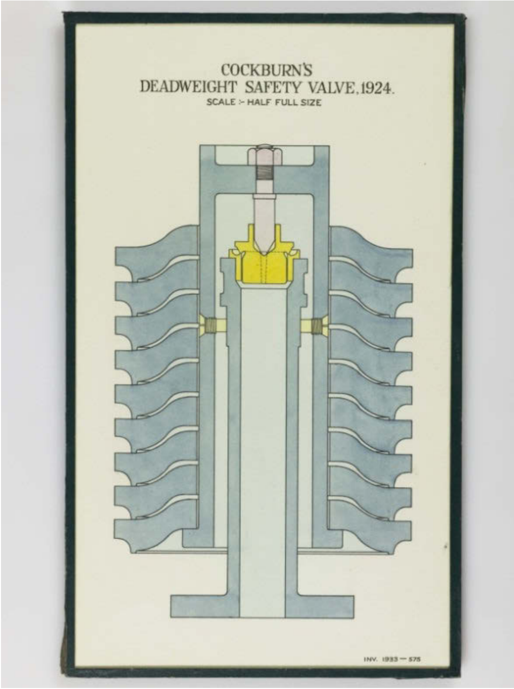


Figure 4-1. A Cockburn deadweight safety valve (1924). In this arrangement the preponderance of weights are located below the valve seat (Science Museum, Kensington, 2012, reproduced with permission).

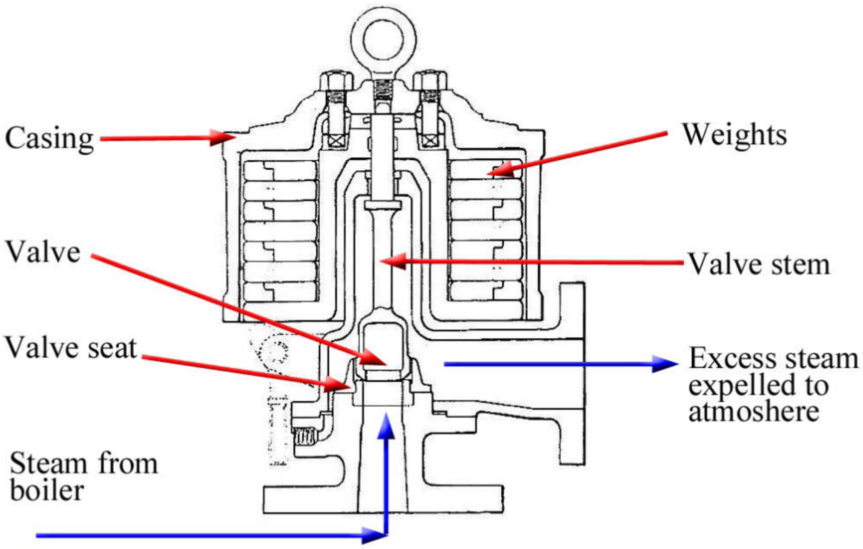


Figure 4-2. Deadweight safety valve with weights located above the valve seat (A. Kilpa, after J. Fuller 1985:110).

Figure 4-3. An example of a 2-inch (ca. 5.4 cm) diameter single deadweight safety valve. Such systems were vulnerable to corrosion and would frequently stick (Science Museum, Kensington, 2012, reproduced with permission).

Unlike lever-weighted valves that will to be discussed later in this chapter, deadweight valves were more difficult to tamper with from a pressure adjustment point of view—especially if located in a canister. There were, however, operational problems associated with their usage. “The least dampness from steam would cause the iron to corrode so that the valve, weights, or both would affix so firmly themselves to the surrounding metal that “all the pressure you could bring to bear would never move it” (Fairbairn 1864:348).

One means of overcoming this problem was through the application of corrosion resistant metals, such as brass and lead. The Maudslay, Sons and Field contract for the building of HMVS *Cerberus*’s machinery in 1867 for example, stated that all materials used for working the safety valves were to be “made of brass, or bossed with brass at the joints and glands to prevent it from rusting” and that the safety valve weights were to be made of lead (Maudslay, Sons and Field 1867:3). How widespread this practice was throughout the Royal Navy is unknown.

Although these materials helped to reduce the incidence of valves sticking, they were considerably more expensive than iron. Furthermore, 1 ton 9 cwt (1473 kg) of lead was required for the safety valves to operate *Cerberus*’s three large and two smaller auxiliary boilers at 30 psi (Wemyss 1870). Another major disadvantage of using this type of valve at sea was the effect rolling and pitching would have on its blow down point. This is discussed later in this chapter.

The Effects of Compounding

The development of compounding engines was another important consequence in the use of deadweight safety valves. Compound engines work on a principle where steam is expanded in two or more stages. Steam from the boiler would first expand in a high pressure cylinder where it would lose some of its energy, but rather than being expelled to the atmosphere the exhaust would be used productively by being directed into one or more low-pressure cylinders. This greater efficiency would also provide an economic advantage by reducing coal consumption.

Triple and Quadruple expansion engines began to appear in the 1870s and 1880s and are examples of engines that operated under this principle. However in order to receive the full economic benefits of compounding it was necessary to have both the engine and boiler capable of operating at pressures exceeding 40 psi (275.8 kPa) (Griffiths 1997:43). As such systems became commercially available and their benefits widely recognised, deadweight safety valves quickly became obsolete. A 3-in (7.62 cm) safety valve operating at 100 psi (689.5 kPa), for example required a weight in excess of 706 lb (320 kg) to be functional and this was totally impractical (Ripper 1909:199–200). Hazelton Robson (1874:49) described the obsolete nature of deadweight safety valves:

> Much of the economy aimed at has been lost owing to the great waste of steam from the Government safety valves, which is caused by the present method of loading them with dead weight. The action of such dead weight alters upon the valve with every action of the ship, and the enormous weight necessary to load a valve for high pressure often bends the spindle, thereby rendering the valve inoperative and untight. Indeed, it is found in practice scarcely possible to keep safety valves so loaded steam-tight, the loss of steam in this way on a long voyage is a serious matter, wasting the supply of fresh water that is absolutely necessary for boilers carrying high pressure steam in as much as all such waste has to be made up from the sea, and this cannot be done without increasing the density of the water in the boiler.

Figure 4-4 shows the rise in boiler pressures in the United Kingdom during the nineteenth century. With the exception of Crimean War era gunboat boilers, such as the ones used to power John Penn's Horizontal Trunk engine (as later fitted to SS *Xantho*), the trend demonstrated that marine boilers generally operated at low pressures until the 1870s. With improvements in boiler construction and the need for faster ships in response to commercial and military demands in the wake of the Crimean War (1854–1856) and American Civil War (1861–1865) (especially for blockade runners), boiler steam pressures gradually increased. The sharp rise in boiler operating pressures from the 1870s onwards, however, can be attributed to the wide spread use of compounding engines and the endorsement of spring-loaded valves by the Board of Trade in 1877 as the preferred choice for marine applications.

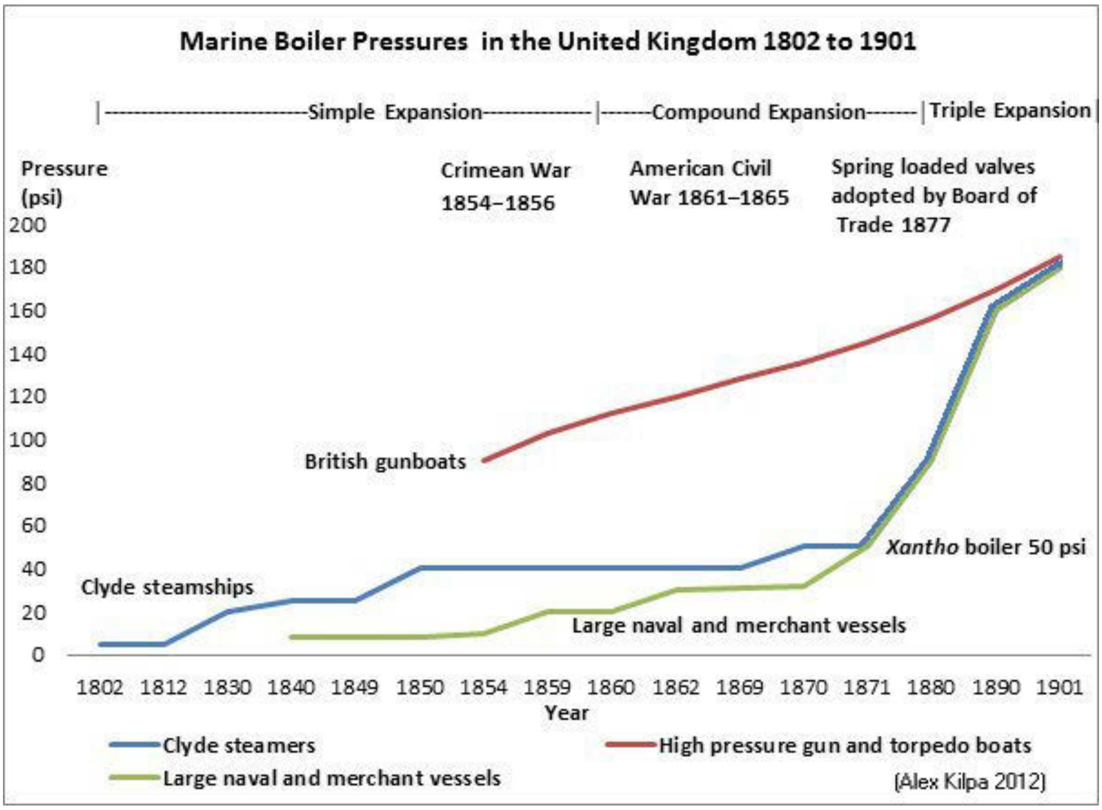


Figure 4-4. Summary chart indicating the effects of compounding and the rise in boiler pressures on gunboats in the service of the Royal Navy, large naval vessels and merchant ships in service of the P&O (McCarthy 2000:21) and Clyde-built passenger steamers 1802–1901 based on data extrapolated from Williamson (1904) (A. Kilpa, after McCarthy 2012).

Lever-Weighted Valves

Like the deadweight valve, the lever-weighted valve is user-friendly and low maintenance. During the course of the first half of the nineteenth century, it was widely employed on boilers in both marine and terrestrial settings. The valve recovered from *Indiana* is an example of this type of system (Appendix A).

Who invented the lever-weighted valve is the subject of some conjecture. Fuller (1985:107) and Robert Thurston (1878:47–48) suggest Denis Papin (1647–1712) invented the lever-weighted valve in 1679, while William Barnet Le Van (1892:10) states it was Salomon de Caus (1576–1626), and that Papin "merely improved" on de Caus's concept by applying it to a practical device that could be used for the softening of animal bones. A drawing of Papin's patented steam digester is presented in Figure 4-5. The lever-weighted valve proved to be a suitable safety device that could be applied to many other forms of pressure vessels.

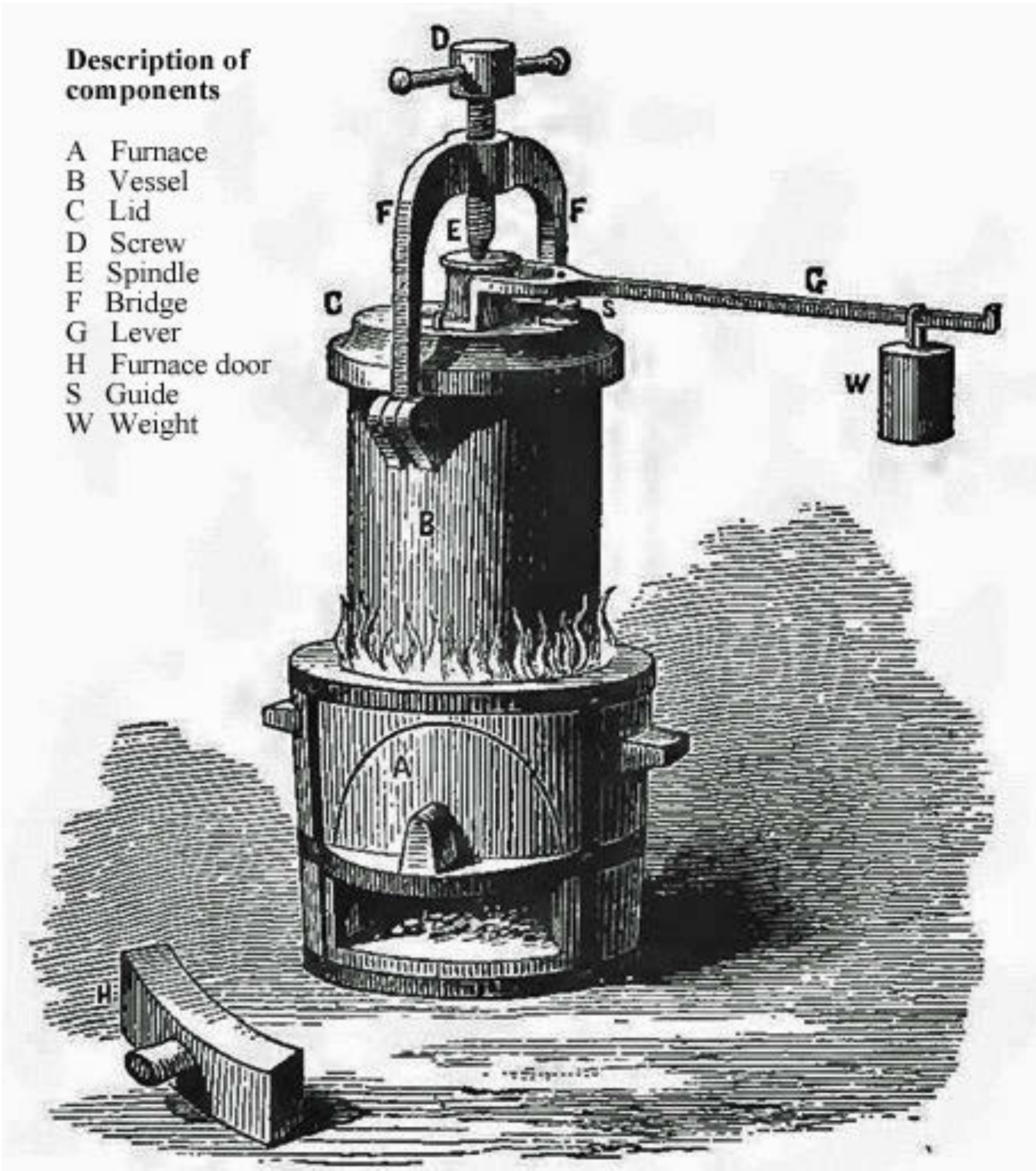


Figure 4-5. Denis Papin's steam digester for softening animal bones, shown with its lever-weighted safety valve (Thurston 1878:48).

Lever weighted safety valves work on the principle that a given weight located on a lever requires a certain amount of force to lift. The greater the distance from the fulcrum, the more force needs to be applied to lift the load. Hubert Collins (1908:84–100) and R.K. Rajput (2005:235) provide examples of how the laws of physics can be applied to predict the amount of force necessary to lift a given weight, at a given distance on a fulcrum. The weights used on lever-weighted safety valves came in various shapes and sizes. Figure 4-6 shows a typical nineteenth century lever-weighted valve with a ball-type weight. This contrasts sharply with the bell-like device presented in Figure 4-7.

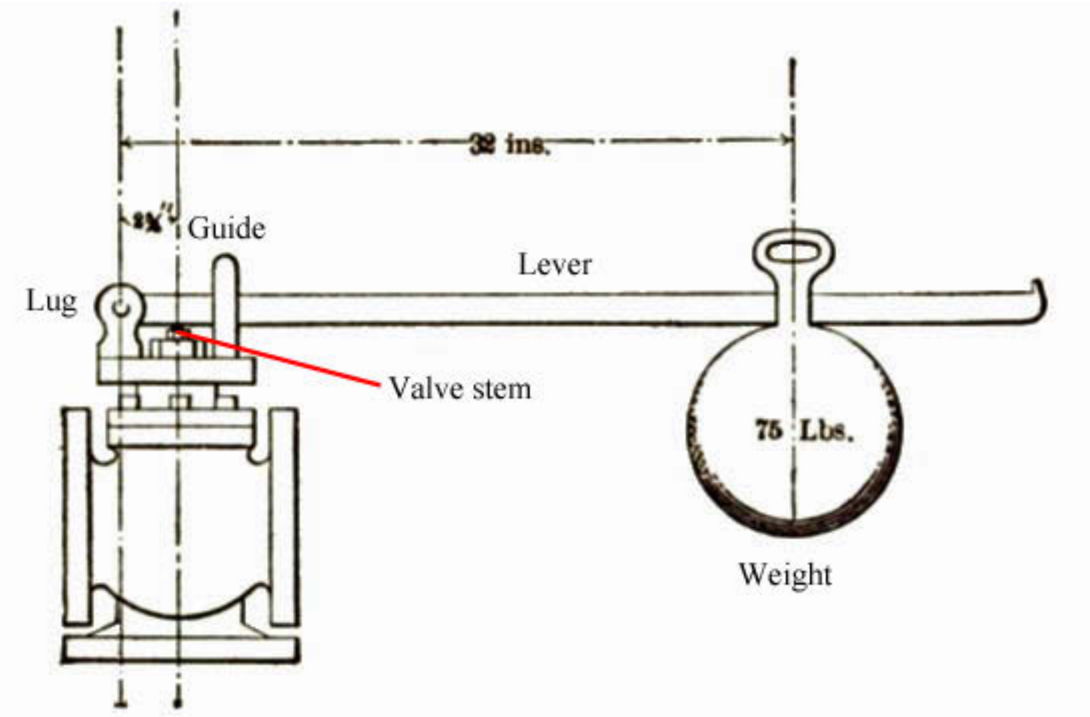


Figure 4-6. An example of a lever-weighted valve. By adjusting the position of the weight on the lever it is possible to alter the amount of force necessary to lift the weight (Collins 1908:89).

Figure 4-7. Weight from a lever-weighted safety valve. This device has a similar profile to the weight recovered from *Indiana* (Science Museum, Kensington, 2012, reproduced with permission).

Junction Valves

As shown in Appendix B there is considerable variation in the design of lever weighted safety valves. In some cases, such as the safety valve removed from *Indiana*, the lever weighted safety valve and the isolating valve share the same housing as seen in Figure 4-8 This type of apparatus is known as a junction valve (McEwen 2010:153).

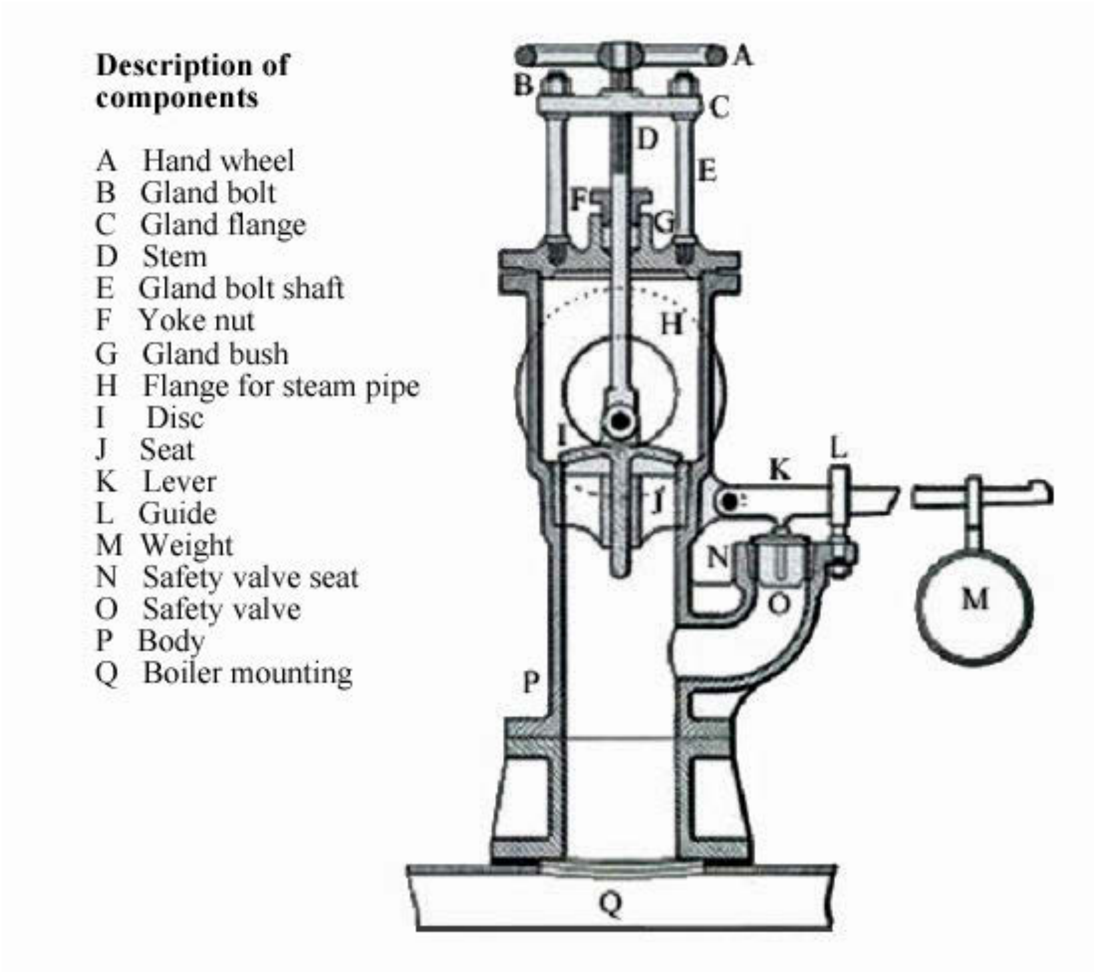


Figure 4-8. An example of a junction valve. This device combined a lever-weighted safety valve with a general isolating or shut-down valve (A. Kilpa, after A. McEwen 2010:153).

Although the safety valve recovered from *Xantho* (discussed in Chapter V) differs from the aforementioned design, it also incorporated the safety valve and isolating valve in one housing and therefore, had a multi-functional purpose.

A 1911 memorandum on steam boilers by William Buchan Inspector of Factories stated that "the bad practice of combining the stop valve and the safety valve chests to form one mounting should be abandoned, for the safety valve is liable to stick if the boiler should prime and cause mud and dirt to be carried towards the valve".

There was also the additional danger of the safety valve being cut off from the boiler if the boiler cleaners plugged up the stop valve inlet branch and forgotten to remove the obstruction before leaving the boiler (Fuller 1985:112).

Other Variations

Another variation of the lever-weighted valve that reflected growing understanding of the multitude of causes associated with boiler explosions was Hopkinson's patented combination valve (Figure 4-9). Developed in the 1850s, this device sought to provide protection in circumstances arising from low water/ high pressure by working on a counterbalance principle. If the level of water in the boiler dropped below a certain level the float would drop, activating the safety valve and releasing excess pressure (Fuller 1985:110; Hutton 1891:307; Rajput 2005:237–238).

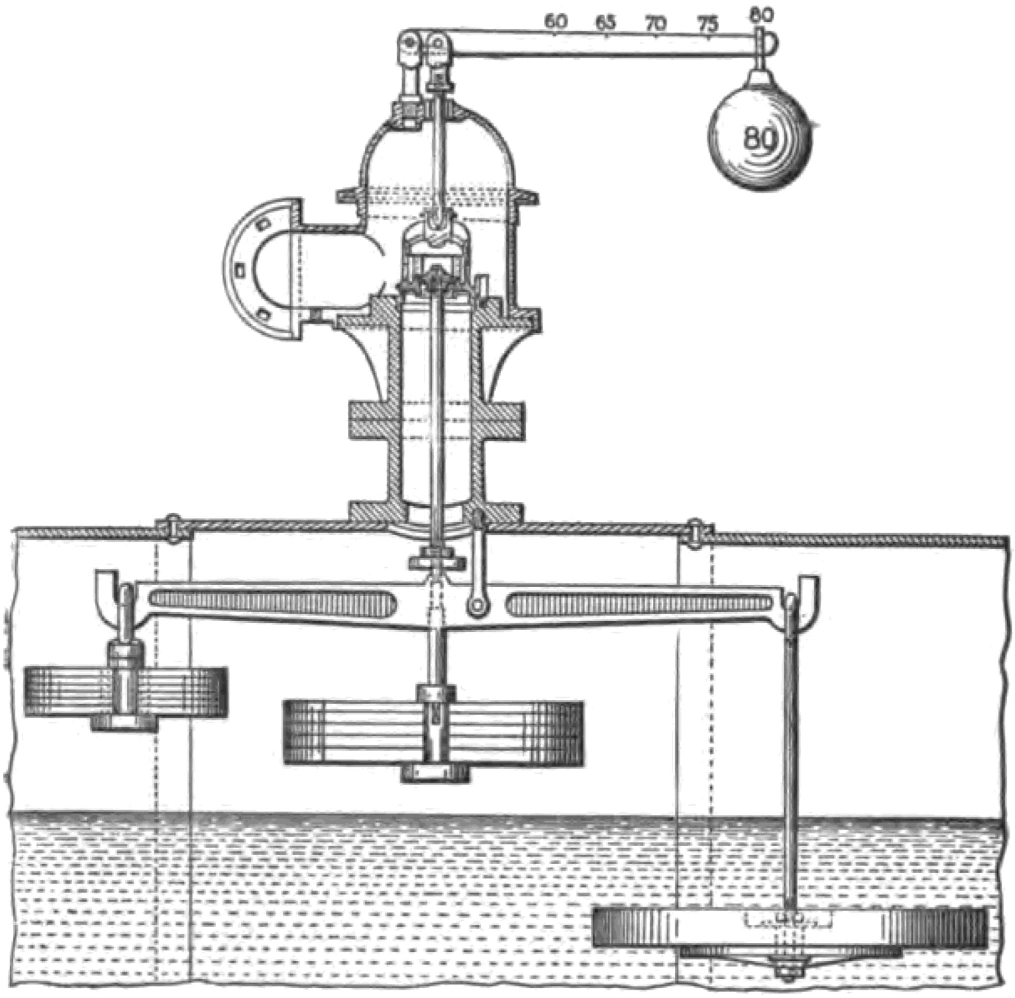


Figure 4-9. A Hopkinson low water/high pressure safety valve (Hutton 1891:307).

Other variations include the self-acting safety and fire extinguishing valve as shown in Figure 4-10 (Hughes 1870:219). As with Hopkinson's valve this system operated on a counter balance principle, but with the additional feature of a built-in fire extinguisher that would extinguish the furnaces if the water in the boiler dropped below a certain level. Both the Hughes and Hopkinson systems were complicated and not suitable for mobile boilers (Rajput 2005:238).

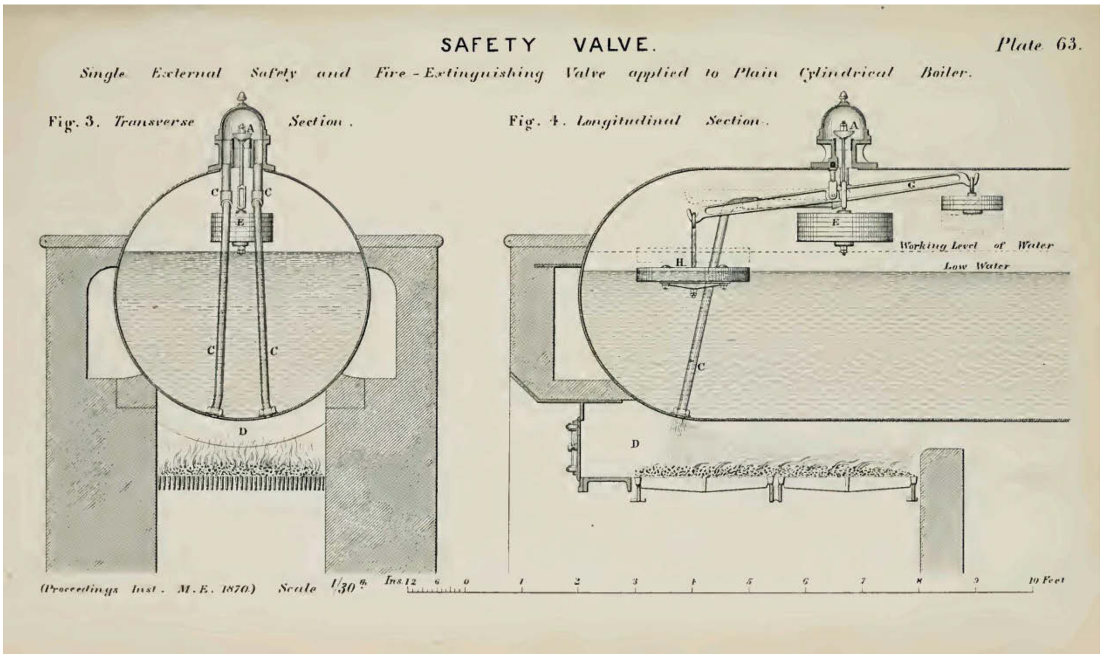


Figure 4-10. An elaborate version of a low water/high pressure valve with fire extinguisher (Hughes 1970: Plate 63).

Spring-Loaded Valves

Spring-loaded valves worked on a different principle from the deadweights because they used the tension of the spring to hold down the valve. Springs could be applied directly on the valve where it would operate under compression, or indirectly through the use of an arm in which case it would be operating under expansion.

Although spring-loaded valves were adopted fairly early in the nineteenth century for locomotives and land applications, it was not until the late nineteenth century that they were universally accepted for marine applications. One possible reason for this delay may be attributed to the traditional conservatism of marine engineers and shipowners. However, it also appears that the Board of Trade had legitimate concerns about the safety of spring valves. In 1873 McFarlane Gray, Chief Surveyor, Board of Trade expressed a reluctance to approve steam pressures over 482 kPa (70 psi) on merchant vessels (Guthrie 1971:118). It is not clear whether this was a general aversion to the use of spring-loaded valves or a reluctance to approve high pressure boilers. In a submission to the Institute of Engineers Hazelton Robson in 1874 states, that the Chief Surveyor of the Board of Trade in London (he did not mention McFarlane Gray by name), had vetoed spring-loaded safety valves and considered them unfit for the purpose of maritime use because they would "not allow the free escape of steam" and "consequently the pressure must accumulate in the boiler to a dangerous degree" (Robson 1874:50).

From the Board of Trade perspective there may have also been a lack of confidence in the metallurgical strength of the springs working under varying degrees of stress. If a locomotive broke down due to a broken safety valve it would be an inconvenience but if a safety valve broke on a ship it could paralyse the ship rendering it inoperable and possibly adrift in a circumstance of isolation where assistance was not readily available. This obviously was unacceptable and potentially disastrous. Deadweight safety valves may not have been as efficient as spring-loaded valves but they were reliable.

Salter Spring-loaded Valves

Salter spring loaded valves are somewhat similar to lever weighted systems but with the weight substituted by a spring that operated on an expansion principle. These devices are often referred to in historical literature as 'ordinary valves' and were used for both land and sea boiler applications. They were popular with engineers in the era pre-dating the Bourdon gauge because they could be fitted with a calibration scale that would provide some indication of the pressure existing in the boiler. An example of a Salter spring-loaded valve with a scale is presented in Figure 4-11. Examples of its installation for maritime and land applications are shown in Figures 4-12, 4-13, and 4-14.

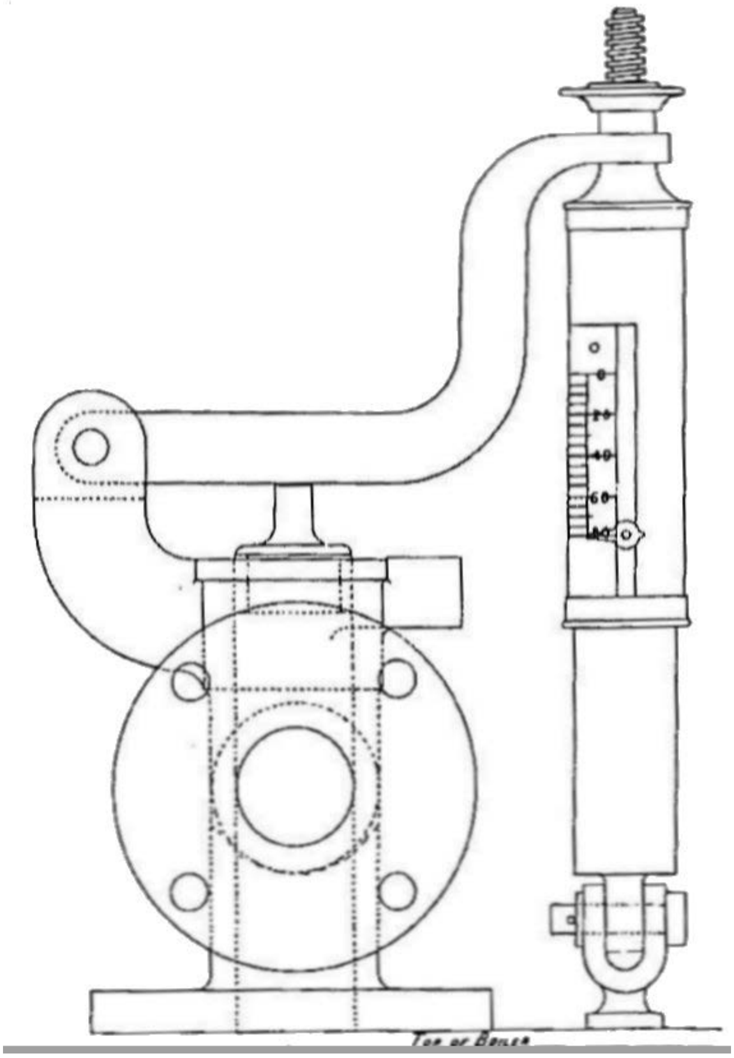


Figure 4-11. Lever and spring-balance safety valve working on the Salter principle. By the turn of the twentieth century, this type fell out of favour because of the ease by which it could be overloaded by over tightening the scale (Fuller 1985:109).

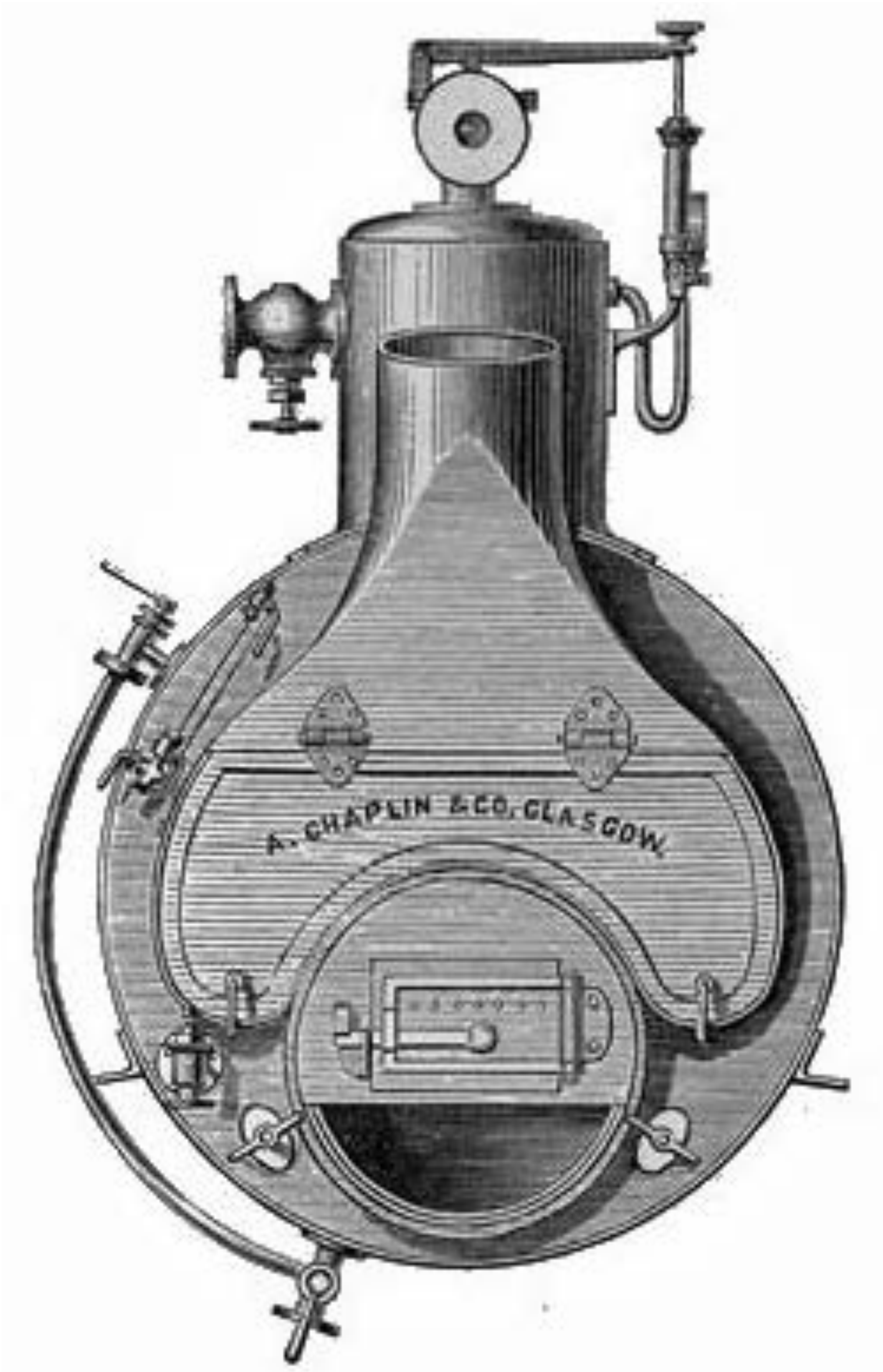


Figure 4-12. Marine boiler with a Salter spring-loaded valve. The ease by which such valves could be tampered with, by simply adding additional weights to the arm, led to their abandonment by the turn of the twentieth century (Alexander Chaplin & Co 1883:43).

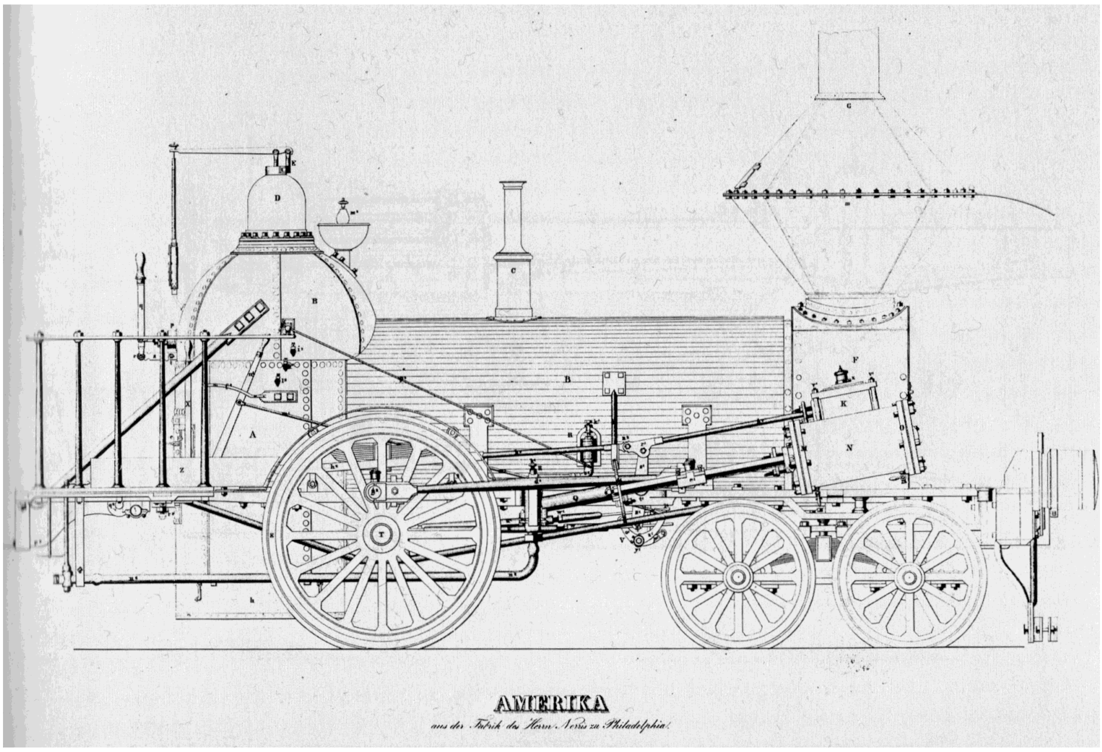


Figure 4-13. ***Amerika*** **built in 1838 for the Berlin-Potsdam Railway. The safety valve attached to the steam dome appears to be a Salter spring-loaded valve (White 1979:39).**

Figure 4-14. Salter spring-loaded valve as installed on the locomotive ***Stepney*** **(1847). These devices are rare to see in operation because they were superseded by 'pop valves' (Matt Durkan Railways, 2012, reproduced with permission).**

There were several drawbacks in the use of this type of valve. Firstly it was far too easy to overload them either by accident or deliberate action. This was accomplished by over-tightening the scale, adding weights to the arm, or tying the arm down. Secondly when the valve lifted the spring, it would provide more resistance, which consequently would not allow the free and rapid decrease of pressure.

In an experiment on a locomotive at Liverpool, its boiler was fitted with ordinary spring valves loaded to 482.6 kPa (70 psi), but on the usual test being applied by representatives of the Board of Trade the pressure went up beyond 758.4 kPa (110 psi) although the valve had lifted and was still going up, the board deemed it necessary on the grounds of safety to open the furnace doors and reduce the pressure. Only when the pressure gauge fell below 418.7 kPa (60 psi) did the valve take its seat again (Robson 1874:50). Other examples of the inadequacy of ordinary spring valves to allow for the free escape of steam are presented by John Wilson (1877:181). By the turn of the twentieth century boiler inspectorate bodies were advocating the abandonment of this type of device in favour of tamper proof ‘pop safety valves’ (Fuller 1985:109).

Ramsbottom Safety Valve

An early variation of the spring-loaded safety valve was the dual safety valve developed by the English mechanical engineer John Ramsbottom (1814–1897). This device gained popularity in the latter part of the nineteenth century and consisted of two safety valves held down by a single stout helical spring located midway between them. The spring holds down both valves with equal force by a crossbar to which the spring is attached and which rests upon both valves (Figure 4-15).

Unlike previous generations of safety valves where they worked best without any interaction of the engineer, this type of system encouraged their involvement to occasionally affect the release of steam. Any movement of the handle by the engineer, whether by depressing or raising the lever, has a positive effect as it would alter the pressure on the other valve. It is, therefore, impossible to tie or fasten this handle down to prevent the escape of steam. When the pressure rises too high, both valves will blow off and rise to the full extent to which the spring is extended. This is a marked improvement on ordinary arrangements that lift one-eighth, or perhaps one-twelfth, of the extension of the spring. “Even with a strong fire, the steam cannot rise but a very few pounds above the pressure at which the valves are set to blow down” (Barnet Le Van 1892:132).

One of the major disadvantages of the Ramsbottom arrangement was that the spring tension could easily be tampered with, either by adjusting the nut (Ripper 1909:198), or as reported by F. W. Webb “putting a clip on two or three coils on the spring” to alter its compression ratio (Wilson 1877:182). An improvement on the Ramsbottom device was the Wilson patent safety valve which had its springs enclosed in two housings making them tamper proof and protecting them from the effects of moisture. An example of this type of valve is shown in Figure 4-16.

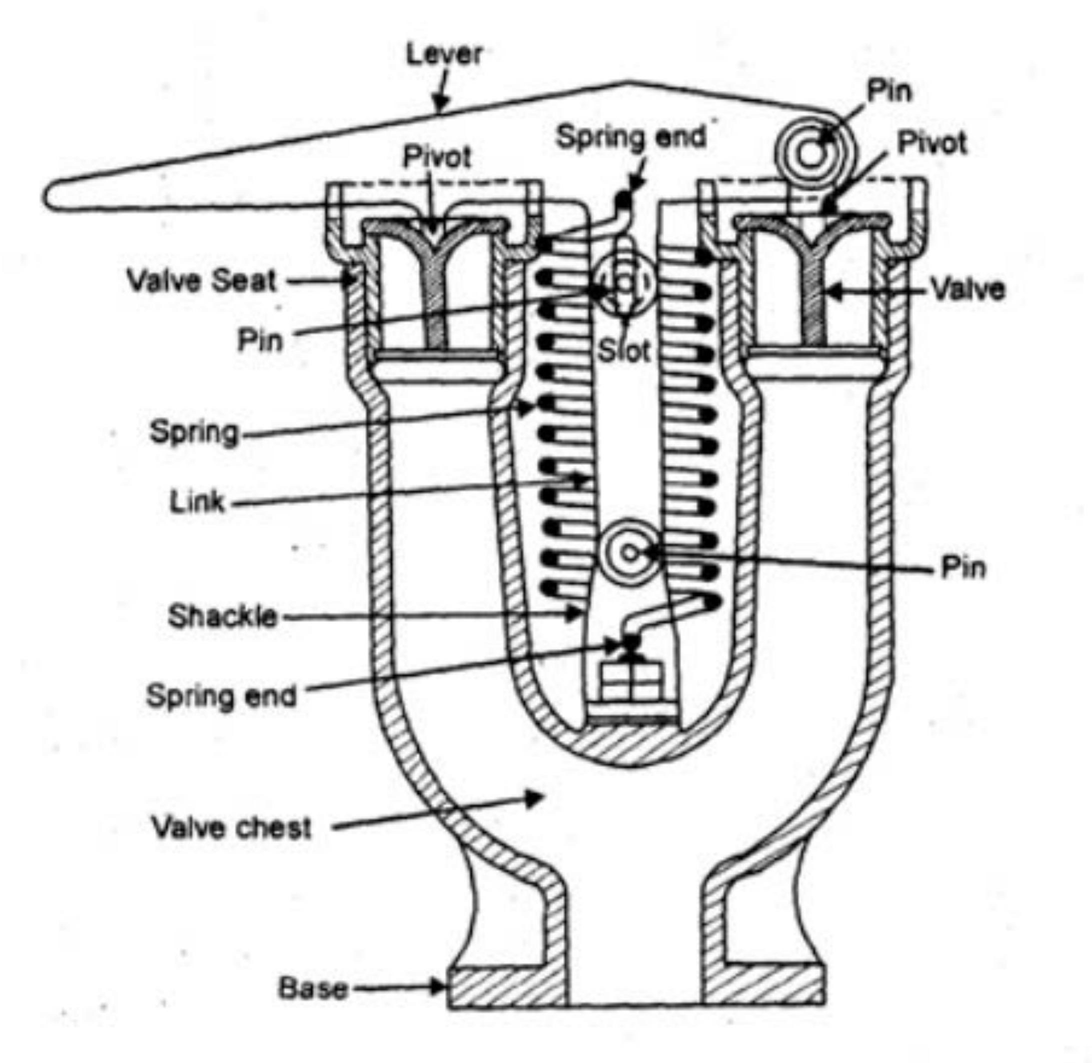


Figure 4-15 Ramsbottom safety valve (Loremate.com, reproduced with permission).

Figure 4-16. Wilson patent safety valve with enclosed springs. This valve operated on similar principles to the Ramsbottom arrangement. Any increase in the tension applied to one of the valves would be counterbalanced by a release of pressure on the other (Science Museum, Kensington, 2012, reproduced with permission).

Pop Valves

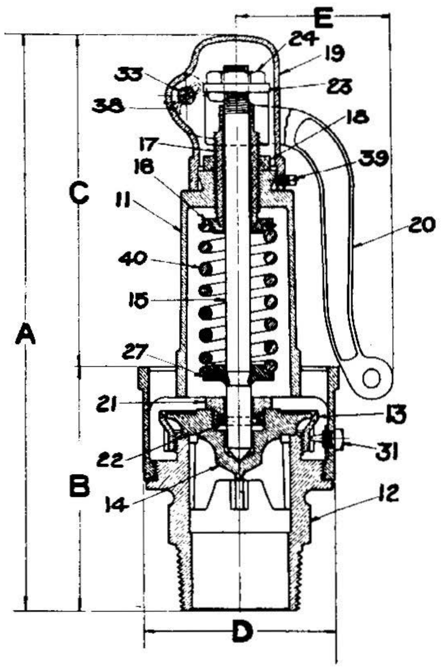
Today,'pop valves' are the most common form of safety valve used in industry. Developed by the locomotive engineer George W. Richardson in the 1860s, the design of this type of spring-loaded valve was a significant improvement over other safety valves as they "opened quickly and fully, relieving the pressure promptly and closed sharply when the pressure fell 3–5 pounds [20.68–34.47 kPa] below that for which the valve was set" (White 1979:148). The term 'pop valve' being popularly adopted because of the noise associated with its quick opening action. Pop valves proved to be ideally suited for mass production and for universal application, i.e.

suitable for both high and low pressure boilers operating in a variety of environmental conditions (White 1979:148).

The valve shown in Figure 4-17 has been calibrated to react to a steam pressure of 758.4 kPa (110 psi). Of note is the inspection tag and plate that provides details of the valve specifications, date and settings. The flange located on the left hand side provides an avenue for the steam to be released to the atmosphere through a blow down pipe.

Similar to the Ramsbottom valve, this system has a lever (Figure 4-18) that could be used to manually release pressure in the case of an emergency or for general maintenance . These bronze safety valves could be calibrated to operate effectively at 2413.2 kPa (350 psi) (Consolidated Ashcroft Hancock Company 1934:1412). This represents a 100 fold increase in the typical pressures used in boilers of 1802 (Fairbairn 1864:358).

Figure 4-17. This 'pop valve' was manufactured by the Consolidated Pop Valve Company. The attached specification plate indicates that it was calibrated to operate to pressures of 758.4 kPa (110 psi) (A. Kilpa, 2012).



Dimensions

VALVE SIZE		$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3
EXTREME HEIGHT	A	$5\frac{5}{8}$	$5\frac{5}{8}$	$6\frac{11}{16}$	$8\frac{1}{16}$	$8\frac{11}{16}$	$11\frac{3}{16}$	$13\frac{1}{16}$	$14\frac{15}{16}$
BOTTOM TO OUTLET	B	$2\frac{7}{16}$	$2\frac{7}{16}$	$2\frac{13}{16}$	$3\frac{5}{16}$	$3\frac{5}{8}$	$4\frac{3}{16}$	$4\frac{15}{16}$	$5\frac{9}{16}$
OUTLET TO TOP	C	$3\frac{3}{16}$	$3\frac{3}{16}$	$3\frac{7}{8}$	$4\frac{3}{4}$	$5\frac{1}{16}$	7	$8\frac{1}{8}$	$9\frac{3}{8}$
DIAMETER	D	$1\frac{11}{16}$	$1\frac{11}{16}$	$2\frac{1}{8}$	$2\frac{9}{16}$	$2\frac{7}{8}$	$3\frac{13}{16}$	$4\frac{13}{32}$	$5\frac{5}{16}$
LARGEST RADIUS	E	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{7}{8}$	$2\frac{1}{4}$	$2\frac{5}{16}$	$3\frac{1}{16}$	$3\frac{5}{16}$	4

REFERENCE TABLE OF PARTS

11-TOP
12-BOTTOM
13-RELIEF RING
14-VALVE PROPER
15-SPINDLE (COMPLETE)
16-FOLLOWER
17-COMPRESSION SCREW
18-LOCKNUT
19-CAP
20-LEVER
21-MARINE NUT
22-SPINDLE PIN
23-SPINDLE WASHER
24-SPINDLE NUT
27-SPRING SEAT
31-RELIEF RING LOCKSCREW
33-LEVER PIN
38-COTTER PIN
39-CAP LOCKING SCREW
40-SPRING
43-NAME PLATE
44-NAME PLATE DRIVE SCREW

Figure 4-18. Components of a model 1451 'pop valve' designed for marine use (Consolidated Ashcroft Hancock Company Incorporated 1934).

Conclusion

The development of boiler safety valves in the nineteenth century was an evolving process with the use of such valves being determined by the level of technology then in existence and the circumstances of their application. Contrary to popular thought, most safety valves used on steam vessels were of the lever weighted or deadweight types until the latter part of the nineteenth century. By the end of the century their use on boilers in marine environments had been superseded by spring-loaded valves, which were safer, more economical, and had the ability to operate at far greater pressures.

CHAPTER V: REASSEMBLY AND ANALYSIS

Introduction

This chapter describes the reassembly of *Xantho'*s safety valve and provides a detailed description of its components. From this research, a hypothesis is developed as to the valve's purpose and how it was installed on the boiler. Most of the research, photography, and determination of technical specifications associated with this object were undertaken at the Western Australian Museum's conservation laboratory.

Background of Recovered Materials

As aforementioned, *Xantho* sank on November 16, 1872 opposite Gold Digger Passage Port Gregory, Western Australia. From 1985 to 1994, archaeologists and volunteers surveyed and partially excavated the shipwreck site under the auspices of the Western Australian Museum (McCarthy 1996, 2000). The main objective of the excavation was to raise the Horizontal Trunk Engine, designed by John Penn and Son for British Gunboats operating in the Black Sea during the Crimean war (1854–1856). In addition, several other large artefacts were recovered from the wreck site including a Chaplin distilling apparatus (Kilpa and Lent 2011) and the safety valve located approximately one metre away from the boiler on the starboard side of the vessel (Figure 5-1).

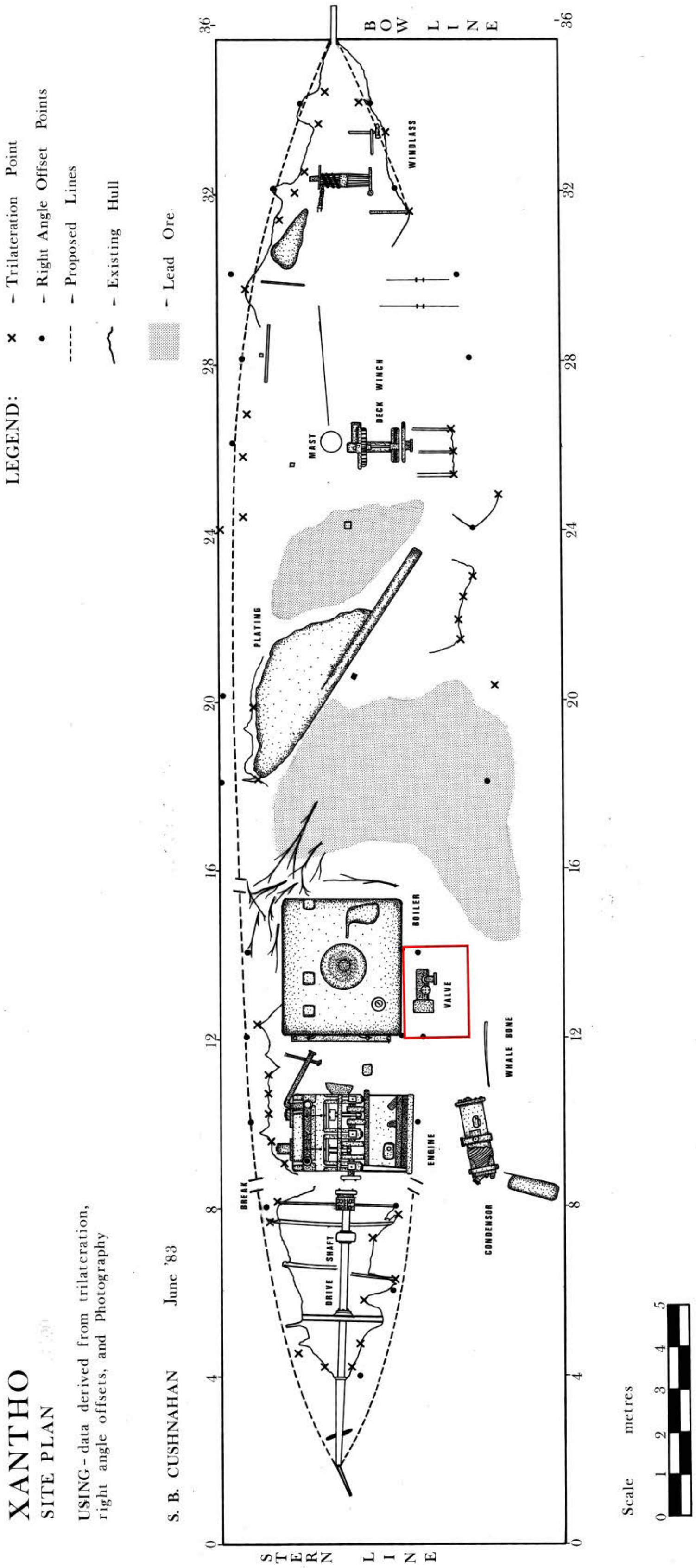


Figure 5-1. Site plan of SS *Xantho* indicating the location of the safety valve (red box) on the seabed (A. Kilpa 2010, after McCarthy 2000:83).

De-concretion and Initial Conservation

Archaeologists removed the safety valve concretion from the shipwreck in 1988. After registration, it was presented for stabilization to the Department of Materials Conservation of the Western Australian Museum. Here, conservators applied a conservation treatment in two stages:

Stage 1. Conservators removed the calcified remains of marine biological matter in a process considered by the archaeological director to be an excavation in its own right. This was accomplished mechanically through the use of hand tools, such as picking devices, chisels, and scalpels. Figure 5-2 shows the safety valve at the commencement of the de-concretion process whereas Figure 5-3 shows the final result.

Stage 2. The object was placed in a solution of 2% sodium hydroxide to facilitate the removal of chlorides through a process of diffusion. Records indicating exactly how long this process took are unavailable, partly because the archaeological director was absent during this time, (Michael McCarthy, personal communication 2012).

Figure 5-2. The safety valve being de-concreted by conservator Alan Kendrick (Western Australian Museum, 1994).

Figure 5-3. The safety valve after de-concretion (Western Australian Museum, 1994).

Accessioning of Components

After de-concretion, the object was accessioned into the collection of the Department of Maritime Archaeology of the Western Australian Museum. To aid in the tracking of the artefact's components, all visible parts and fragments were given a unique identification number as per standard museum practice (Table 5-1).

Table 5-1 Summary of Safety Valve Components.

Registration number	Description
XA339	Main housing with XA339i and XA339ii
XA339A	Boiler flange. Concave structure.
XA339B	Safety valve plate. Has piece broken off handle bracket
XA339C	Weight circular with depression
XA339D	Weight circular
XA339E	Oblong weight lower
XA339F	Oblong weight
XA339G	Oblong weight
XA339H	Oblong weight top off at an angle
XA339J	Gasket fabric located between XA339 and XA339A

Reconstruction

All artefacts excavated from *Xantho* were recorded in *The Xantho Accession Book 1985–1994.* Figure 5-4 shows a sketch of the safety valve with an itemised inventory of its components. Unfortunately, the object was severely damaged at some point during the treatment process due to causes unknown and now consisted of more than 500 shards. In 2010, I commenced the task of reconstructing this object.

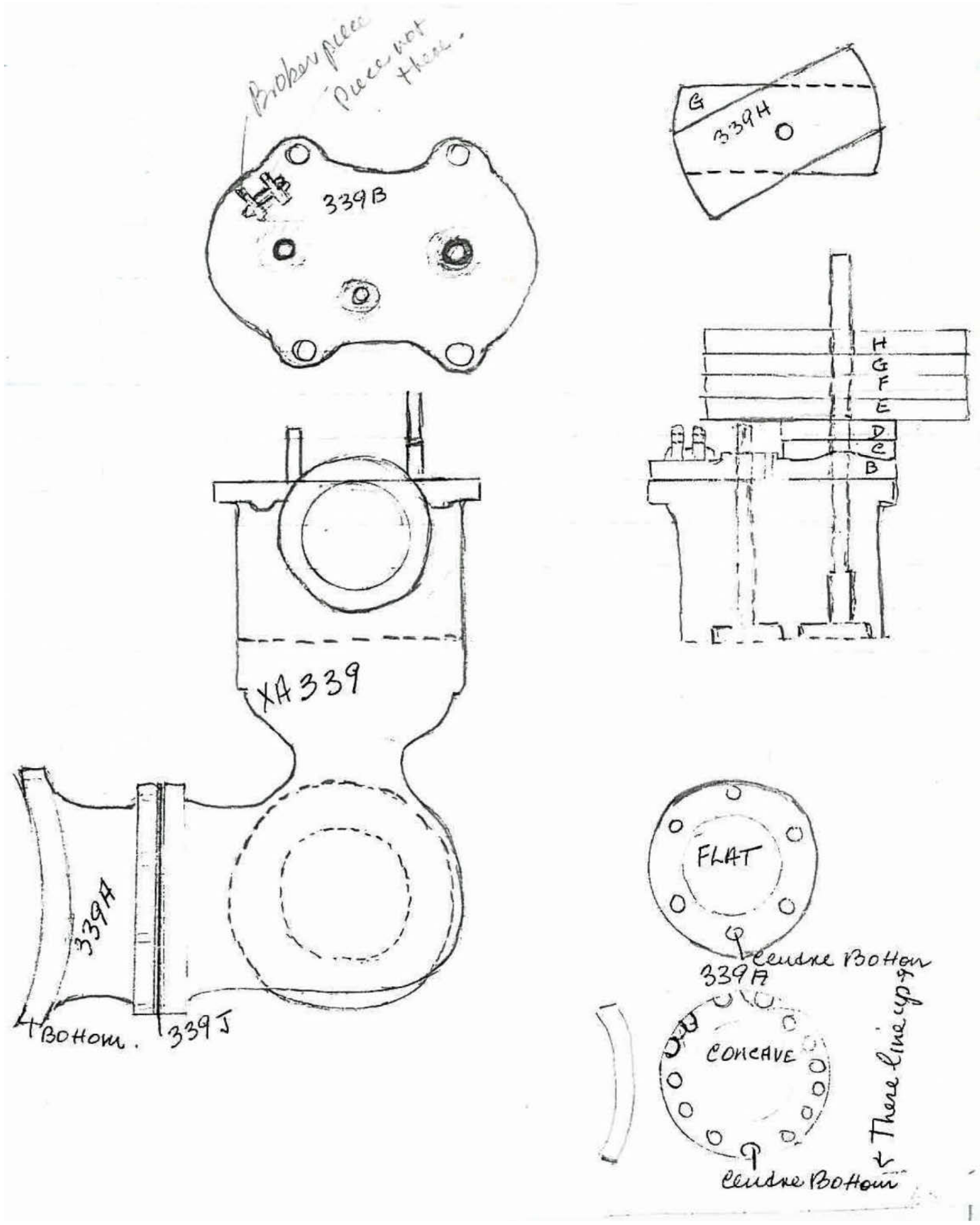


Figure 5-4. Extract from *The Xantho Accessioning book 1985-1994*, showing breakdown of safety valve components (Western Australian Museum *Xantho* Accessioning book, (1994:84).

The failure of the conservation process led project leader Michael McCarthy (2000:174) to conclude that nothing further could be done with the object other than to use it, along with the other data to bring into question the capacities of the ship's owner operator Charles Edward Broadhurst (See also foreword of this thesis). It remained in pieces until the author offered to attempt its reassembly and reconstruction. Initially this project was undertaken purely as a conservation rescue operation, but as this artefact had not been archaeologically interpreted other than to recognise that it was a weighted safety valve, historical and engineering records were consulted in order to better understand its construction, method of operation, and relationship to *Xantho*'s propulsion system in general.

To achieve this objective every component relating to the safety valve with the exception of the valve spindles had to be reconstructed from the available shards. To complicate issues further the remains of this artefact had merged with other unrelated materials in the conservation treatment containers creating a highly complex 3D jigsaw puzzle. Additionally there was some uncertainty as to completeness of the object due to an absence of photographic evidence from the de-concretion and desalination processes. Figures 5-5, 5-6, 5-7, 5-8, 5-8, 5-9, and 5-10 show various components of the safety valve before, during, and after their reconstruction. A complete photographic record of its reassembly can be found in Appendix C.

Figure 5-5. The remains of *Xantho*'s safety valve housing prior to reconstruction. In this state the artefact had little interpretative value. The larger of the spindles (XA339 i) is for the deadweights (A. Kilpa, 2010).

Figure 5-6. Boiler flange mounting (XA339A) prior to reconstruction. Additional fragments found at a later date are now also integrated into the object (A. Kilpa, 2010).

Figure 5-7. Fragments of the safety valve plate prior to reconstruction (XA339B) (A. Kilpa, 2010).

Figure 5-8. Circular deadweight prior to reconstruction (XA339D). This component alone consisted of 39 pieces (A. Kilpa, 2010).

Figure 5-9. One of the oblong deadweights before reconstruction (XA339F) (A. Kilpa, 2010).

Figure 5-10. The author reconstructing the valve housing with three flanges. The block with the valve bores, shown in Figure 5-5, has already been integrated internally, while the valves are excluded from this photograph (M. Myers, 2010).

Parallels can be drawn with the Sutton Hoo helmet, an artefact recovered in 1939 from an eleventh-century Anglo-Saxon burial site located in Suffolk. Over time the burial chamber had collapsed on the helmet reducing it to more than 500 pieces. This helmet was initially reconstructed in 1947, but research indicated that it was inaccurate. A subsequent re-construction was undertaken in 1968 that was based purely “on the evidence of the fragments and not on preconceived ideas —the aim of all modern archaeological conservation” (British Museum 2012). Figure 5-11 shows the Sutton Hoo helmet during reconstruction with Figure 5-12 showing the finished product.

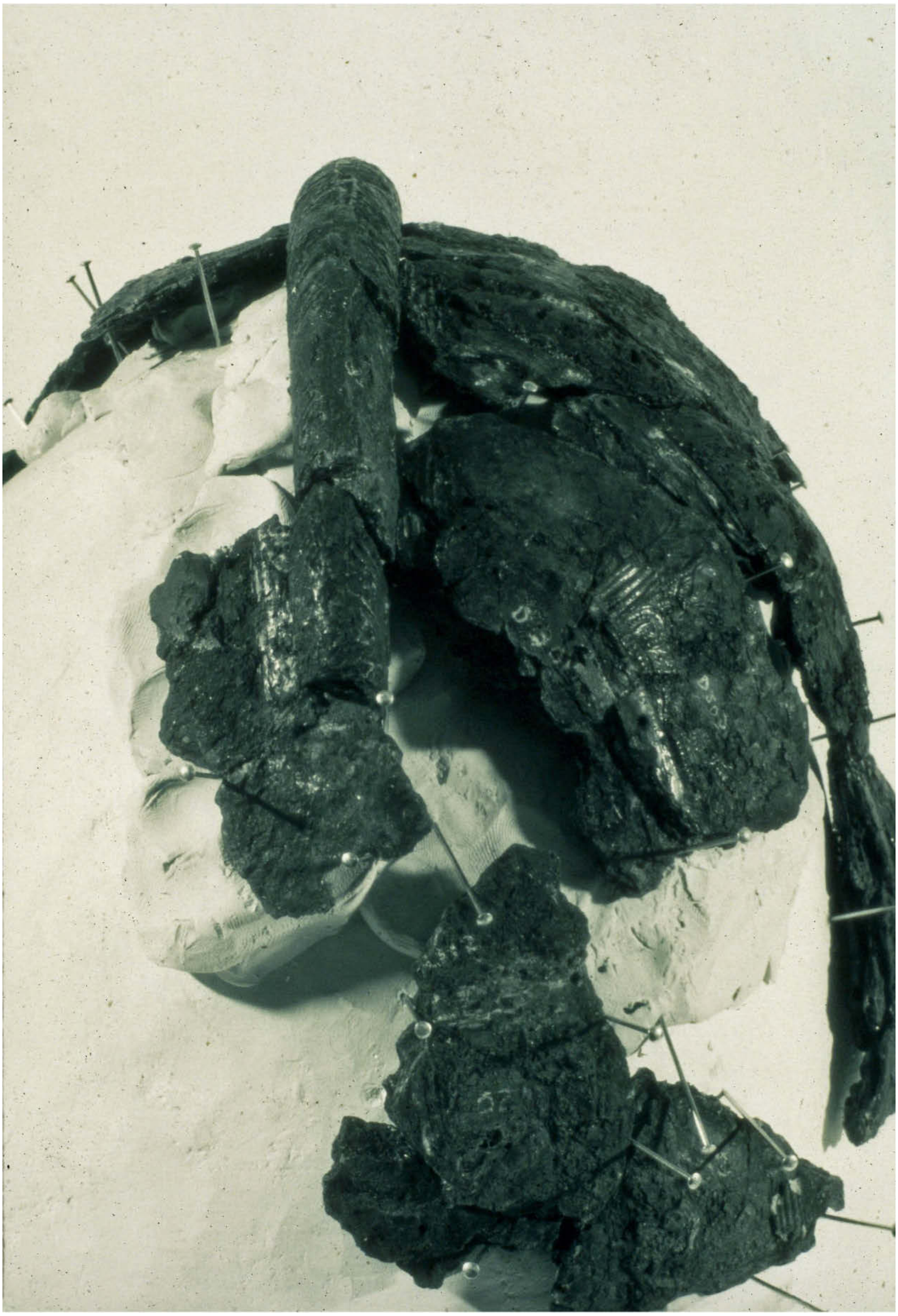


Figure 5-11. Piecing the Sutton Hoo helmet back together (British Museum, 2012, reproduced with permission).

Figure 5-12. The restored Sutton Hoo helmet (British Museum, 2012, reproduced with permission).

Materials Analysis

After reconstruction the safety valve consisted of ten major components. All observed diagnostic features of the objects components, as well as all analytical tests conducted and their results, were obtained after the reconstruction process was completed. It is therefore probable that there is a slight variation in the weight and dimensions of components from when the artefact was originally accessioned due to the use of adhesives and infilling materials employed in the reconstruction process.

Main Valve Housing (XA339)

The largest component of *Xantho*'s safety valve was the main valve housing which was manufactured by a casting technique. This process, conducted in an iron foundry, involved heating the metal until it reached a liquid state and then pouring it into a mould. Nineteenth century foundry manufacturing techniques are described by Bolland (1893), but this is beyond the scope of this dissertation.

Although analytical equipment suitable for conducting an elemental analysis of the metal was not readily available, the magnetic properties of the housing indicate it was constructed of iron. In the early to mid-nineteenth century, cast iron was the material of choice when hardness was required. This usually consisted of iron alloyed with 2–4% wt. carbon and 1–3% wt. silicon. In the late nineteenth century steel came into vogue after the invention of the Bessemer process (Selwyn 2004:98–99).

Bolts

An examination of the bolts used on the valve housing indicate that British Standard Whitworth (BSW) thread patterns were used. This parallels the findings of previous studies on *Xantho'*s fasteners that identified their use in the engine and pipe works (McCarthy 2000:178–179; McCarthy and Garcia 2004:330–337). Although badly degraded, it was determined that the shaft diameter of these bolts was 1.9 cm (0.75 in). There was insufficient evidence however to determine the length, or type of head.

Design of Housing Chamber

Internally the housing was found to be divided into two chambers. The bottom chamber appears to be where the steam entered via the large curved flange attached to the steam dome (XA339A). From there the steam exited the flange located on an elbow traveling along the steam pipe through to the engine. If however the pressure in the boiler accumulated to a high enough level, the pressure would lift the valves and divert steam into the upper chamber (Figure 5-13) where it would be expelled to atmosphere. This is represented schematically in Figure 5-14.

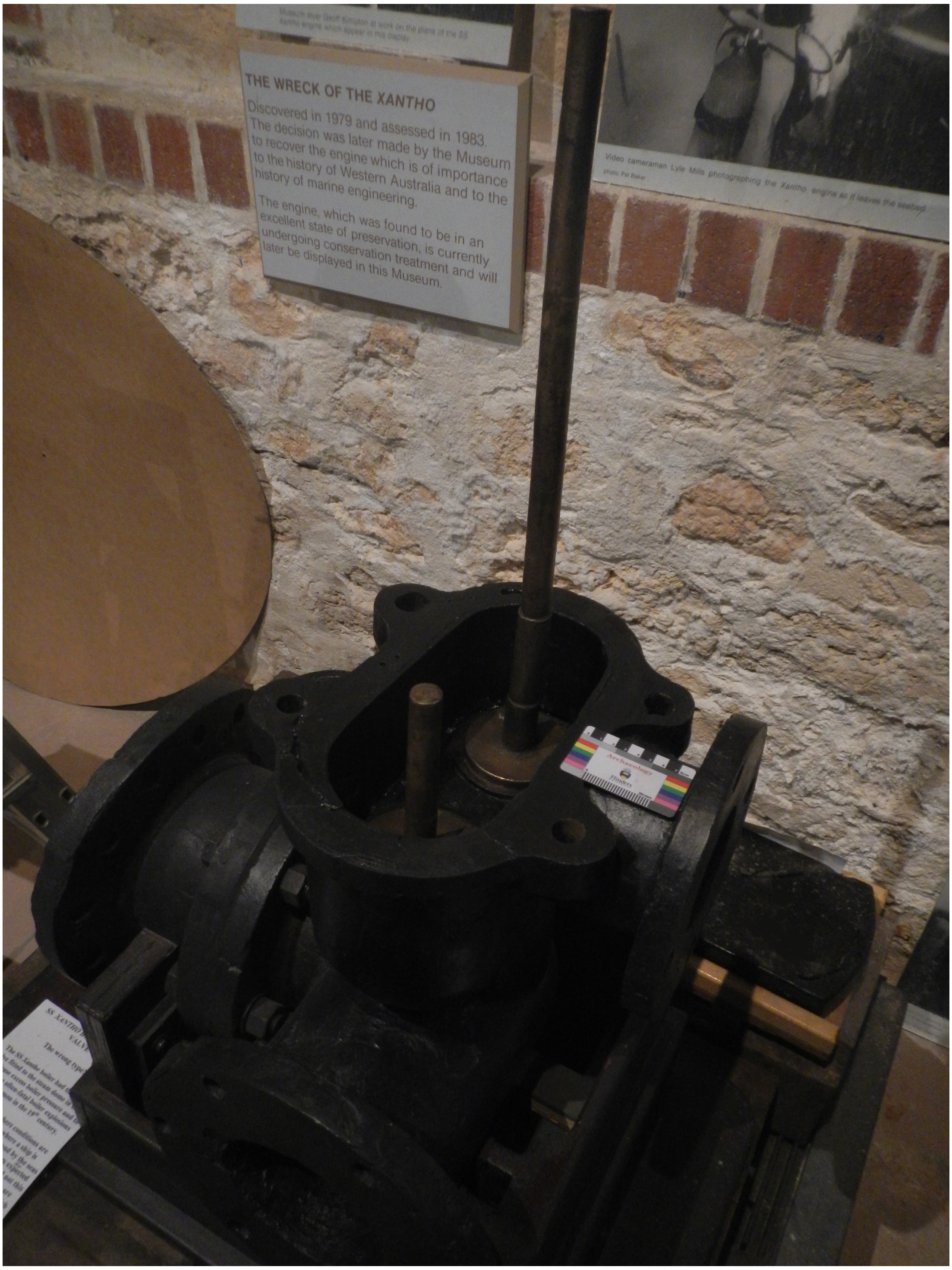


Figure 5-13 Top view showing the upper chamber of the valve housing of *Xantho*'s safety valve. The large spindle is for fixing the weights (A. Kilpa, 2012)

Schematic representation of safety valve operations

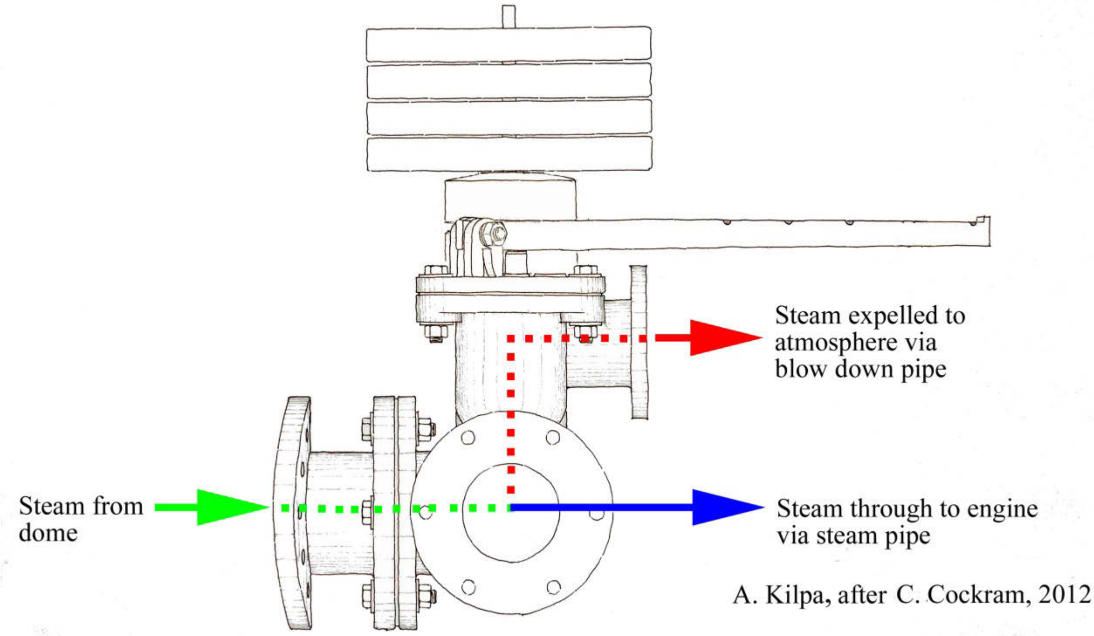


Figure 5-14. Schematic representation of how the safety valve operates indicating the direction of steam from the dome through to the engine. When the steam pressure exceeded the setting of the safety valves the pressure would lift the valves and enter the upper chamber (shown in red), where it would be expelled to atmosphere (A. Kilpa, after C. Cockram, 2012).

Analysis of Valves (XA339i and XA339ii)

Xantho's safety valve actually consists of two valves. The taller of these was recovered with its dead-weights still attached. There is a noticeable bend in the deadweight valve spindle (XA339i). It is unknown whether this bend occurred during usage or during the post-depositional processes, i.e. as it lay on the seabed in a horizontal position over an extended period of time. It is also possible that the valve could have been damaged in the disassembly process. The smaller valve is believed to be associated with a lever-weighted system. Both appear to have been cast as one piece using a copper alloy. After casting, they were machined to exact specifications to fit the bores located in the chamber. The specifications for these valves is summarised in Table 5-2.

Table 5-2 Specifications of Valves.

	Lever-weighted valve XA339ii	**Deadweight valve XA339i**
Weight	1574.1 g (3.47 lb)	3245.9 g (7.16 lb)
Diameter of cylinder bore	9.99 cm (3.9 in)	8.25 cm (3.25 in)
Diameter of valve	10.39 cm (4.1 in) including seat	9.29 cm (3.66 in) including seat
Height of valve	21.5 cm (8.5 in)	60.5 cm (24.0 in)
Guide thickness (fins)	1.18 cm (0.46 in)	0.92 cm (0.362 in)
Valve seat thickness	0.918 cm (0.36 in)	1.03 cm (0.45 in)
Step position on stem	10.5 cm (4.13 in) step 1	11 cm (4.30 in) step 1
		19.5 cm (7.68 in) step 2
		44.5 cm (17.52 in) step 3
Height of guides (fins)	4.5 cm excluding seat (1.77 in)	4.5 cm excluding seat (1.77 in)
Thickness of stem (at bottom)	2.293 cm (0.90 in)	2.9 cm (1.14 in)
	2.15 cm (0.85 in) at step 1	2.62 cm (1.03 in) step 1
		2.36 cm (0.95 in) step 2
		2.29 cm (0.90 in) step 3
Chamber size	11 cm x 28 cm x 13.5 cm wide	

The two copper alloy valves located in the valve assembly were analysed for their elemental constituency by Kalle Kasi, Scientific Officer, Western Australian Museum. The instrumentation used was a Bruker AXS portable X-ray fluorescence (XRF) analyser. Figure 5-15 indicates the position where the samples were taken with the results summarised in Table 5-3.

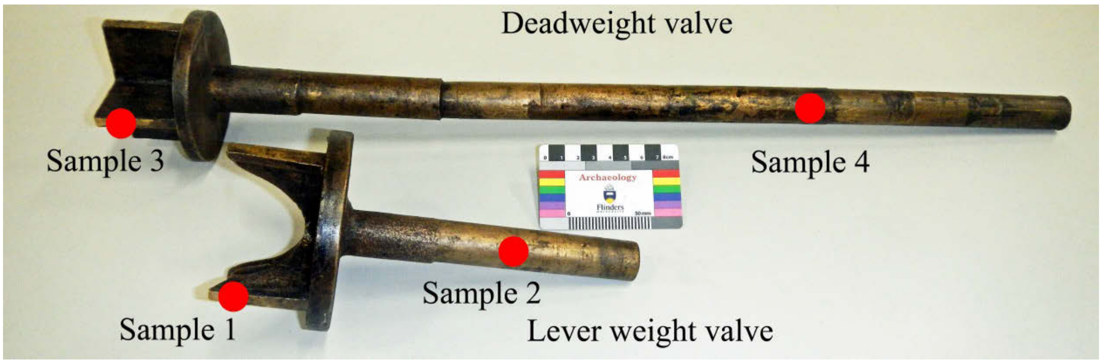


Figure 5-15. The two safety valves removed from their housing. The larger one XA339 (i) is for the dead-weights and the smaller XA339 (ii) is believed to have been for a lever-weighted mechanism. The red dots indicate the positions where elemental analysis was undertaken (A. Kilpa, 2011).

Table 5-3. Spot Surface Analysis of Valves Indicating Relative Values of Sample.

Element	XA339i Deadweight valve. Sample taken from position 3	XA339i Deadweight valve. Sample taken spindle position 4	XA339ii Lever-weighted valve. Sample taken from position 1	XA339ii Lever-weighted valve. Sample taken from position 2
Fe	0.07	0.23	0.07	0.82
Cu	82.09	86.39	80.71	83.35
Zn	7.82	5.38	7.67	6.20
As	0.29	0.22	0.41	0.15
Pb	5.39	2.74	7.89	2.29
Ag	0.39	0.41	0.80	0.26
Sn	3.90	4.09	3.99	4.11
Sb	0.02	0.02	0.02	0.07

The data from Table 5-3 indicate that the valve's primary elements were copper, zinc, lead, and tin. However, this data provides only relative values and not a true percentage of the spindles elemental compositions. It would appear in both instances the lead concentration was higher on the fins than on the spindles. This may have been due to a slow quenching process that resulted in a greater percentage of lead settling at the bottom of the mould. It could also have been a deliberate manufacturing process to make the valves less susceptible to sticking, a frequent problem associated with weighted safety valves (see Chapter IV for the use of deadweight safety valves on *Cerberus*). Further research on valve manufacturing techniques is necessary to clarify this point.

Reintegration of Components

After reassembly and analysis of its components, the safety valve was reconstructed and displayed. As with the aforementioned Sutton Hoo ship's helmet, it was necessary to fill in missing fragments of *Xantho*'s valve to improve its structural integrity so that it will not collapse. Though reversible, the decision to do so was as a result of considerable discussion with Dr Michael McCarthy, the curator responsible for the *Xantho* project. Figure 5-16 shows the object on display in the Steamships-to-Suffragettes Gallery of the Western Australian Museum's Shipwreck Galleries. Colin Cockram of the Maritime Archaeology Association of Western Australia (MAAWA) created a scaled plan of the *Xantho* safety valve after its reconstruction (Figures 5-17–5-19).

Figure 5-16. ***Xantho*****'s safety valve on display in the Steamships-to-Suffragettes Gallery, Shipwreck Galleries, Western Australian Museum. The large blocks located on top of the housing are foam replicas of the deadweights. The arm and ball weight are interpretative and have been added to facilitate discussion on the direction of future excavation activity at the wreck site and also to assist the public and scholars to visualise the operation of the valve (A. Kilpa, 2010).**

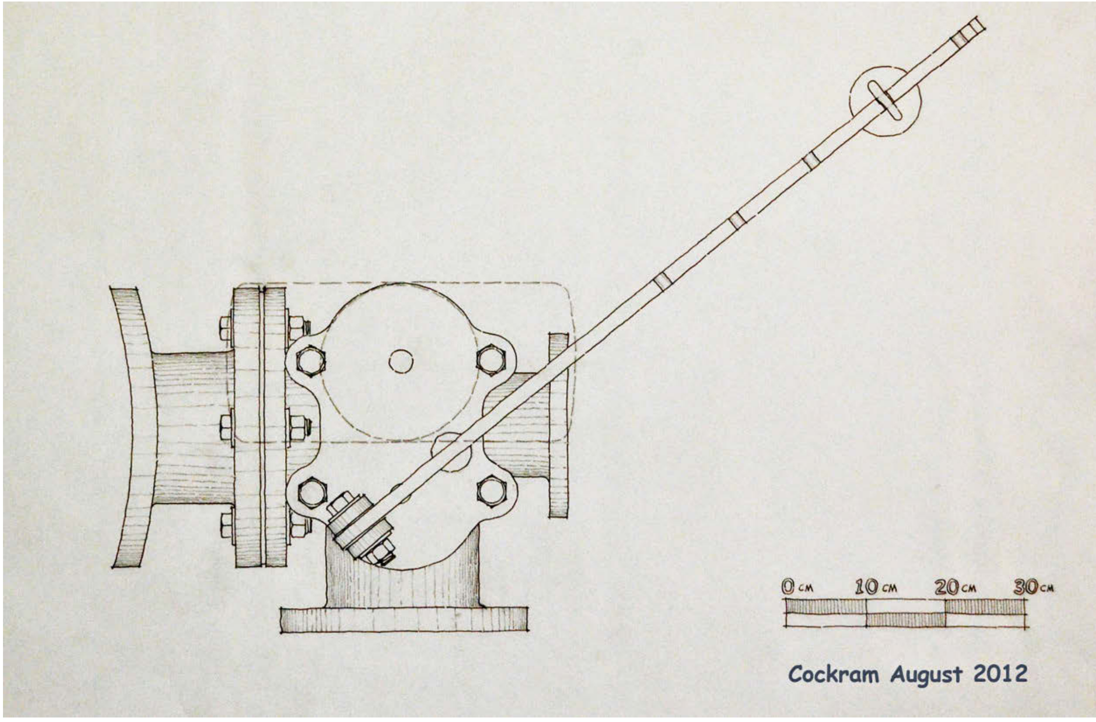


Figure 5-17. Top view of safety valve after reconstruction (C. Cockram, 2012).

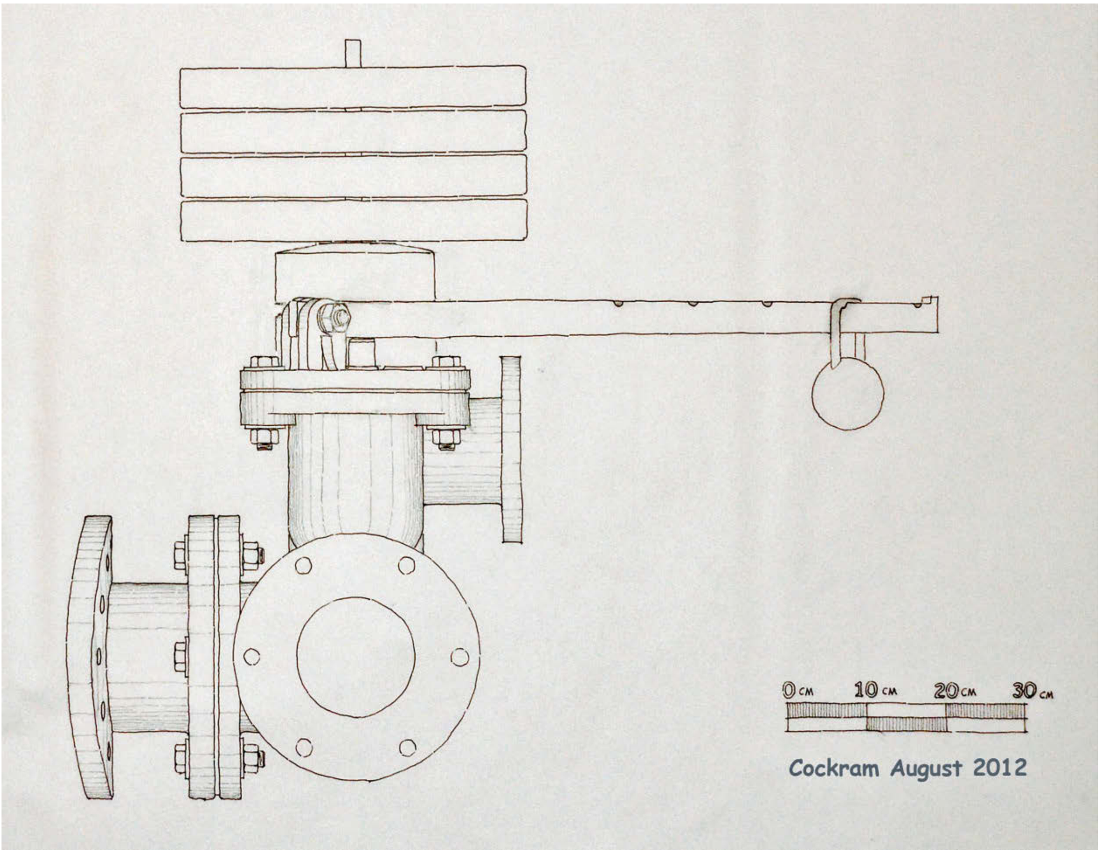


Figure 5-18. Side profile of safety valve after reconstruction (C. Cockram, 2012).

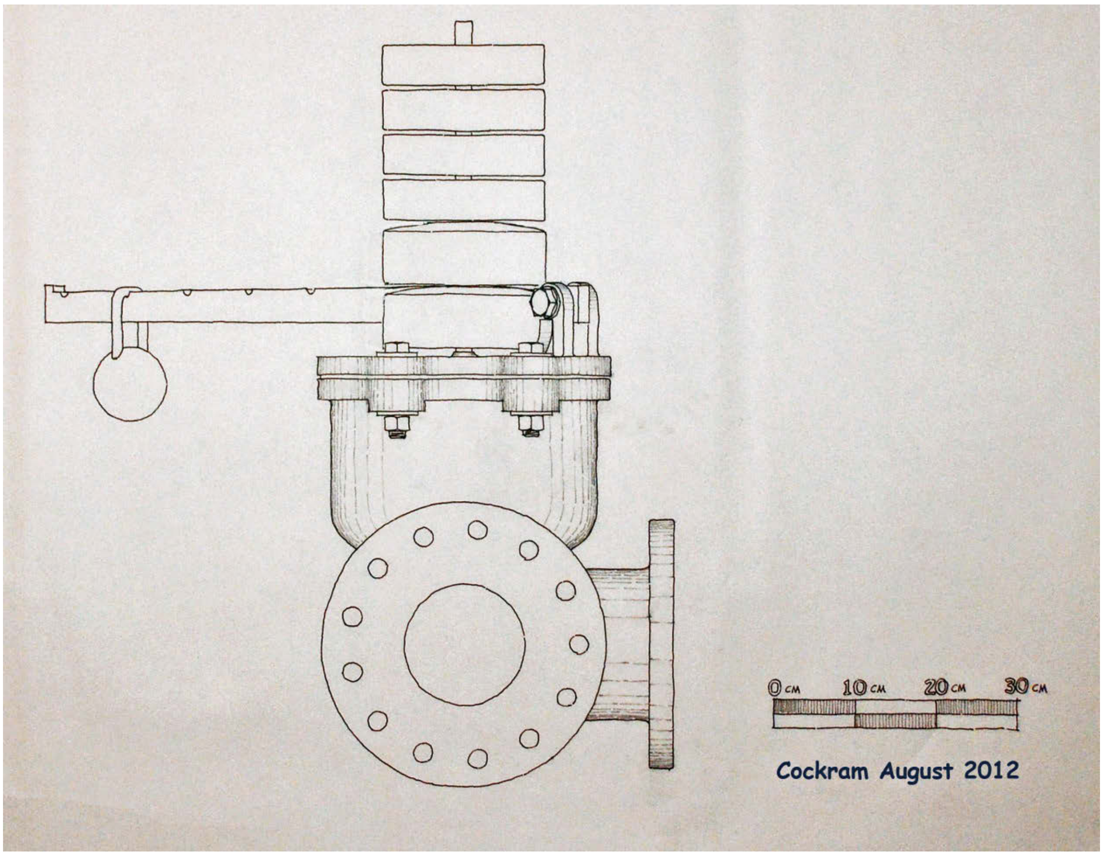


Figure 5-19. Front view of safety valve after reconstruction (C. Cockram, 2012).

Installation on Boiler

After reconstruction, the safety valve was studied in its complete state to determine how it was installed on the boiler. An earlier interpretation from 1985 (Figure 5-20) suggested that this device may have been fitted on the starboard side of the boiler on an angle but this possibility was ruled out for two reasons. Firstly, it was highly unlikely that a deadweight safety valve would be installed in this manner because it could not operate effectively in such a position (see Chapter IV for deadweight operations), and secondly the curvature of the flange and size did not match the profile of the boss plate.

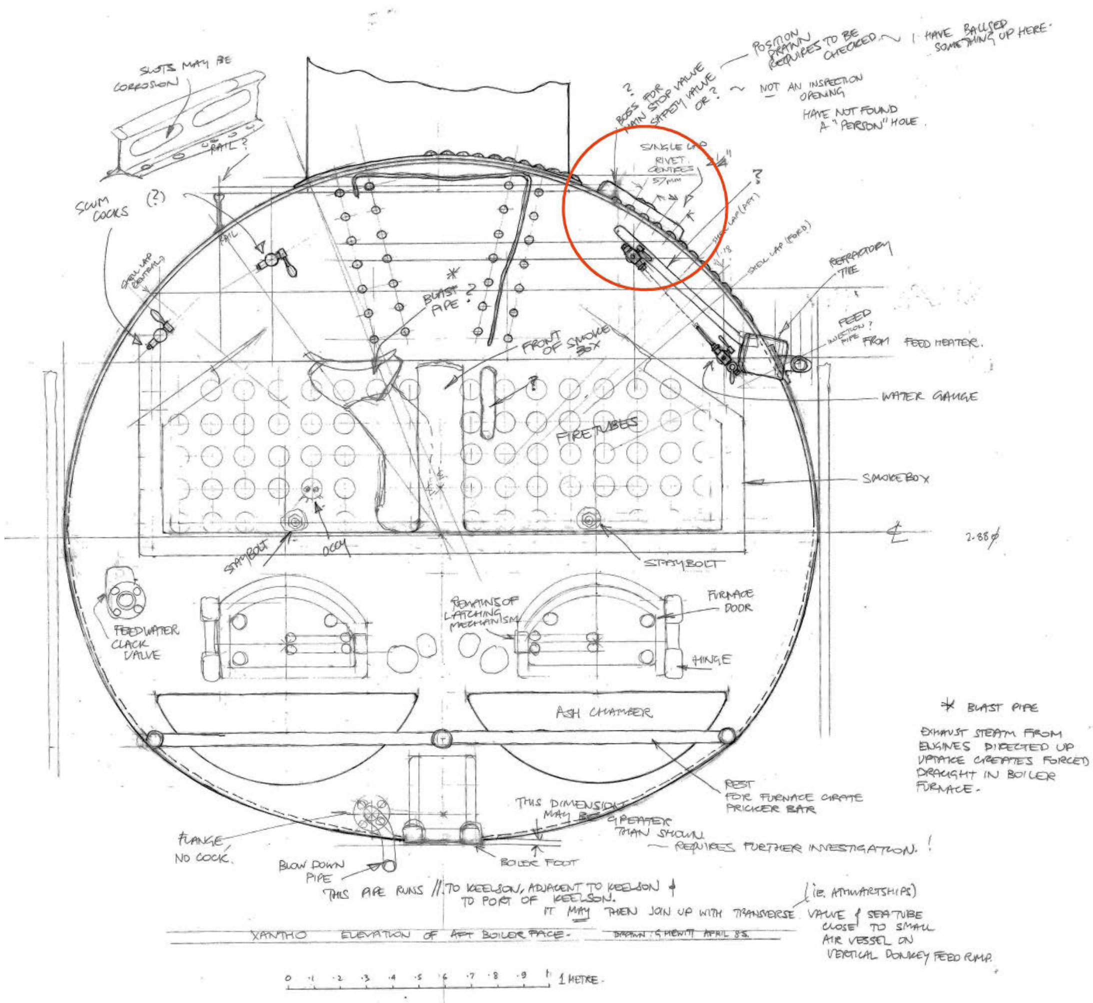


Figure 5-20. Drawing of *Xantho'*s boiler. This diagram indicates some uncertainty on the position of the stop and safety valves with the boss located in the red circle as the possible mounting position (A. Kilpa, 2012 after G. Hewitt April 1985).

A re-evaluation of the safety valve that took into consideration the concave structure of the large flange (XA339A) suggested that the valve housing was attached to a cylinder and that it was installed in a vertical position. After studying the site plans relating to *Xantho*'s boiler, the author hypothesized that the safety valve may have been attached to the side of the steam dome. To test this theory a 91.4 cm (36 in) diameter template representing the known dimension of the steam dome was constructed and butted against the curvature of the valve flange. The results clearly indicate a snug fitting profile match (Figure 5-21).

Figure 5-21. The template constructed representing the width and curvature of the steam dome matched exactly the concave shape of the safety valve flange (M. Myers, 2010).

Attachment of Safety Valve to Steam Dome

The safety valve was most likely attached to the steam dome by the use of rivets rather than studs or bolts. An example of this arrangement is shown in Figures 5-22 and 5-23. The method of installing rivets on nineteenth-century boilers is described by William Ford (1887:44–57). Riveting was carried out either by hand or using powered tools. Regardless of the method used someone of slight build would have to enter the boiler via the manhole to hold the rivet in place while it was hammered externally. Census details from 1871 indicate *Xantho*'s boilermaker David Davidson (1820–1883) (County of Renfrew 1883) employed 179 men and 20 boys in his workshop (Census Enumerator 1871). It is likely that many of the boys' employed in the workshop were used exactly for this purpose.

Figure 5-22. A cylinder boiler with two furnaces (Hochhaus, 2007).

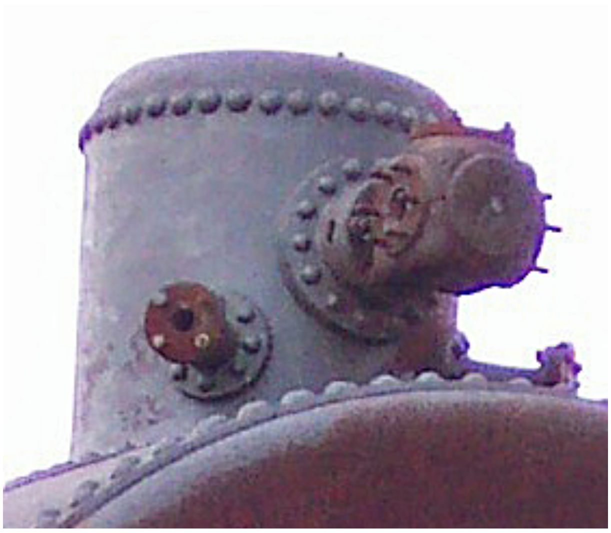


Figure 5-23. A close-up of the steam dome located on the boiler shown in Figure 5-22. The safety valve mounting on this boiler appears to have been installed by using rivets (Hochhaus, 2007).

Analysis of Deadweights

The deadweights found on the safety valve consisted of four oblong and two circular weights. These appear to have been cast in iron to a specific size and weight. The four oblong weights (XA339E, XA339F, XA339G, and XA339H) are located on the upper part of the spindle, with the two circular weights (XA339C, XA339D) located at the bottom (See Figure 5-4). This unusual arrangement made the valve top heavy and may have caused the spindle to bend if the vessel was rocking in rough seas. As discussed in Chapter IV, this arrangement was identified in the nineteenth century as a major contributing factor to boiler explosions. The bottom circular weight (XA339C) has a centrally-located copper-alloy bush (Figure 5-24). In operation this sat on the step located on the valve spindle. This bush was not present on any of the oblong weights (Figure 5-25) or the other circular weight.

Figure 5-24. Circular disc after reconstruction showing the copper-alloy bush in its centre (XA339C). This bush sat on a step located on the spindle (A. Kilpa, 2010).

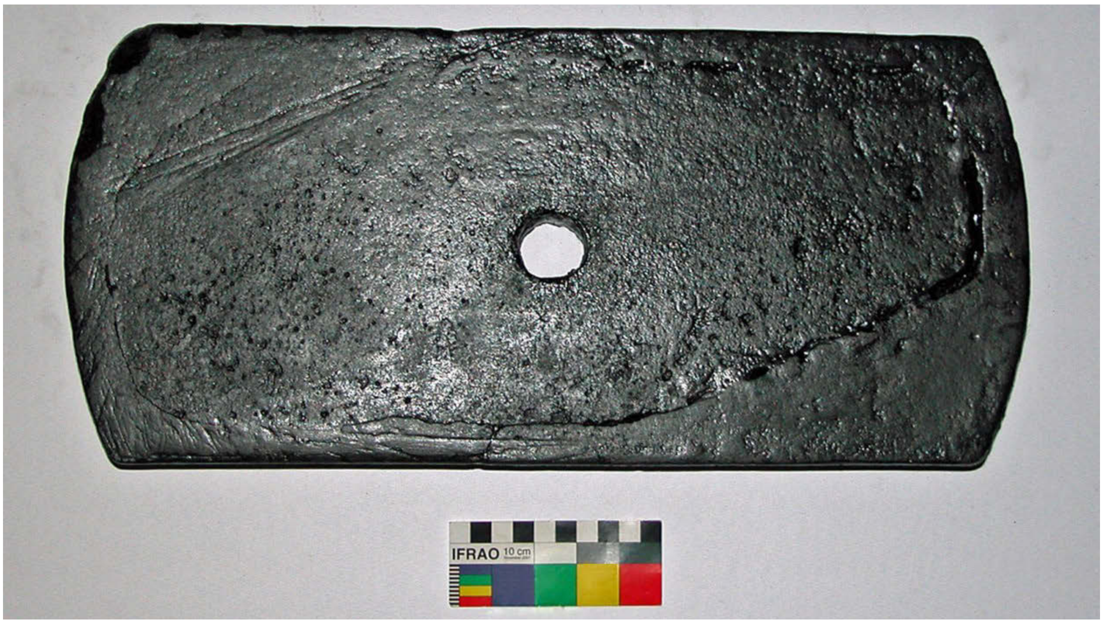


Figure 5-25. One of the four oblong dead-weights (XA339F) located on top of the safety valve after reconstruction. Although heavier than the circular weights, shape made it easier to handle (A. Kilpa, 2010).

The basic principles associated with deadweight safety valve usage were identifiable in this object, but the use of oblong weights was unexpected and can be considered unique. It is possible that David Davidson manufactured this device because its profile indicated someone who knew the basics of safety valve operation but did not fully appreciate the problems associated with their operational use in a marine environment. The author found it easier to lift the oblong weights than the circular ones, even though they are nearly twice the weight. It is possible that the design purposely allowed for quick removal in the case of emergency.

Table 5-4. Dimensions of Deadweight Safety Valve.

Valve component		Diameter		Surface area	
		(cm)	(in)	(cm^2)	(in^2)
Bore		8.3	3¼	–	–
Valve		–	–	53.5	8.3
Deadweight component	Total number	Estimated original unit weight		Total weight	
		(kg)	(lb)	(kg)	(lb)
Oblong weight	4	22.7	50	90.7	200
Circular weight	2	13.6	30	27.2	60
Weight spindle	1	3.2	7.2	3.2	7.2
Total weight				121.2	267.2

Determining the Safety Valve Settings

Previous research demonstrates that *Xantho*'s engine was designed by John Penn and Son and that the same type was used in gunboats during the Crimean war (1854–1854) (McCarthy 1996, 2000). These engines were unique amongst other ship engines used by the British Admiralty because they were designed to be powered by high-pressure boilers capable of operating at pressure exceeding 620.5 kPa (90 psi) (Preston and Major 1965:109; The Engineer 11 February 1898).

To test the operational pressure of *Xantho*'s boiler, the author calculated the amount of pressure in pounds per square inch (psi), required to lift the six weights (Table 5-4) using a simple formula developed by George Tower (1889:53):

$P = (W_d + W_v) / A$	P	= Pressure (psi)
	W_d	= Weight of discs (lb)
	W_v	= Weight of valve (lb)
	A	= Valve surface area (in^2)

Thus, the valve set pressure was (260 lb + 7.2 lb) / 8.3 in^2 = 32 psi (221 kPa). As this engine was designed to operate at 620.5 kPa (90 psi) (Preston and Major 1965:109), it would not have operated at its maximum capacity. Further evidence that *Xantho*'s boiler operated at low pressure, is presented in the historical record which refers to the boiler's design capacity being 344.7 kPa (50 psi) (*The Herald*, 25 January 1873).

Although higher than the blow down calculations established for the deadweight safety valve, it is nevertheless far below the specifications required for the engine to operate to its maximum potential. One explanation for the discrepancy is that there was no requirement for safety valves to be set to the boiler's maximum capacity (only that its settings should not exceed it), It is possible that the safety valve on *Xantho*'s boiler was intentionally kept at a lower setting.

Safety Valve Plate From Main Housing (XA339B)

Xantho's safety valve plate manufactured from cast iron. Its purpose was to provide access to the chamber so that the valves could be maintained or replaced when required. The plate was have been attached to the chamber by four fasteners evenly spaced on the perimeter of the housing. Two centrally located holes indicate where the valve spindles protrude. Through the reassembly process, it was determined that part of the lug that held the lever was missing (Figure 5-26).

A threaded hole, measuring 1.27 cm (0.5 in) in diameter, was found in the plate in line with the small valve spindle and remaining lug. The typology of other lever-weighted valves suggests that this was probably the location of a guide to stop the lever from dislodging at high velocity in times of blow down, i.e. when pressure was released by the valve. The remnants of the fasteners and the size of the holes in the plate indicate that 1.9 cm (0.75 in) diameter bolts were used. Although positive identification of the thread type was not possible due to their corroded state, they likely were British Standard Whitworth (BSW) similar to those found on the rest of *Xantho*'s machinery (McCarthy and Garcia 2004).

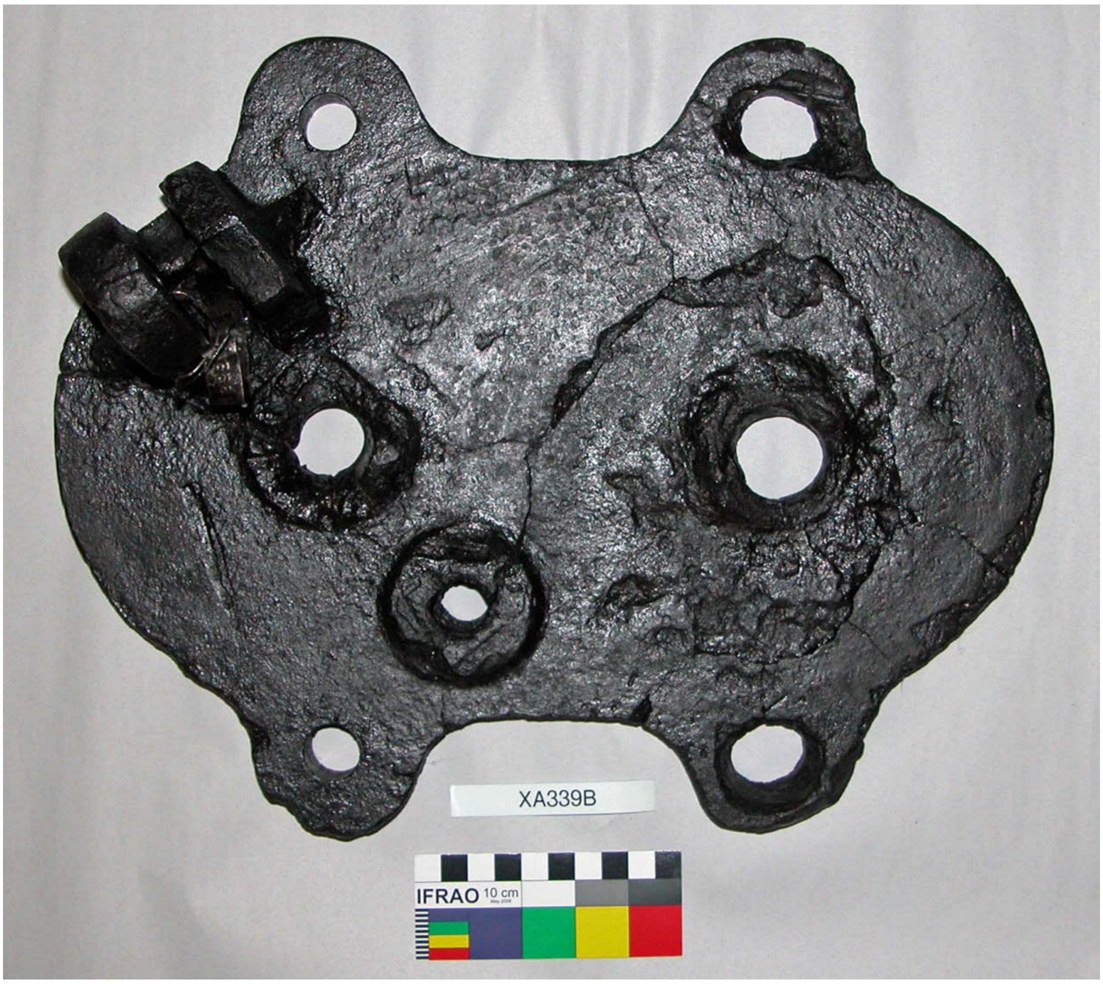


Figure 5-26. Safety valve plate after reconstruction (XA339B) (A. Kilpa, 2010).

Gasket (XA339J)

Most of the gasket material was destroyed in the disassembly process. However, a small sample was kept for research purposes (XA339J) (Figure 5-27). Visually, this appears as a woven fabric, light brown in colour with sporadic patches of orange. Under a stereo microscope at x40 magnification, the fibres appear as twisted flat ribbons with tapered closed tips. These features are characteristics associated with cotton which are distinctly different from the diagnostic features of wool, linen, or hemp (Hodges 1976:125–126). The sample was then analysed using Fourier Transform Infrared Spectroscopy (FTIR) and the resultant spectrum indicated a high probability match for cotton (Figure 5-28).

The sample was then analysed by X-Ray Fluorescence spectroscopy (XRF) to establish what inorganic elements may be associated with the gasket. The spectra from this analysis indicated the strong presence of lead (Figure 5-29). This evidence tends to support historical claims that lead was used in the nineteenth century as a paste for gaskets in boilers and pipework (Miller 2011). It is also possible that its application had the additional effect of acting as a sealant between butted joints.

Figure 5-27. Micrograph of the gasket fibres from XA339J, stereomicroscope, magnification x40. The dark areas are possibly burn marks resulting from the treatment process and not in-service usage because the metal was heated to break off the concretion (K. Kasi, 2012).

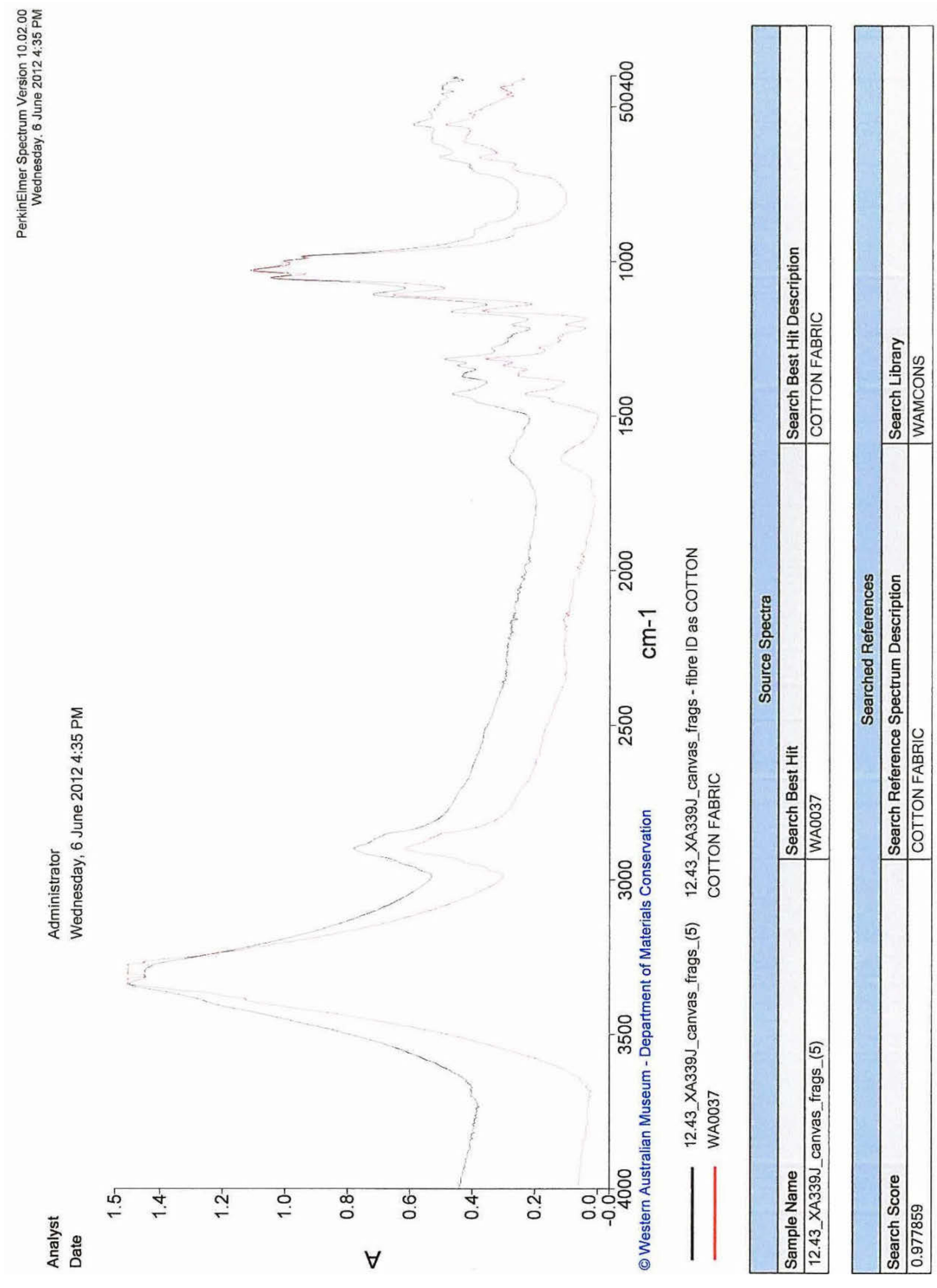


Figure 5-28 Spectrum of gasket material. The Fluka reference library supplied by Perkin-Elmer suggests that this fabric is cotton (K. Kasi, 2012).

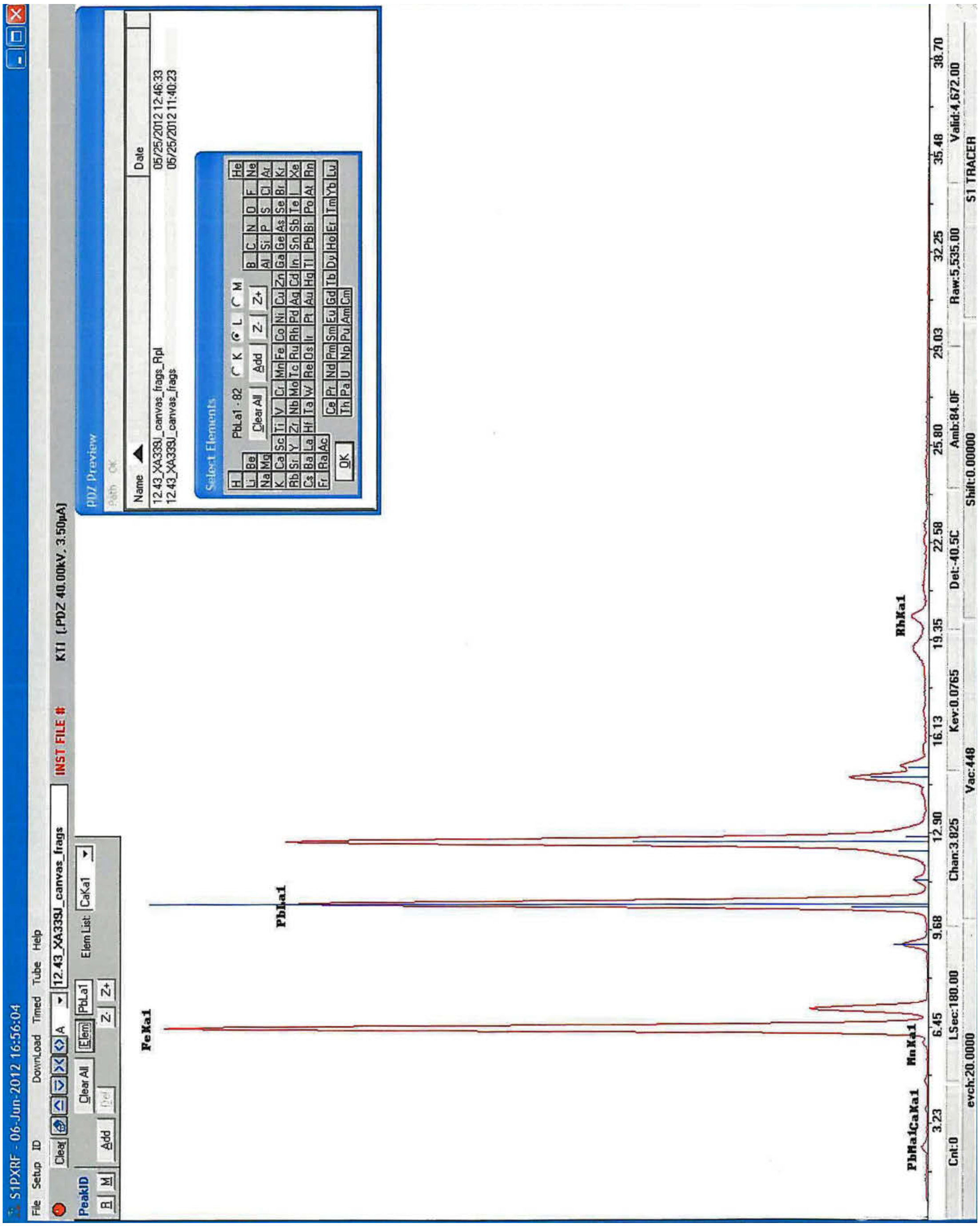


Figure 5-29. XRF spectrum of gasket material (XA339J) from concave flange (XA339A). The data indicates the presence of both iron and lead as the principle elements. Bruker AXS handheld portable XRF, model Tracer III-V (K. Kasi, 2012).

Steam Isolating or Shut Down Valve

In June 2012, a team of maritime archaeologists led by Michael McCarthy revisited the SS *Xantho* wreck site in transit to fieldwork in Ningaloo and Cossack. Although an excavation had been planned, it was cancelled as a result of an adverse report on the sand level around the wreck suggesting it was buried. One objective of the intended excavation or minimal disturbance examination of the site was to ascertain if other ancillary machinery such as the isolating valve was present, as hypothesized by this author as a result of this research. When the sand level was found to be far lower than earlier reported, archaeologists undertook a close examination of the area where they recovered the safety valve in 1988. This resulted in the discovery and removal of a large object resembling the isolating valve.

After excavation and field registration, the team members wrapped the device in wet hessian bags and transported it back to the Western Australian Museum's Conservation Laboratory. There, the author recorded the object and placed it in a stabilizing solution of 2% sodium hydroxide. The author was then requested to take responsibility for the archaeology and engineering analysis by the project leader and the artefact was x-rayed prior to initiating any de-concretion or desalination. Although heavily concreted with up to 10 cm of marine growth, the artefact was well preserved and still contained solid metal allowing the de-concretion process to be undertaken with few complications. Figure 5-30 shows the isolating valve prior to de-concretion and Figure 5-31 after the event. A detailed photographic record of the de-concretion process is presented in Appendix C.

Figure 5-30. The isolating valve in the conservation court yard prior to being de-concreted (A. Kilpa, 2012).

Figure 5-31. Conservator Jon Carpenter de-concreting the isolating valve recovered from the wreck site. The metal in the concretion was found to be more solid than anticipated (A. Kilpa, 2012).

Preliminary investigations indicate that the de-concreted isolating valve has diagnostic features similar to the one found in a Dewrance and Co sales catalogue of 1910 (Figure 5-32) (Dewrance 1910:128). Although the isolating valve recovered from the wreck site is of a different style, its functionality and purpose appear identical.

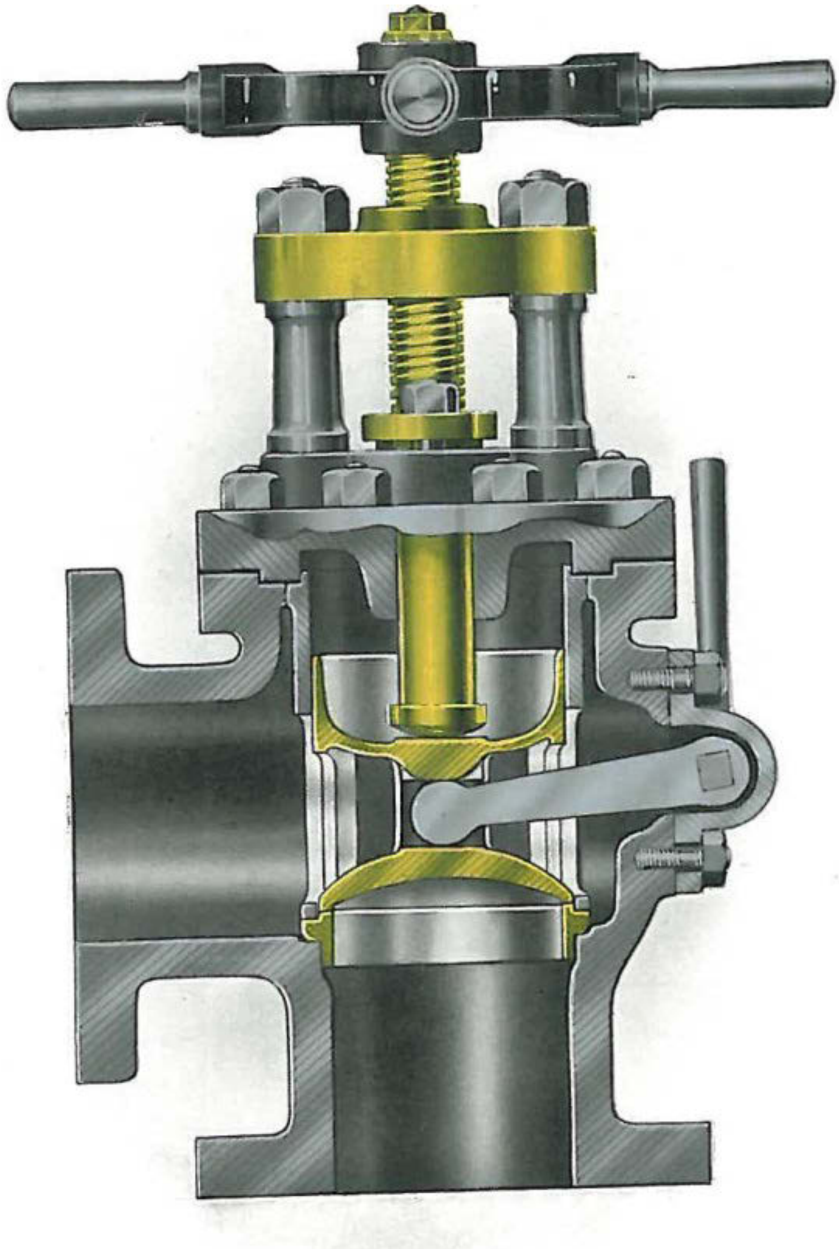


Figure 5-32. A Dewrance isolating valve. This device resembles the overall profile of the device recovered from *Xantho* (Dewrance and Co, 1910:128).

The *Xantho* isolating valve measures 94 cm in height by 43 cm in width. The size of the flange located on the side of the valve and the position of its fastening holes indicate an exact match with the flange on the safety valve. These appliances were most likely butted together to form one unit (Figure 5-33). The integration of this object with the safety valve and its installation in relation to the rest of *Xantho*'s propulsion system is discussed in Chapter VI.

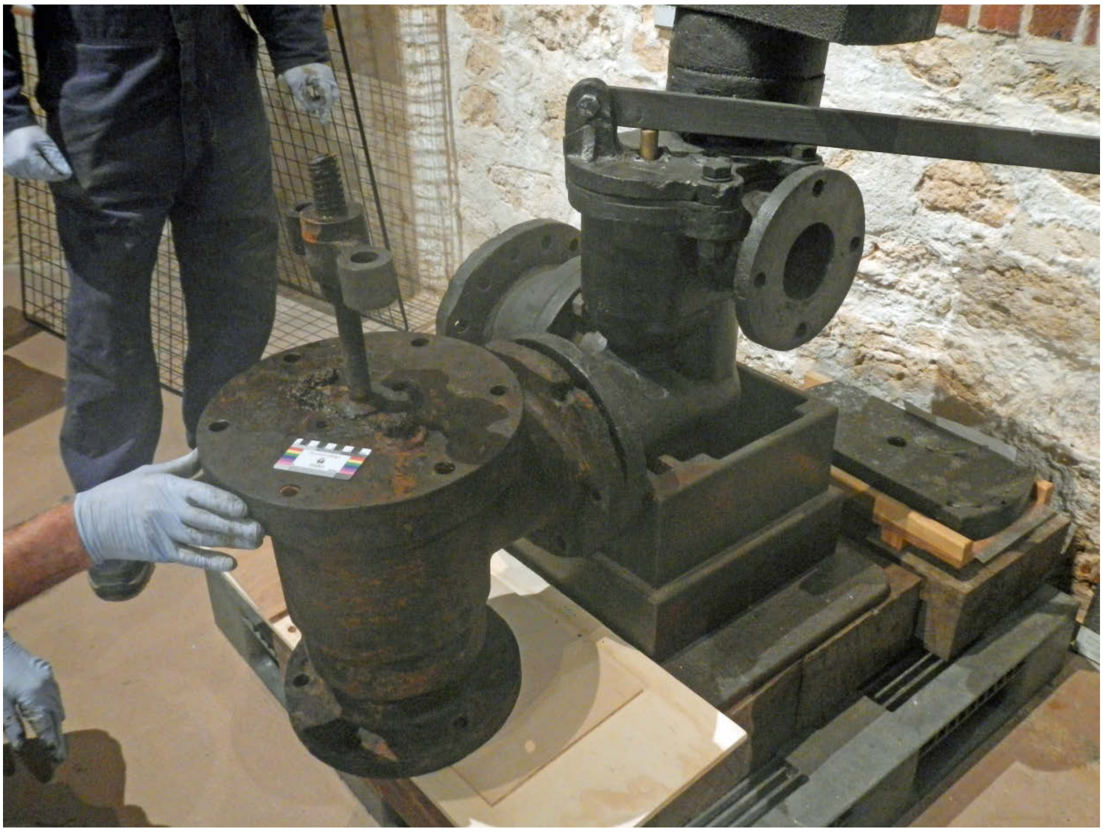


Figure 5-33. The isolating valve being butted against the safety valve flange. The fastening holes indicate an exact match for the pattern found on the safety valve (N. Bigourdan, 2012).

Conclusion

In 1988, a safety valve from *Xantho* was recovered from the starboard side of the vessel approximately two metres away from the boiler. Although this object was recovered intact and some preliminary measurements taken, a failed conservation procedure resulted in the artefact being shattered into hundreds of pieces.

As a result of its reassembly and in-depth study, it became obvious that the artefact was more complex than anticipated. While the use of a deadweight valve as a mechanism to relieve pressure was earlier noted by McCarthy (1996, 2000:174), examination of the second valve located in the housing and the typology of other nineteenth century safety valves suggests that this was a lever-weighted valve (Appendix A for the example from *Indiana*).

In addition to its key function as a safety device for preventing boiler explosions, this assemblage appears to have also acted as a junction point for the distribution of pressure generated from the boiler through to the engine. This possibility was not considered by McCarthy (1996, 2000) and is discussed in Chapter VI that deals specifically with the reconstruction of *Xantho*'s propulsion system. The diagnostic features of the curved flange (XA339A) and the typology of boilers with steam domes from the mid to late nineteenth century indicate that this safety valve was installed on the side of the steam dome located directly behind the smoke box.

The holistic approach to understanding *Xantho*'s propulsion system led to the hypothesis that the valve housing had a third safety device attached to it—a general shut down valve used to isolate the boiler's steam from the rest of the system. Such a mechanism was critical for isolating steam in the advent of a burst pipe or when the engine needed maintenance but the boiler still needed to be operational (Nesbitt 2007:82). In June 2012, archaeologists raised the shutdown valve from the shipwreck site. Pending the completion of its conservation treatment, the shutdown valve will eventually be integrated with the safety valve on display in the Steamships-to-Suffragettes Gallery of Shipwreck Galleries in Fremantle. Research on this new find continues and will be completed in a few years.

CHAPTER VI: RECONSTRUCTION OF *XANTHO*'S PROPULSION SYSTEM

Introduction

In Chapter II reference is made to the necessity to consider shipwreck sites as an integrated whole. Although Bass (2011:10) proposes the best means of achieving this is through total excavation, in the case of *Xantho* the initial work conducted by McCarthy (1996, 2000) focused on the engine and the excavation of materials aft of the boiler and inside the hull. Unfortunately this targeted approached resulted in a number of important features being missed by the archaeologist and the marine engineering advisors.

This study expands on McCarthy's earlier assessment by investigating the safety valve as a unique artefact and explaining how it interacted with the engine, ancillary machinery, and piping. From this, the author develops a theoretical model from the in situ and recovered archaeological material showing how the propulsion system may have appeared at the time of *Xantho*'s wrecking in 1872. This study also provides an explanation of what factors may have contributed to the deterioration and derangement of this assembly whilst on the seabed.

An Earlier Interpretation of *Xantho*'s Propulsion System

McCarthy's interpretation of the layout of *Xantho*'s propulsion system and other parts of the vessel appears in the form of a concept plan for the future exhibition that was produced under his direction by the project artist Chris Buhagiar in the late 1980s (Figure 6-1). The interpretation also appears in a working model prepared by then master's student Joel Gilman (2001:8) as part of an internship program at the Western Australian Museum. Neither concept takes into consideration, however, all archaeological evidence available, such as the safety valve and existing pipework recovered from the site. Furthermore, no one recognized the steam dome as the mounting for the two valves described in the previous chapter.

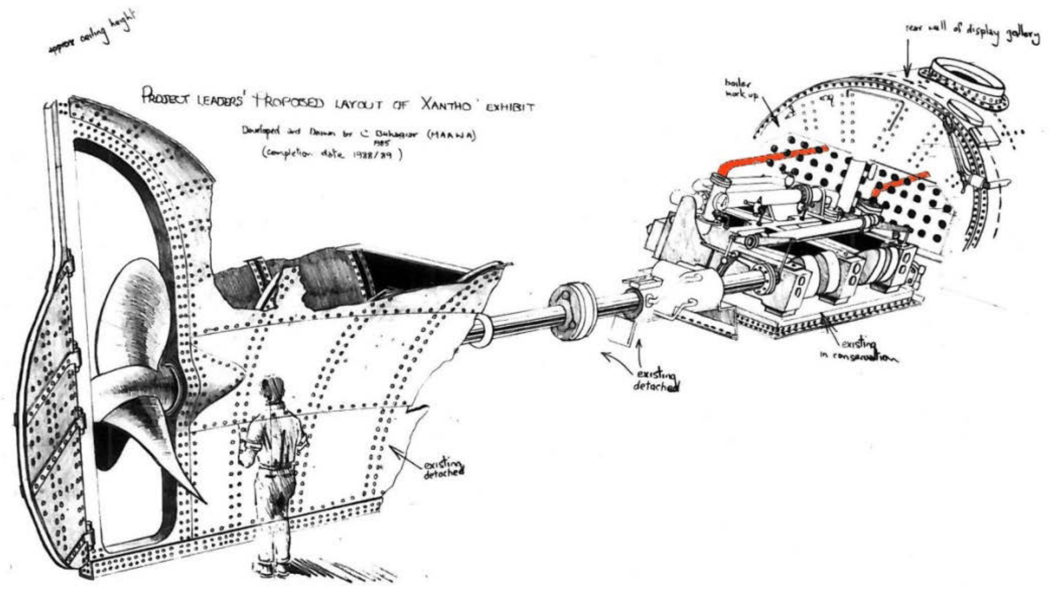


Figure 6-1. An earlier interpretation of *Xantho*'s propulsion system. This schematic representation with the main steam and exhaust pipes highlighted in red shows uncertainty as to how steam was transmitted from the boiler through to the engine. Illustration by Chris Buhagiar 1985 (Gilman 2001:8).

A Re-evaluation of *Xantho*'s Propulsion System

A new interpretive model of what *Xantho*'s propulsion system would have looked like in 1871 is advanced by considering four factors:

1. The typology of steamships and boilers from the 1870s;
2. The in situ and recovered archaeological material evidence from the site;
3. Salvaging activities by Charles Broadhurst;
4. Known instances of looting at the site.

Furthermore, this model goes beyond the study of its components in isolation and assesses how they interacted as a whole. As discussed in Chapter III, steam technology in the United Kingdom was an evolving process influenced by engineering innovations, legislative processes, and regulatory enforcement. By 1871 British law mandated that all core safety devices be incorporated into a boiler's design (Figure 6-2). Such devices included a pressure gauge (which usually would be located at the top of the crown, two safety valves, and the general shut down or isolating valve. (Appendix D: Board of Trade rules).

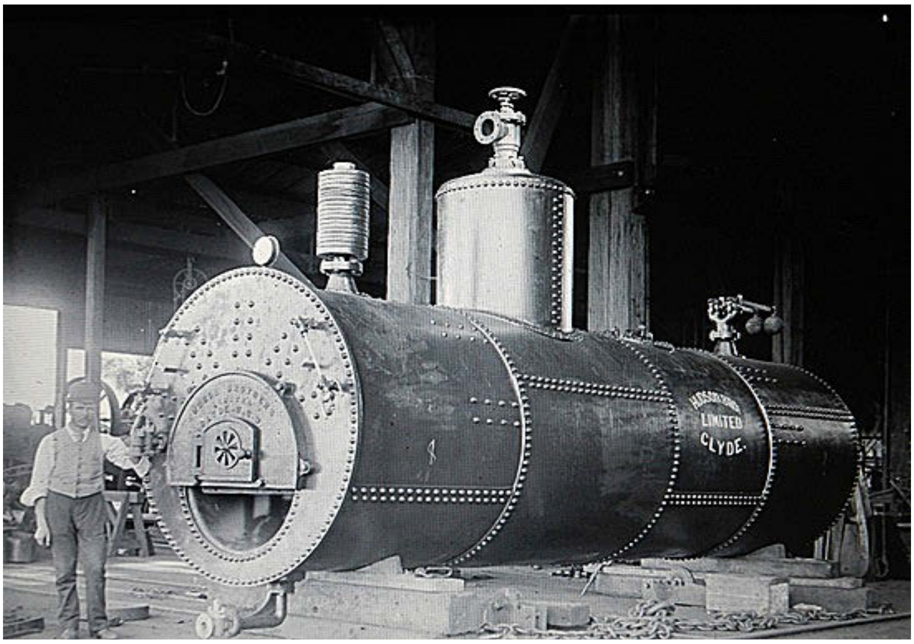


Figure 6-2. A Cornish boiler, made by Hudson Brothers and Company, Granville, New South Wales, Australia (1880–1898) with a Bourdon gauge (located on the boiler crown), deadweight safety valve, isolating valve located on top of the steam dome, and a duplex lever-weighted valve (Powerhouse Museum, Sydney, 2012, reproduced with permission).

Following is an itemised inventory of the key components associated with horizontal boilers of the 1870s, along with an explanation of their function.

Xantho's Boiler

The boiler installed on *Xantho* is known in historical literature as a scotch boiler. This is a generic term given to describe any multi-furnace cylindrical boilers with fire tubes. The first scotch boilers appeared in the 1860s. One of the earliest examples was developed by Randolf and Elder installed on the steamer *McGregor Laird* in 1862 (Griffiths 1997:66).

Xantho's boiler was manufactured by David Davidson's, Iron Foundry located on North Street in Glasgow. Testimonials from 1875 suggest that the quality of craftsmanship at the workshop was held in high regard (Figure 6-3 3), a tribute to both its owner and workers. The dimensions of *Xantho*'s boiler are 284 cm (108 in) (diameter of crown shell) x 315 cm (120 in) (overall length).

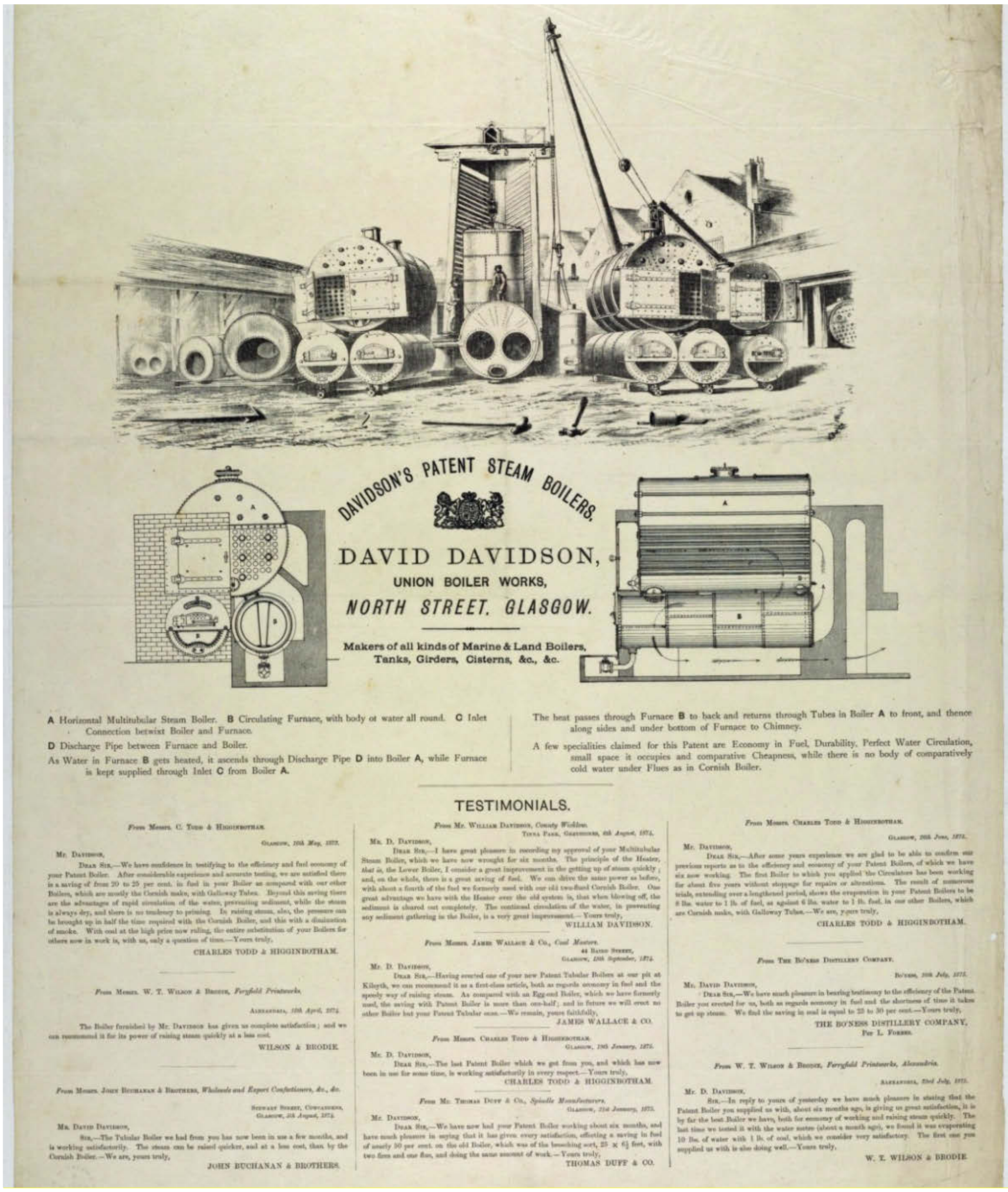


Figure 6-3. A promotional advertisement for Davidson's Union Boiler Works (1875). The accompanying testimonials indicate a high regard for the craftsmanship of its workers. (National Library of Scotland, Edinburgh, 2012, reproduced with permission).

Steam Dome

Steam domes were a common feature of mid to late nineteenth century vertical return tube boilers. Figure 6-4 shows a typical arrangement with its mountings, i.e. the isolating valve and safety valve located on the side of the dome. In this particular case the safety valve appears to be a spring-loaded valve of the Salter type.

As explained in Chapter V, the purpose of the safety valve is to allow the free escape of pressure prior to reaching the designed maximum operating pressure of the boiler. The purpose of the isolating valve is to control the flow of steam to the engine. The main difference between the example in Figure 6-4 and the one installed on *Xantho* is that the isolating valve and safety valve on the latter share the same mounting on the steam dome.

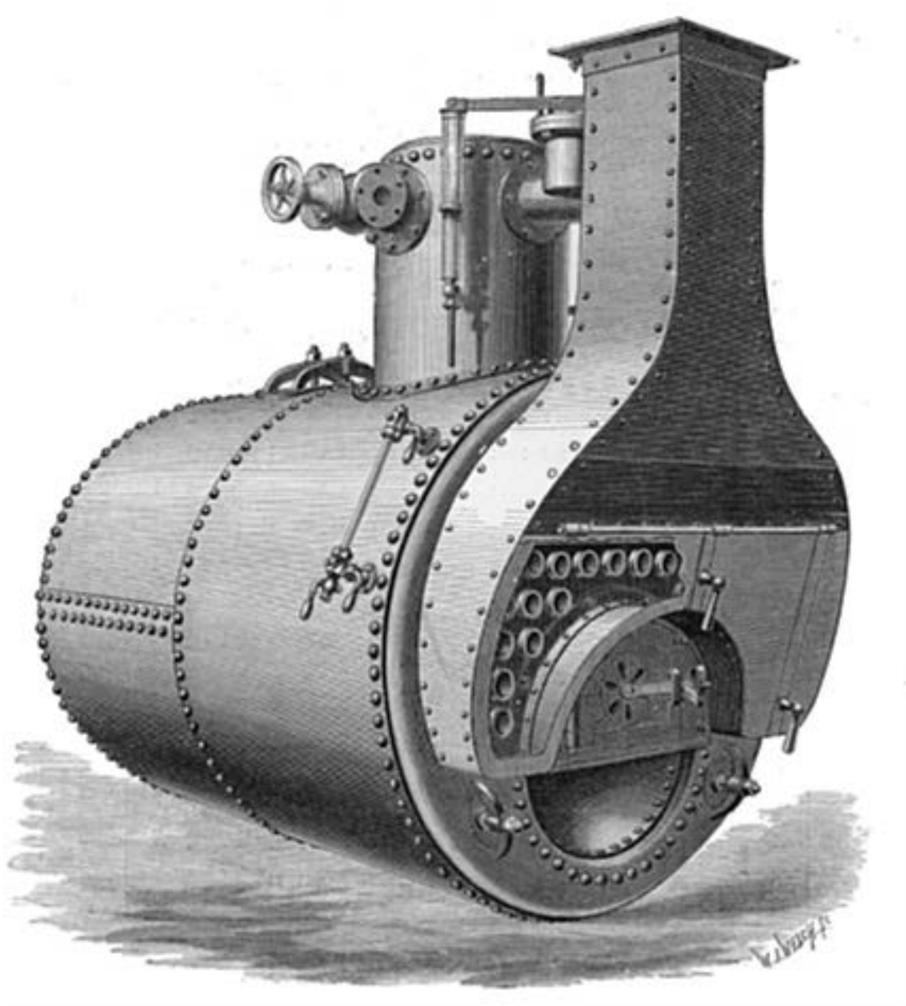


Figure 6-4 Extract from an Alexander Wilson and Co. sales catalogue of 1875, showing a marine return tube boiler with a large steam dome and a Salter spring loaded safety valve mounted on the face of the drum. On the left in a vertical position is the isolating valve to which the steam pipe would have been attached (Alexander Wilson and Co 1875:32).

The primary purpose of the steam dome was for the collection of dry steam which flowed through to the engine via the steam pipe. In practice, however, it was found that the effectiveness of the dome was nullified by the condensation of steam due to the large cooling surface it presented to the atmosphere. By the end of the century such devices had been dispensed with in preference to perforated steam collecting pipes located in the boiler shell (Figure 6-5) (Hutton 1891:314).

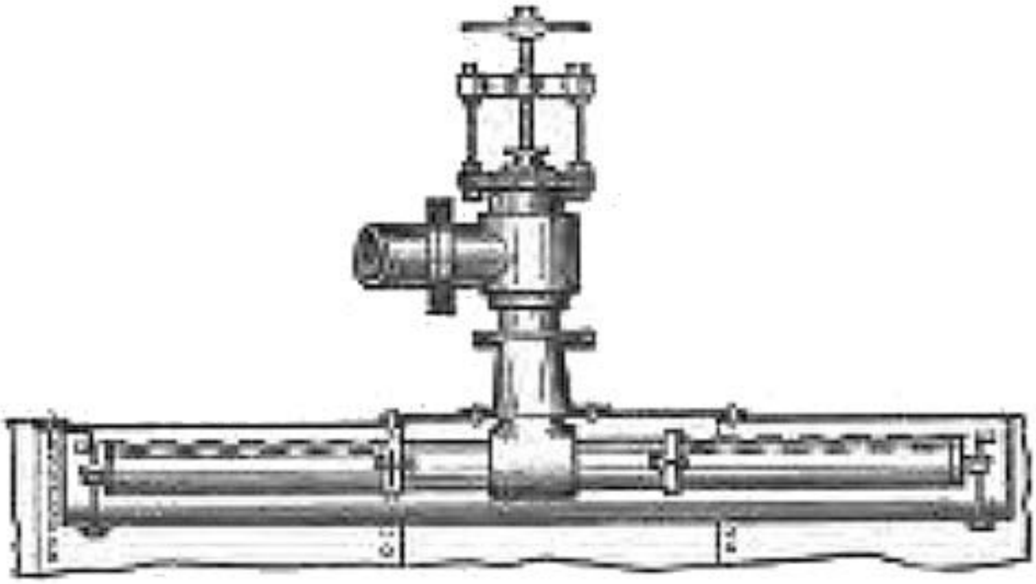


Figure 6-5. An example of a steam collecting pipe with an isolating valve. With the abandonment of the steam dome these pipes were fitted inside the shell of the boiler to reduce heat loss (Hutton 1891:314).

The archaeological investigation of *Xantho*'s steam dome indicates that it measured 91 cm (36 in) in diameter (Figure 6-6). Although the height could not be established, photographic evidence of other nineteenth-century steam domes suggests that the height and width of these devices were often similar, if not identical.

Figure 6-6. The collapsed remains of *Xantho*'s steam dome. Data from the 1985 site survey indicate that the width of the dome measured 91 cm (36 in) (Western Australian Museum, 1994).

Steam Pipe

The main steam pipe transferred steam from the boiler to the engine. Such pipes were constructed to take the shortest and most direct course to the engine with as few bends as possible (Hutton 1891:306). *Xantho*'s main steam pipe consisted of two sections: A horizontal pipe (remnants of this were attached to the isolating valve) (Figure 6-7) and a connecting vertical pipe that was attached to the engine (Figure 6-8). The author's initial hypothesis was that the horizontal pipe was constructed of the same material as the vertical pipe, i.e. bronze, and being a valuable metal this was most likely salvaged by Broadhurst in 1872. The de-concretion of the isolating valve in August 2012 however revealed that part of the steam pipe was still attached to the isolating valve and that it was cast iron. The de-concretion of the isolating valve also confirmed that the horizontal steam pipe was connected to the isolating valve and not directly to the boiler.

Figure 6-7. The isolating valve recovered in June 2012. The de-concretion of this artefact showed that part of the steam pipe (left) was still attached and that it was constructed of iron (A. Kilpa, 2012).

Figure 6-8. ***Xantho*****'s horizontal trunk engine after excavation on the beach at Port Gregory. The twisted steampipe is seen here in a horizontal position. This led to confusion and resulted in an erroneous interpretation of how the boiler and engine were connected (P. Baker, 1985).**

Although the wreck of *Xantho* is located in a highly dynamic environment, both sections of the steam pipe show damage beyond what would normally be expected from this factor alone. When the steam-ship *Kurnalpi* (Figure 6-9) called into Port Gregory in February 1918 to pick up cargo, the master requested that the wreck be removed as it "constituted a hazard to navigation" (McCarthy 1996:161). Whether *Kurnalpi* collided with *Xantho* is unclear, but *Xantho*'s location and its shallow depth (the steam dome perhaps only a metre below the water's surface) must have created a significant obstacle for vessels going in and out of the harbor.

The steam pipe recovered from *Xantho* appears to be kinked at the base with split seams (Figures 6-10 and 6-11). This suggests that it was struck by an object with considerable force.

Figure 6-9. The steam-ship *Kurnalpi* in 1918 loading up cargo at Port Gregory (Northampton Museum, Northampton, reproduced with permission, NHS261).

Figure 6-10. The author Alex Kilpa holding the copper alloy steam pipe recovered from *Xantho* in a vertical position (C. Cockram, 2012).

Figure 6-11.The distorted base of the steam pipe. This pipe would have been installed on the engine in an upright (vertical position). It is possible that the copper alloy pipe bent and rotated on its swivel when struck by a ship or other heavy object (A. Kilpa, 2012).

Exhaust Pipe

As with the horizontal steam pipe described previously, it was initially thought that the steam exhaust pipe was made of bronze and salvaged by Broadhurst in 1872. An examination of the *Xantho Accessioning Book* revealed the existence of an iron flange, fragments of this were still attached to the engine but broke off during the de-concretion process and had largely been forgotten. This flange (XA260) is presented in Figure 6-12 and confirms that both the exhaust pipe and the horizontal steam supply pipe were constructed of cast iron.

Figure 6-12. The flange and several fragments from *Xantho*'s steam exhaust pipe (A. Kilpa, 2012).

Bourdon Pressure Gauge

The Bourdon pressure gauge was invented in 1849 by Eugene Bourdon (1808–1884) and was quickly adopted for boiler purposes (White 1979:134). The advantages of having a safety device for measuring the pressure in a boiler was recognised from the early days of steam technology as they could validate the calibration of the safety valve and assist in reducing coal consumption by providing the engineer with an indication of how much stoking was required to achieve a particular pressure level.

By 1894 its installation on steam boilers was a requirement endorsed by the Board of Trade (Appendix D).

In 1979 members of MAAWA saw what they believed to be a pressure gauge on the seabed in close proximity to the boiler (Sledge 1980:1; Totty 1980; Worsley 1983:2). Subsequent dives after 1981, however, were unsuccessful in locating it. This important device probably fell victim to a treasure hunter which was unfortunate, since it could have revealed much more about the construction of the boiler and its working pressure. By the 1870s there were many manufacturers of Bourdon-type safety gauges. Figure 6-13 shows a Crosby deadweight tester with pressure gauge. Figure 6-14 illustrates a restored pressure gauge found off the Albany Town Jetty during dredging activities in 2002. The provenance of this device is unknown.

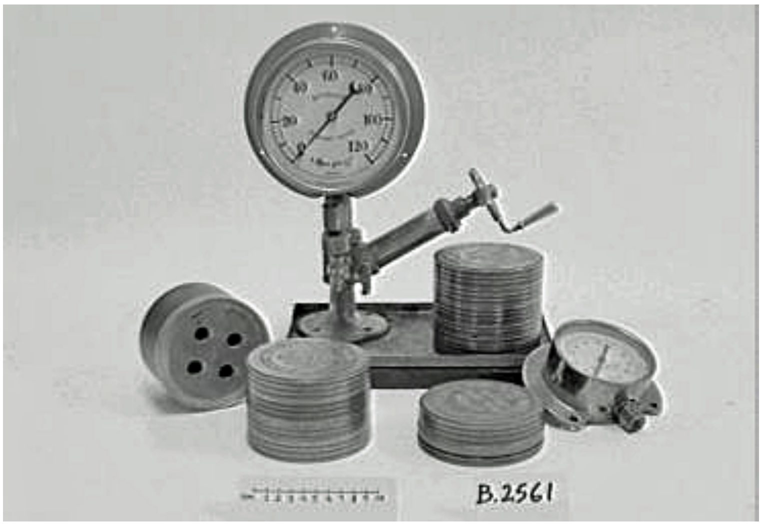


Figure 6-13. A deadweight pressure gauge and tester (Powerhouse Museum, Sydney, 2012, reproduced with permission).

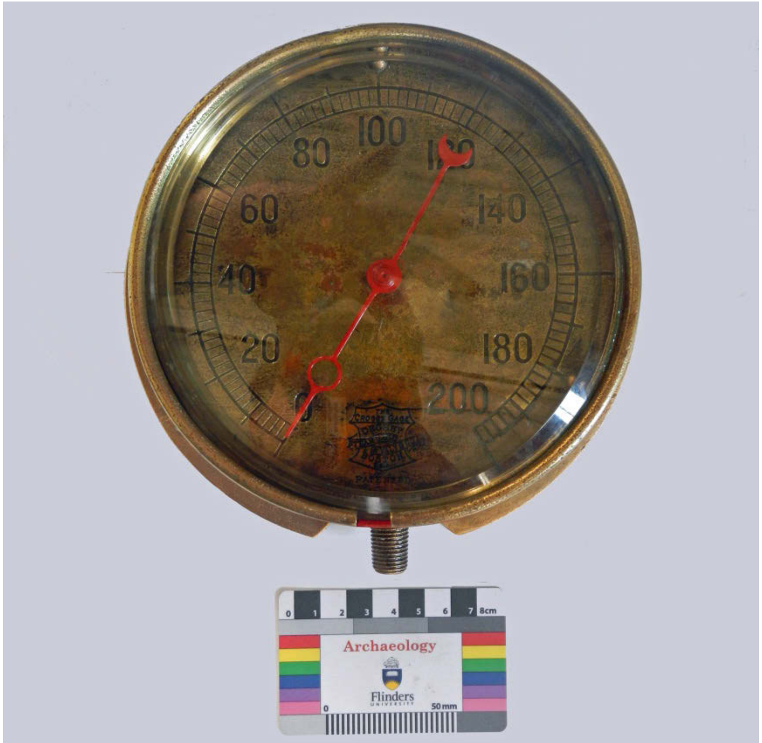


Figure 6-14. A restored Bourdon pressure gauge manufactured by Crosby. This gauge was excavated off Albany town jetty during dredging activities in 2002. Its provenance is unknown (A. Kilpa, 2012).

Blow-down Pipe

A blow-down pipe was as a safety device that allowed the free escape of steam from the safety valve to atmosphere. Most blow down pipes tended to be made of copper and were attached to the funnel by brackets to provide stability. Figure 6-15 shows the paddle steamer *Vulcan* (1879) releasing steam via its blow-down pipe. The pipe vented high above the deck to prevent accidental scalding.

Xantho's blow-down pipe has yet to be located on the shipwreck. It is possible that it was salvaged by Broadhurst in 1873 because it was considered to be a valuable metal. The *Xantho* auction list of salvaged materials of 1873 makes mention of a ‘copper branching’ although no details of its size or dimensions are given (Appendix E).

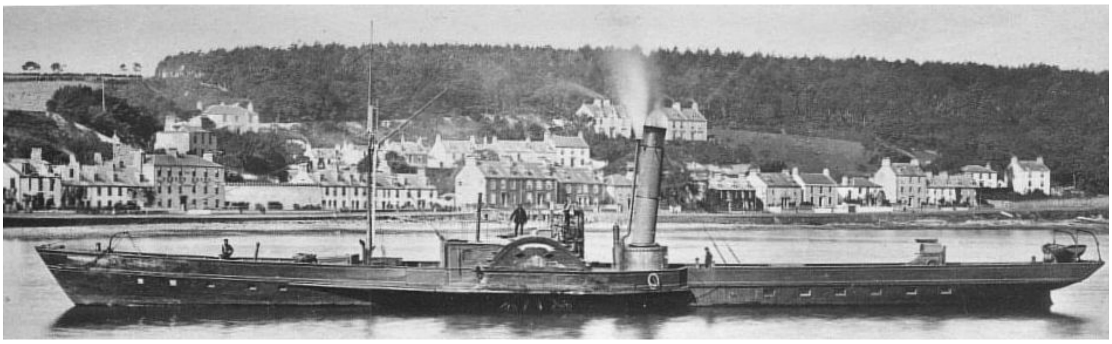


Figure 6-15. *Vulcan* (1879). A close examination of this photograph reveals that steam is being emitted from its blow-down pipe (Fletcher 1904:110).

Smoke box and Funnel

The purpose of the smoke box was to provide an avenue for the escape of heat and smoke after they passed through the boiler. With the exception of the brackets used to affix the cowling to the boiler crown, little evidence of the smoke box was found at the wreck site (Figure 6-16). It is possible that some of this material broke off and buried itself in the silt. It is known however, that the iron used in the construction of these devices was generally quite thin and may therefore have simply corroded away. The profile of the support brackets on the boiler shown in Figure 6-16 suggest that the width of the funnel may have been around 91.44 cm (36 in). Figure 6-17 shows a smoke box and funnel on a nineteenth-century scotch boiler. It is possible that *Xantho*’s boiler was similar in appearance.

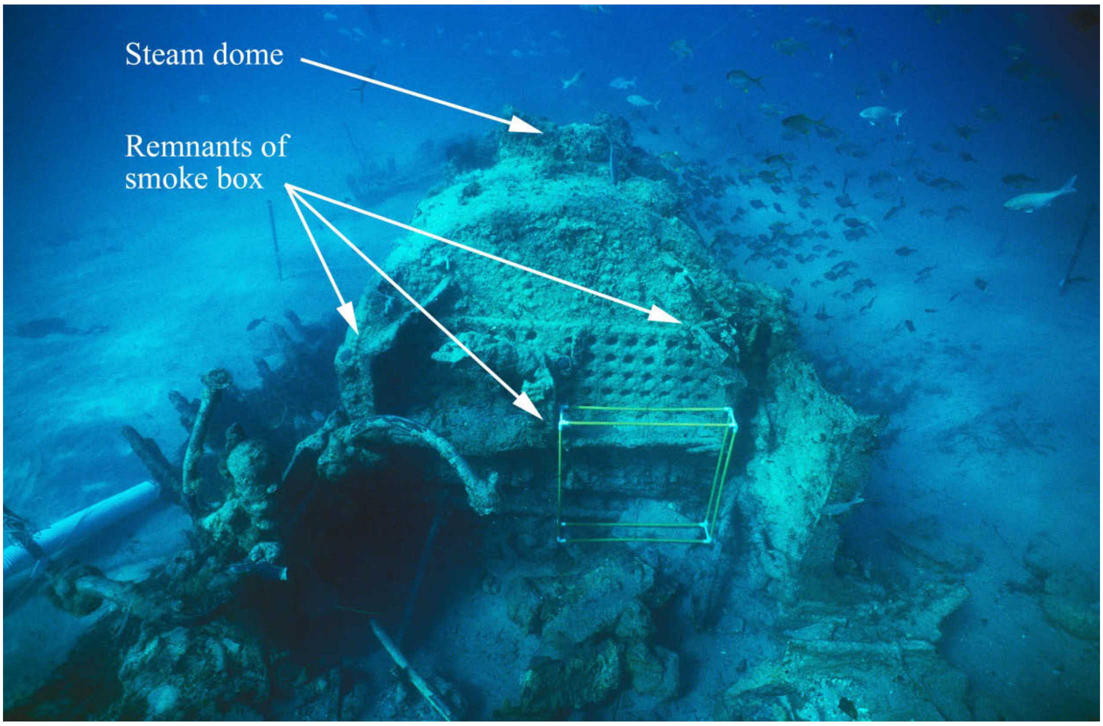


Figure 6-16. ***Xantho*****'s boiler in 1985 with remnants of the smoke box visible on the boiler crown (P. Baker, 1985).**

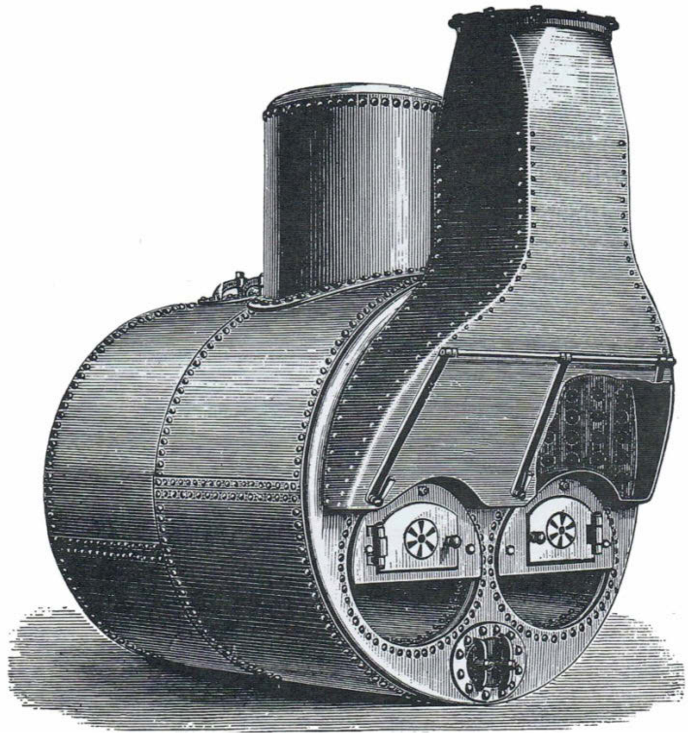


Figure 6-17. An engraving depicting a twin furnace scotch marine return-tube boiler with large steam dome, smoke box, and funnel. The archaeological evidence suggests a similar profile for ***Xantho*****'s boiler (McEwen 2010:92).**

The Reconstruction of *Xantho*'s Machinery

The typology of boilers and their mountings from this period and the archaeological evidence led to the conclusion that *Xantho*'s boiler was a scotch marine return tube boiler. This boiler had a steam dome, two safety valves, a general shut down (also known as an isolating valve) and a Bourdon gauge to indicate steam pressure. This machinery was used to turn a large a three-bladed screw propeller via a shaft directly connected to the horizontal trunk engine. The proposed layout of *Xantho*'s propulsion system parallels that of a small steamer found in an Alexander Wilson catalogue of 1875 claiming "exact representation of the propulsion system" (Figure 6-18). Of interest is the absence of a condenser (also absent on *Xantho*) with the exhaust being fed directly into the funnel.

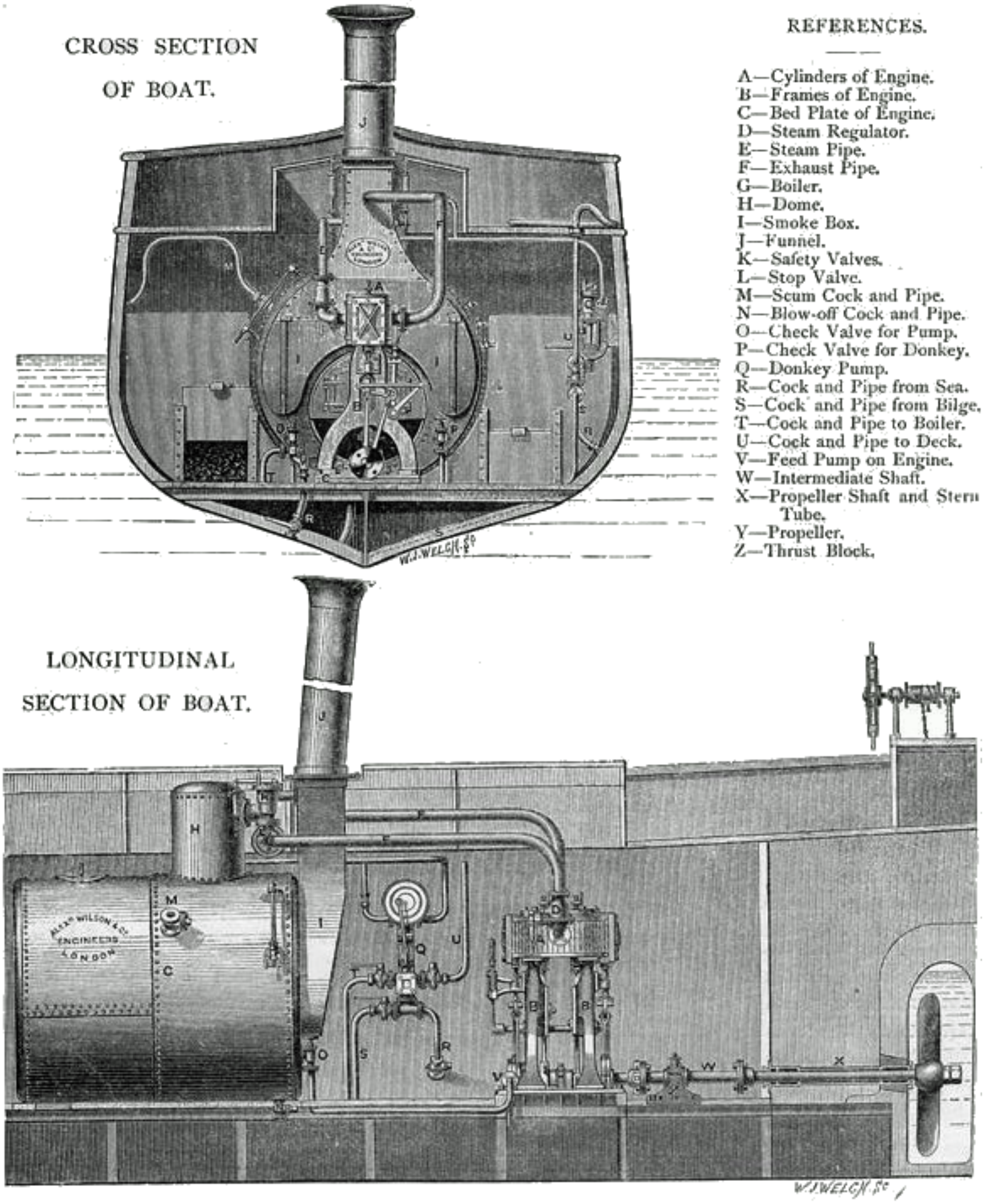
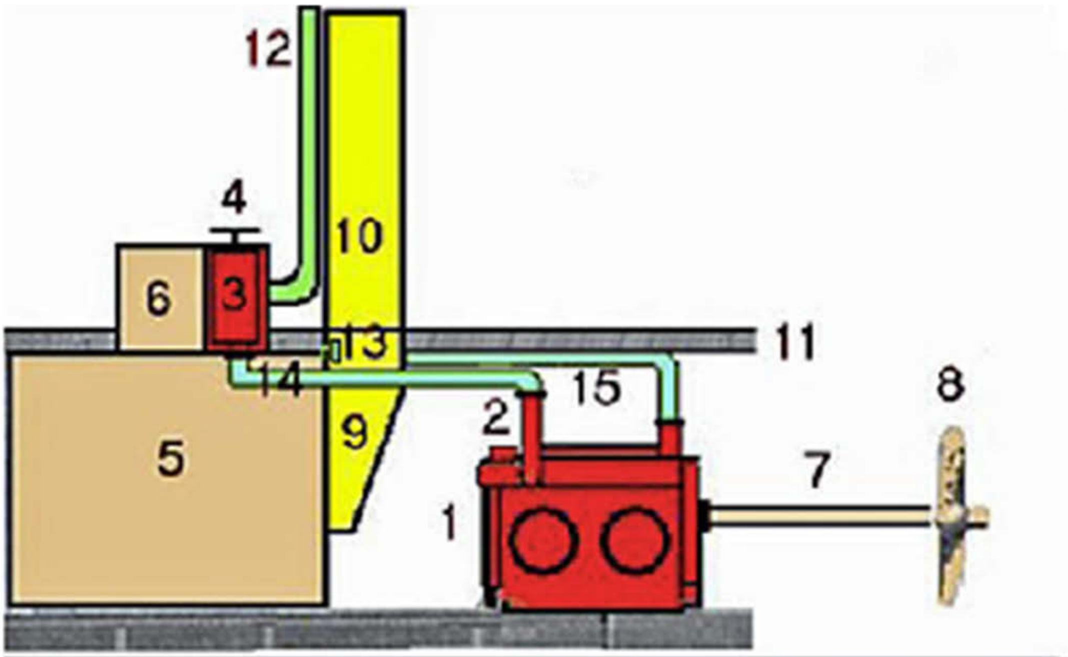


Figure 6-18. Extract from an Alexander Wilson and Co catalogue (1875) showing the relationship between the marine boiler, safety valve, and the engine, which in this case comprises a double-cylinder screw engine (Alexander Wilson and Co. 1875:35).

Based on this design and the archaeological evidence a hypothetical model of *Xantho*'s 1872 propulsion system was generated. This schematic representation is presented in Figure 6-19.



ID	Description of component	Notes
1	Horizontal Trunk Engine	Archaeologically recovered 1985
2	Steam pipe (vertical component)	Archaeologically recovered 1985
3	Isolating valve	Archaeologically recovered 2012
4	Safety valve	Archaeologically recovered 1988
5	Boiler	Left in situ at shipwreck site
6	Steam dome	Left in situ at shipwreck site
7	Propeller shaft	Left in situ at shipwreck site
8	Propeller	Left in situ at shipwreck site
9	Smoke box	Remnants on boiler left in situ at shipwreck site
10	Funnel	Remnants on boiler left in situ at shipwreck site
11	Deck	Remnants on seabed left in situ at shipwreck site
12	Blow-down pipe	Probably salvaged by Broadhurst 1872
13	Bourdon gauge	Believed to have been treasure hunted, c. 1980
14	Steam pipe (horizontal)	Remnants archaeologically recovered 2012—remnants possibly still at site
15	Exhaust pipe	Archaeologically recovered excavated 1985—remnants possibly still at site

Figure 6-19. A schematic representation of *Xantho*'s propulsion system (A. Kilpa, 2012).

This schematic representation will be used in the near future to develop a scaled plan of *Xantho*'s propulsion system, that incorporates the outcomes of this research and the site survey work undertaken by McCarthy (1996; 2000). Figures 6-20, 6-21, and

6-22 show a more detailed plan of the safety and isolating valves in relation to the boiler and steam dome.

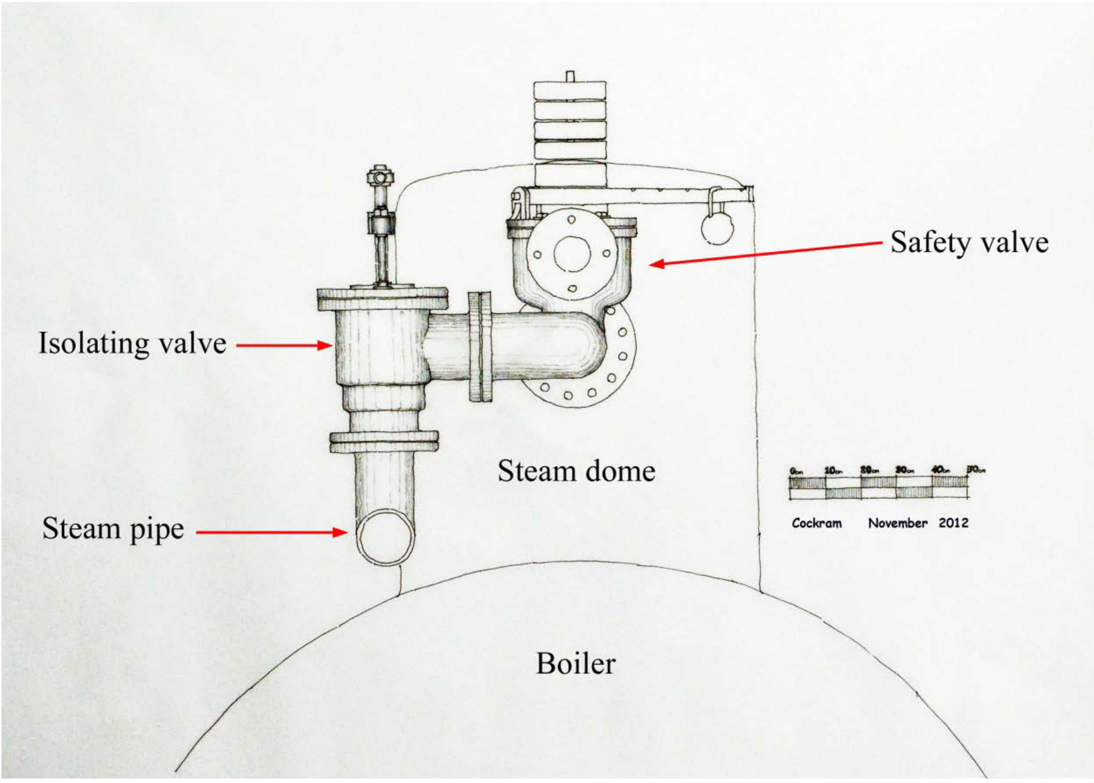


Figure 6-20. Front view of safety valve and isolating valve in relation to the steam dome and boiler (A. Kilpa, after C. Cockram, 2012).

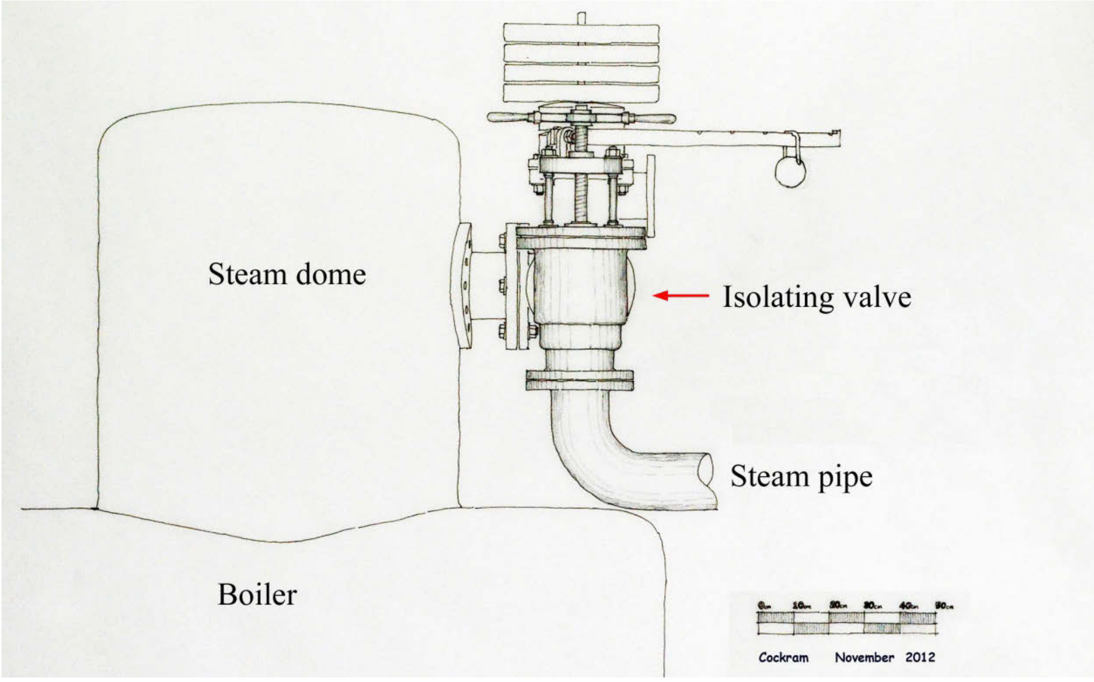


Figure 6-21. Side view of safety valve and isolating valve in relation to the steam dome and boiler (A. Kilpa, after C. Cockram, 2012).

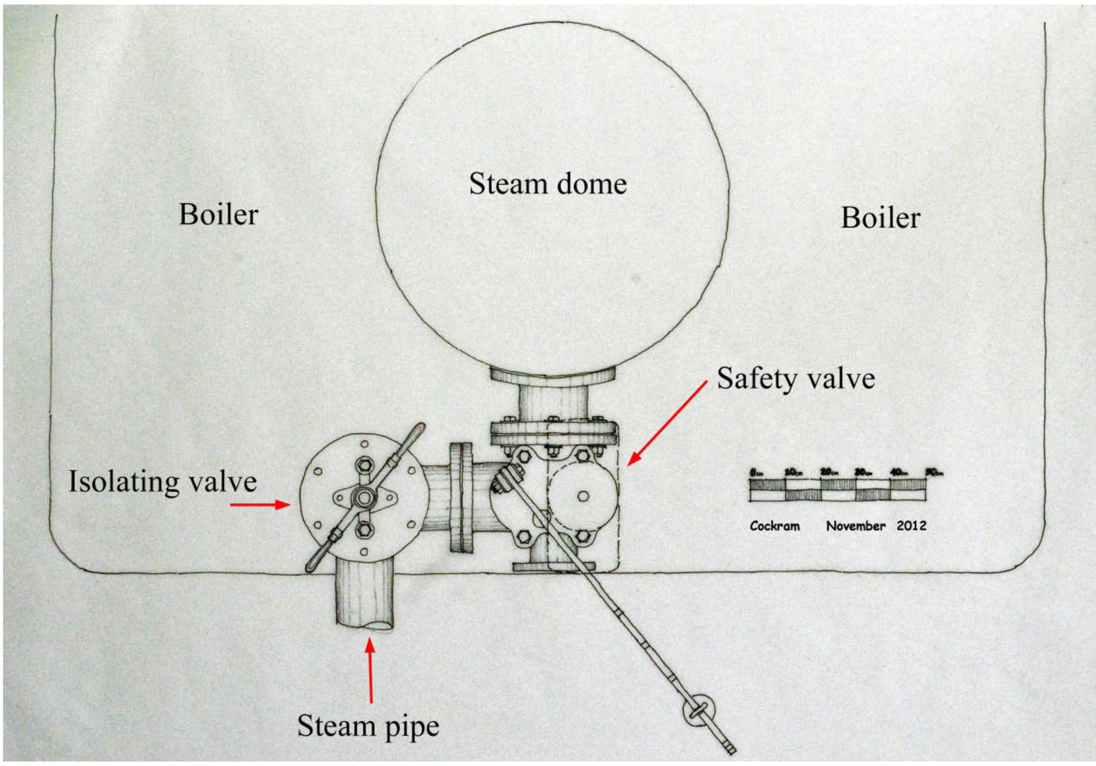


Figure 6-22. Plan view of safety valve and isolating valve in relation to the steam dome and boiler (A. Kilpa, after C. Cockram, 2012).

Conclusion

The proposed layout of *Xantho's* propulsion system consolidated data derived from the archaeological investigation with information available from historical documentation. This model suggests that *Xantho*'s safety valve acted both a safety device and as a junction point for the distribution of steam via the attached steam and blow down pipes. The purpose of the deadweight and lever-weighted valves was to act as automated safety devices that would allow the quick release of steam in circumstances where boiler pressure exceeded its recommended settings. The purpose of the isolating valve that shared the same housing as the safety valves was to regulate the control of steam from the boiler through to the engine.

The value of producing a theoretical model such as the one described in this chapter was that it not only allowed for a better understanding of how the propulsion system operated but also provided clues to what happened to some of its componentry. The examination of the remnants of these materials suggests that *Xantho* was hit by an object with considerable force (perhaps *Kurnalpi* in 1918) and that this was responsible for damage to the steam dome, steam and exhaust pipes, and the isolating valve. This concurs with an earlier hypothesis generated by McCarthy (1996:161).

CHAPTER VII: DISCUSSION AND CONCLUSION

Aims Revisited

In Chapter I the following research question was proposed. "What can the safety valve recovered from SS *Xantho* (1872) reveal about the development of safety features on nineteenth-century steamships?"

To address this question, this study adopted a holistic research approach in its methodology that utilized six data sets, including:

- Socio-economic factors that influenced the development of nineteenth-century safety valves;
- Historical documentation including photography that provided evidence of mounting types associated with mid to late nineteenth century horizontal boilers;
- Information derived from the reconstruction of the safety valve;
- Associated archaeological materials, such as the boiler, still present at the shipwreck site;
- Materials previously recovered from the *Xantho* shipwreck site such its engine and associated pipework; and
- Literature, diagrams, and manufacturer's catalogues of marine propulsion systems that could aid in the development of a hypothetical model of *Xantho*'s propulsion.

This thesis was developed in two stages with sub-sets of secondary questions relating to this research theme.

Stage one initiated research questions relating to the identification and functionality of the artefact, i.e. safety valve. These including:

- What was the purpose of this object?
- What was its material composition?
- How did this device function? and
- Where was it located on the boiler?

Stage two posed comparative questions relating to safety valve options for boilers in the mid nineteenth century. These included:

- How did the mechanism recovered from *Xantho* compare in terms of composition, safety rating, and design to other types of safety valves available in the mid nineteenth century, i.e. lever-weighted and spring-loaded valves?
- Under what environmental circumstances would these mechanisms be best suited, i.e. at sea, land, rivers, lakes?
- Were there guidelines, legislation, or regulations for the installation of such mechanisms?

The outcome of this study addressing these research aims is presented as follows:

What was the Purpose of This Object?

The purpose of the deadweight and lever-weighted valves is to act as automated safety devices that would allow the quick release of steam in circumstances where boiler pressure exceeded its recommended settings. The purpose of the isolating valve that shared the same housing as the safety valves is to control the passage of steam from the boiler through to the engine.

This study suggests the installation of weighted safety valves on steamship boilers was commonplace well until 1870s. This differs from the position of Denis Griffiths (1997:58), who states that "initially safety valves [on steamships] were of the deadweight type, but spring-loaded safety valves became normal in the 1850s following their general adoption on railway locomotive boilers."

In comparison with the more commonly encountered Cockburn deadweight systems that were mass produced and had a universal installation capacity, the curvature of *Xantho*'s mounting flange (XA339A) indicates that the safety valve could only be installed on a steam dome 91 cm (36 in).

Xantho's safety valve is unusual because its duplex configuration combined two safety valves and an isolating valve on the same housing. The profile of this device does not match any of the patent safety valves presented in Appendix B. It is possible that this device was constructed by a small safety valve manufacturing company or by the boiler maker David Davidson.

What was its Material Composition?

The safety valve recovered from *Xantho* comprised of

- Cast iron for the construction of the casing, boiler mounting flange, and deadweights,
- Copper alloy for the construction of the valves, and
- A composite of cotton and lead for the gaskets.

The suitability of these materials in the construction of the safety valve is discussed in Chapter V. The safety valve's metal components were manufactured in a foundry. The discovery of woven cotton gasket material used to prevent the loss of steam at flange joints identifies an important trade.

How did This Device Function?

Xantho's safety valves operated on the weighted principle. This was calibrated to respond when then boiler pressure exceeded a specific pressure. It was not possible to determine the lifting point at which the lever weighted valve would come into play due to the absence of the arm and the weight. The application of a simple formula provided by George Tower (1889:53) indicates that the amount of pressure necessary to lift the deadweight valve was 220.6 kPa (32 psi).

Where was the Location of the Valve on the Boiler?

An analysis of the archaeological data obtained from *Xantho*'s boiler that was left in situ, and the creation of a template matching the diameter of the steam dome indicated that the safety valve was installed on the side of the dome.

How did the Mechanism Recovered From *Xantho* Compare in Terms of Composition, Safety Rating, and Design to Other Types of Safety Valves Available in the mid Nineteenth Century, i.e. Lever-Weighted and Spring-Loaded Valves?

The safety valve recovered from *Xantho* was initially considered an anomaly because in modern day engineering spring-loaded valves for marine applications are better suited than those operating under the weighted principle. Historical and archaeological evidence derived from this study indicates the use of weighted safety valves was normal practice for most of the nineteenth century as it was not until 1877 that direct loaded spring valves was fully adopted by the Board of Trade as the preferred choice for marine purposes. As discussed in Chapter IV, one possible explanation for this persistence in obsolete technology, even when other options such as spring-loaded devices were commercially available, may lay in the lack of confidence by the Board of Trade in valve designs that did not allow the free and rapid release of steam.

Under What Environmental Circumstances Would These Mechanisms be Best Suited, i.e. at sea, Land, Rivers, Lakes?

Many first generation nineteenth century steamships were used for towing or transportation in calm or sheltered waters on lakes and rivers. When operating under these conditions weighted safety valves are less susceptible to the influences of wave movement and operate quite successfully.

The mid to late nineteenth century witnessed rapid advancements in steamship technology. The advent of compounding engines resulted in a greater efficiency in coal consumption but required high boiler pressures. With these developments weighted safety valves became impractical and were replaced by spring loaded valves that could operate more efficiently. *Xantho's* safety valve was perhaps amongst the last generation of weighted systems used at sea.

Were There Guidelines, Legislation, or Regulations for the Installation of Such Mechanisms?

As discussed in Chapter III early nineteenth century steamship technology was noted for the high incidence of boiler explosions. In response, the UK Parliament introduced legislation designed to reduce their occurrence. From the early 1850s onward steamships were heavily regulated by the Board of Trade whose representatives were required to inspect steamships twice a year and issue permits authorising their usage. This involved the testing of safety valves and other machinery to ensure it was safe and operational. These provisions were mandatory under the *Steam Navigation Act 1851*. Although *Xantho*'s safety valve in modern engineering would appear primitive, it nevertheless met the minimum safety requirements in 1871 as set by the Board of Trade.

Future Research

The historical evidence presented in this study is suggests that the installation of deadweight safety valves on boilers operating at sea was normal practice until the 1870s, however given the limitations of the archaeological data set derived from two sources— *Xantho* and *Indiana,* further research is necessary. As discussed in Chapter 1, one of the major difficulties in conducting research on this topic in Australia is that many steamships located in shallow waters have been subject to salvaging by their original owners, or suffered from the activities of treasure hunters. Consequently there are few known examples where safety valves and boiler pressure gauges are still onsite.

Wreck sites located in deep or turbulent waters will have a high archaeological potential for further research in this field of study. *Clonmel* (1841), *Mimos*a (1863), *Blackbird* (1878), and *Tasman* (1883) for example are known to have their propulsion machinery still intact. In some of these cases the use of remotely operated vehicles (ROVs) may be able to assist in overcoming operational difficulties of utilizing divers where the wreck site is at great depth or where the conditions have previously been considered too hazardous to conduct research.

Given the large body of historical literature describing the general profile of these devices (Appendix B), further archaeological research on this topic need not necessarily require the recovery of materials as much data could be acquired through developing an in situ investigative methodology that focused on general valve characteristics, i.e. whether the safety valve was spring loaded or weighted and how it was installed on the boiler, rather than focusing on understanding the internal mechanisms associated with their function which is largely understood through historical documentation. A research proposal developed along these parameters would therefore comply with UNESCO's preferred option for non-intrusive studies adopted for managing cultural materials under the sea as stipulated in its *Convention on the Protection of the Underwater Cultural Heritage Under the Sea* (2001).

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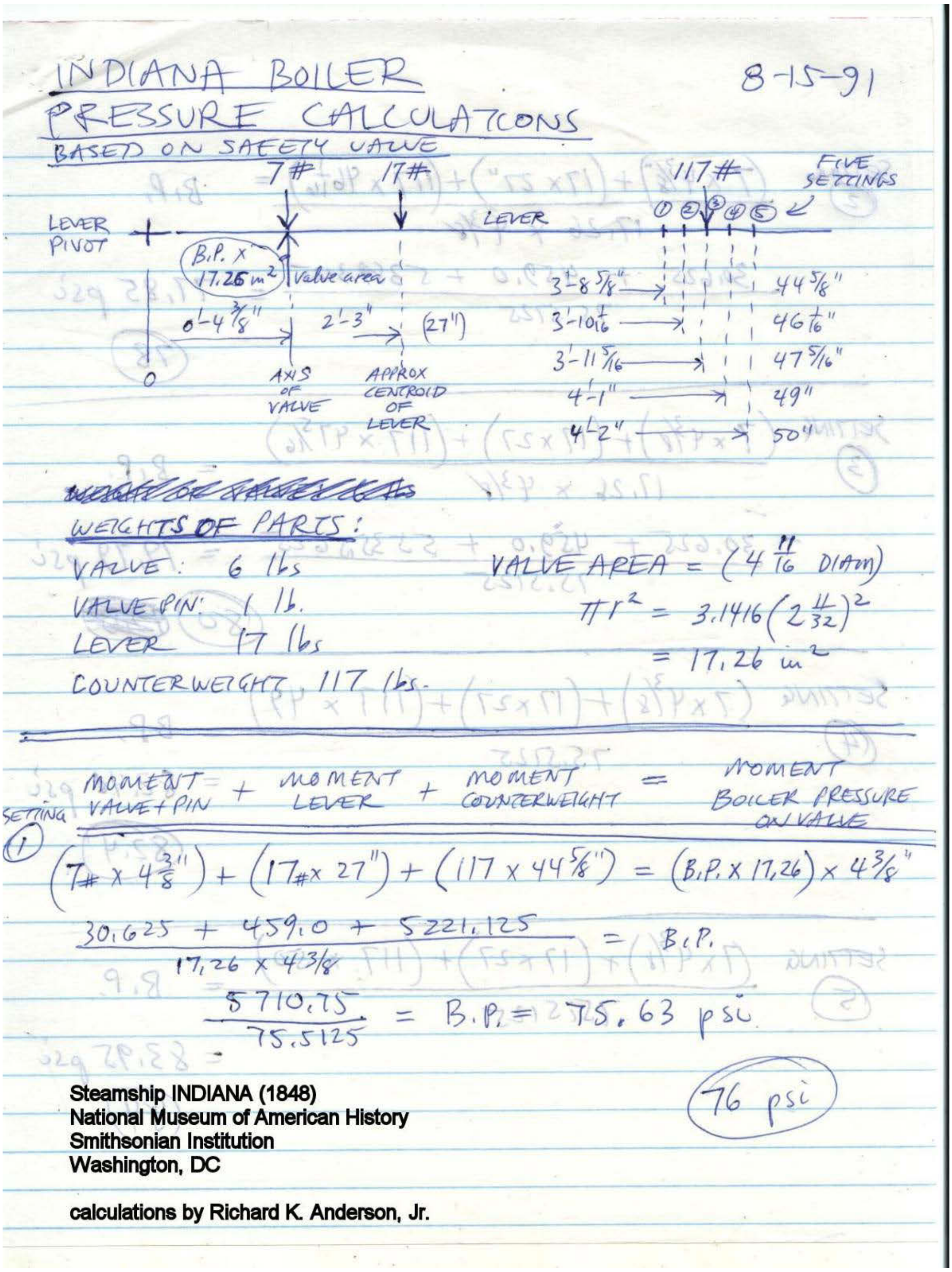
APPENDIX: A

SPECIFICATIONS OF PROPELLER *INDIANA* (1848)

LEVER-WEIGHTED VALVE

These field notes, drawings and measurements of *Indiana*'s boiler and safety valve have been provided courtesy of Richard Anderson (1982, 1991). It is believed that a similar type of mechanism would have been fitted on the multi-functional device removed from *Xantho*. An analysis of the lever-weighted safety valve found on the *Indiana* boiler suggests a pressure blow off point of between 517.1 kPa–620.5 kPa (75 psi–84 psi). These calculations were derived from a formula where the position of the weight 53.18 kg (117 lb) on the arm 121.9 cm (48 in) is taken into consideration (Collins 1908:89–100).

There is considerable debate as to whether *Indiana*'s boiler should be seen as a high-pressure or overworked low-pressure boiler. An analysis of the plates indicate significant bulging and suggest the boiler was on the verge of exploding at the time the ship was wrecked in 1848.



INDIANA BOILER
PRESSURE CALCULATIONS
BASED ON SAFETY VALVE

8-15-91

LEVER PIVOT — 7# — 17# — LEVER — 117# — FIVE SETTINGS ① ② ③ ④ ⑤

B.P. x 17.26 in² Valve area

0'-4 3/8" → AXIS OF VALVE
2'-3" (27") → APPROX CENTROID OF LEVER

3'-8 5/8" → 44 5/8"
3'-10 1/16" → 46 1/16"
3'-11 5/16" → 47 5/16"
4'-1" → 49"
4'-2" → 50"

~~WEIGHT OF VALVES ETC~~

WEIGHTS OF PARTS:

VALVE: 6 lbs
VALVE PIN: 1 lb.
LEVER 17 lbs
COUNTERWEIGHT 117 lbs.

VALVE AREA = (4 11/16 DIAM)

$\pi r^2 = 3.1416 (2 \frac{11}{32})^2$

$= 17.26 \text{ in}^2$

MOMENT VALVE + PIN + MOMENT LEVER + MOMENT COUNTERWEIGHT = MOMENT BOILER PRESSURE ON VALVE

SETTING ①

$(7\# \times 4\frac{3}{8}") + (17\# \times 27") + (117 \times 44\frac{5}{8}") = (B.P. \times 17.26) \times 4\frac{3}{8}"$

$\frac{30.625 + 459.0 + 5221.125}{17.26 \times 4\,3/8} = B.P.$

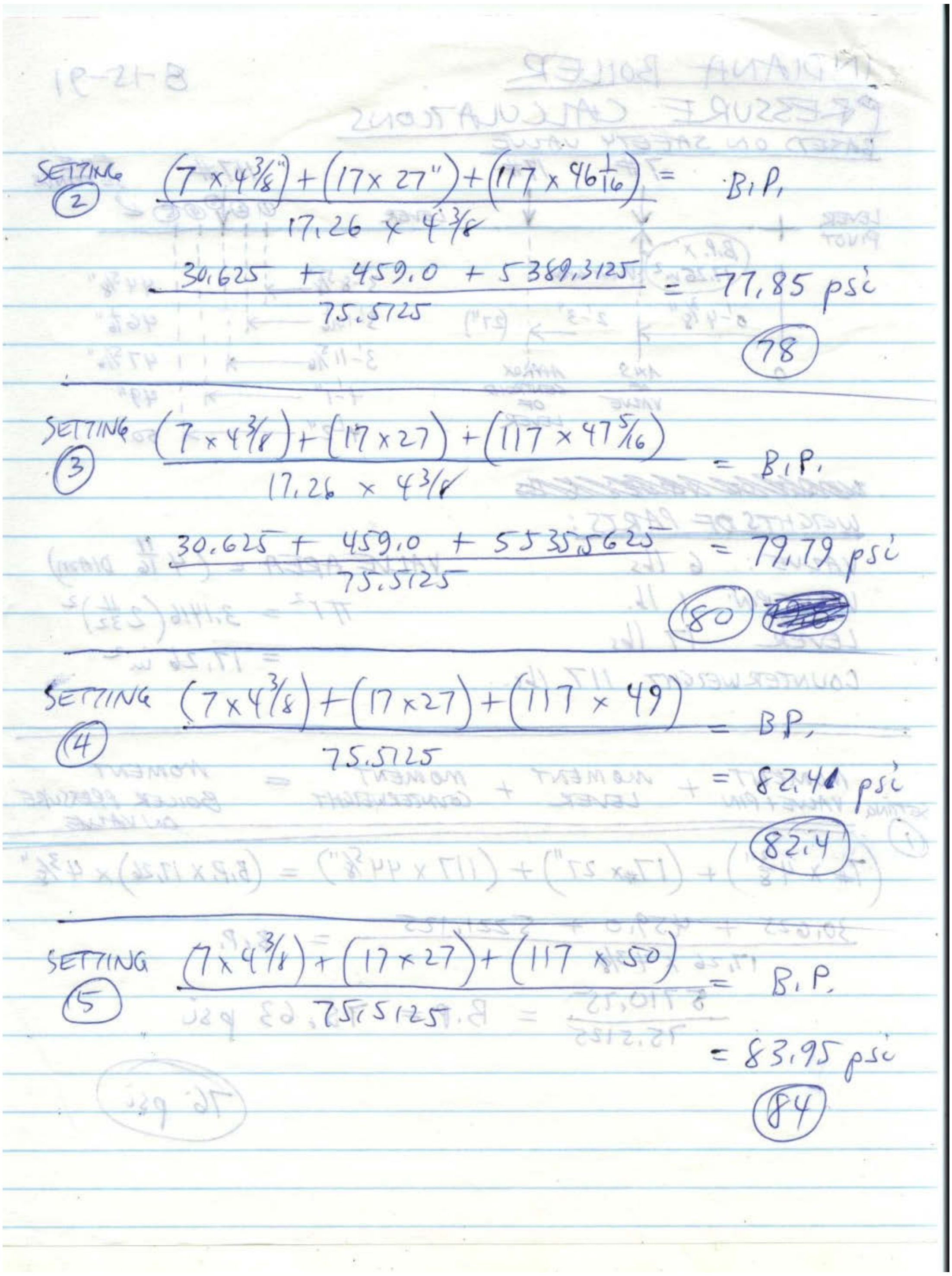
$\frac{5710.75}{75.5125} = B.P. = 75.63 \text{ psi}$

76 psi

Steamship INDIANA (1848)
National Museum of American History
Smithsonian Institution
Washington, DC

calculations by Richard K. Anderson, Jr.

Figure A-1. ***Indiana*** **boiler pressure calculations based on the specifications of the safety valve (Anderson, 1991).**



SETTING (2)
$$\frac{(7 \times 4\tfrac{3}{8}") + (17 \times 27") + (117 \times 46\tfrac{1}{16})}{17.26 \times 4\tfrac{3}{8}} = B.P.$$
$$\frac{30.625 + 459.0 + 5389.3125}{75.5125} = 77.85 \text{ psi}$$
(78)

SETTING (3)
$$\frac{(7 \times 4\tfrac{3}{8}) + (17 \times 27) + (117 \times 47\tfrac{5}{16})}{17.26 \times 4\tfrac{3}{8}} = B.P.$$
$$\frac{30.625 + 459.0 + 5535.5625}{75.5125} = 79.79 \text{ psi}$$
(80)

SETTING (4)
$$\frac{(7 \times 4\tfrac{3}{8}) + (17 \times 27) + (117 \times 49)}{75.5125} = B.P.$$
= 82.41 psi
(82.4)

SETTING (5)
$$\frac{(7 \times 4\tfrac{3}{8}) + (17 \times 27) + (117 \times 50)}{75.5125} = B.P.$$
= 83.95 psi
(84)

Figure A-2. ***Indiana*** **boiler pressure calculations based on the safety valve (Anderson, 1991).**

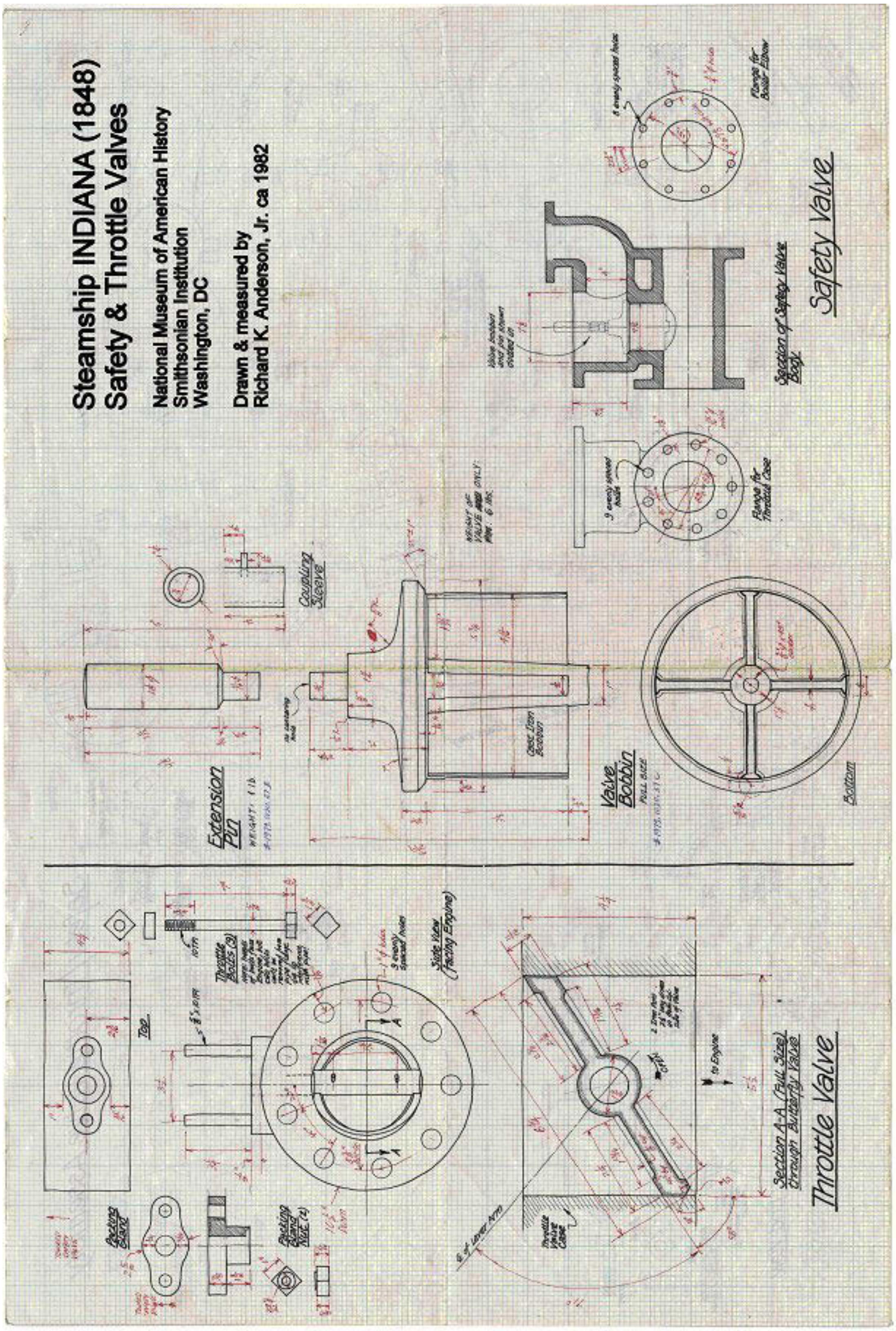


Figure A-3. ***Indiana*** **(1848) safety/throttle valve assembly (Anderson, 1982).**

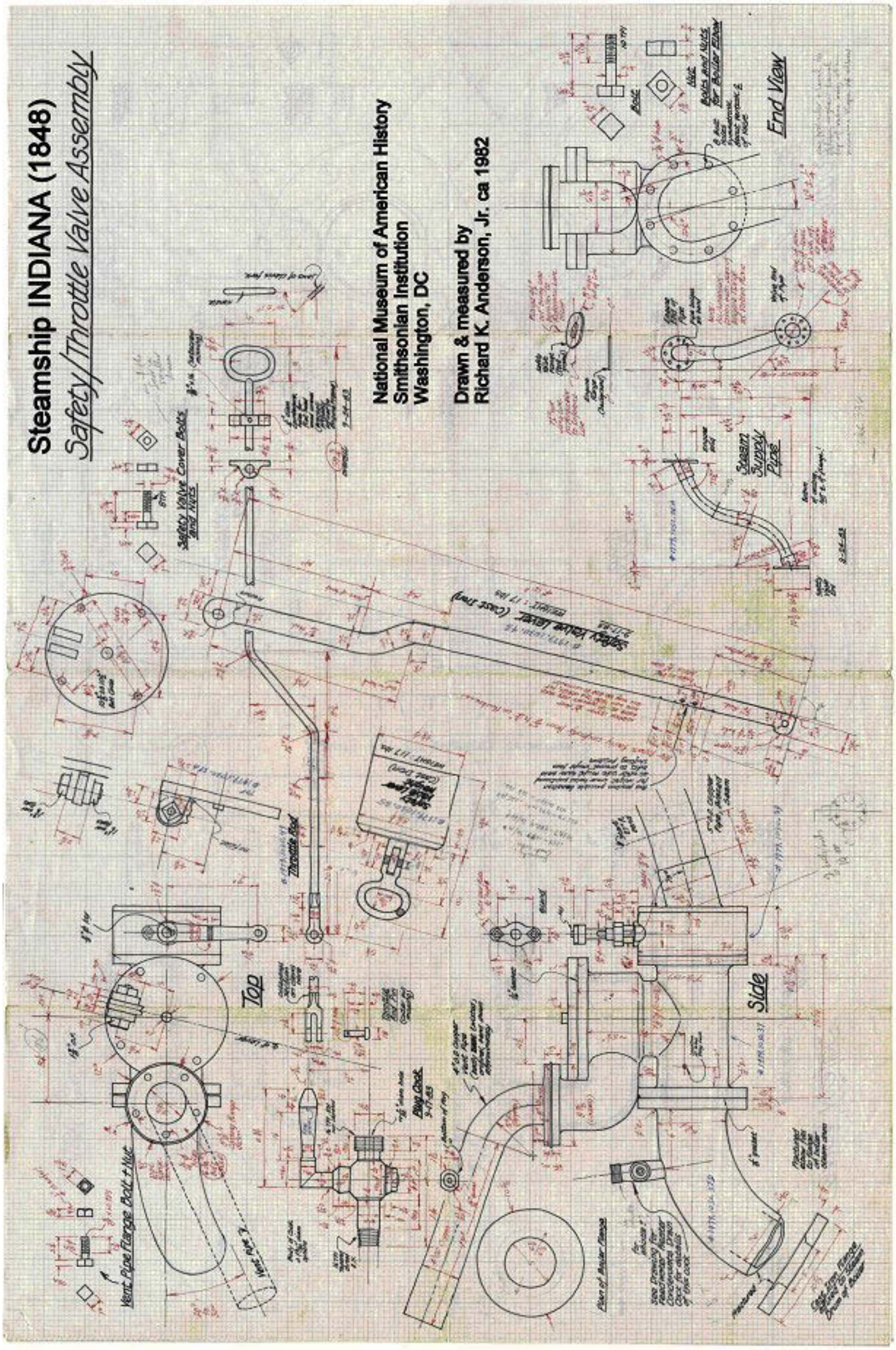


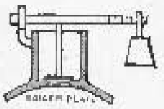
Figure A-4. ***Indiana*** **(1848) safety/throttle valve assembly (Anderson, 1982).**

APPENDIX B:

PATENTED SAFETY VALVES

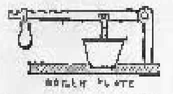
This extract from Burgh (1873:279–296) provides a comprehensive listing of over 150 patented safety valves from 1695–1873. This documentation in conjunction with other examples discussed in Chapter IV was used to assess the diagnostic features and functionality of the safety valve removed from *Xantho*.

Fig. 749.



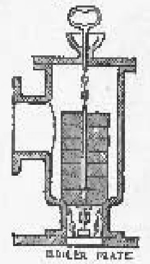
Papin's Safety Valve, consisting of a disc and rod seated in a recess formed with the boiler or digester, as it was termed; the disc was acted on by a weight lever. Invented in the year 1695.

Fig. 750.



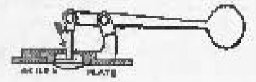
Savery's Safety Valve, consisting of a solid cone seated on the boiler plate and acted on by a weight lever. Used in the year 1698.

Fig. 751.



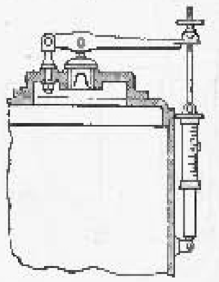
Watt's Land Stationary Safety Valve, consisting of a disc acted on by series of direct weights, and a chain and handle connected to the valve rod above the weights to raise them and the valve. Invented in the year 1800.

Fig. 752.



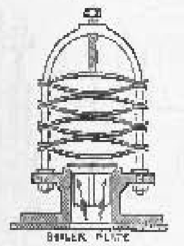
Vacuum or Atmospheric Safety Valve, for the purpose of permitting the atmosphere to fill the boiler when empty and prevent collapsing. Used since the year 1800.

Fig. 753.



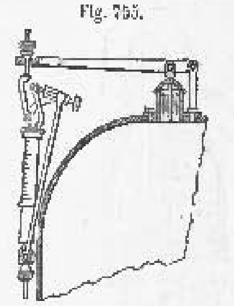
Locomotive Safety Valve, consisting of a disc acted on by a lever and box spring at its end, as used first in the year 1831.

Fig. 754.



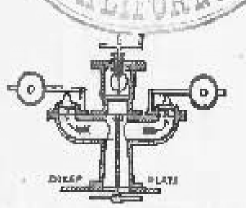
Stephenson's Locomotive Safety Valve, consisting of a disc acted on by a series of curved flat springs adjusted by a set screw. Invented in the year 1833.

Fig. 755.



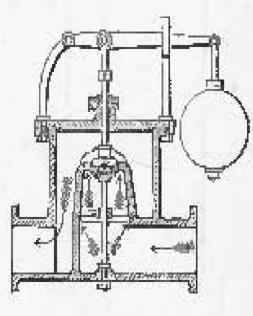
Locomotive Safety Valve, consisting of a half globe acted on by a lever fitted with adjustable lever gear in connection with the spring box. Used in the year 1840.

Fig. 756.



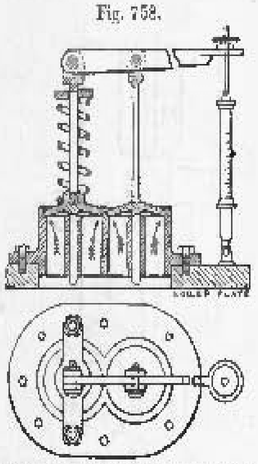
Twin Safety Valves and Stop Valve, used for land stationary boilers since the year 1850.

Fig. 757.



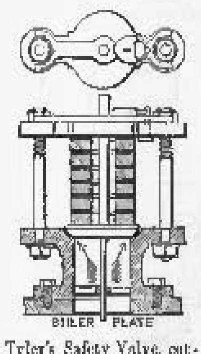
Spencer's Safety Valve, consisting of a double seated cone, the bottom seat being formed in the casing, and the top seat a disc secured by a vertical support rod and nut. Patented in the year 1852.

Fig. 758.



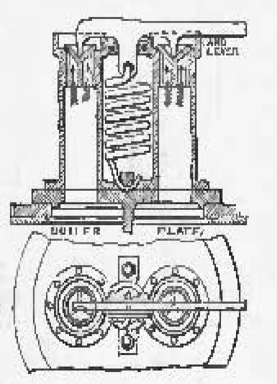
Scott's Twin Safety Valves, consisting of two discs that are acted on above by a spring lever and a spring direct, so that both valves lift the lever. Patented in the year 1853.

Fig. 759.



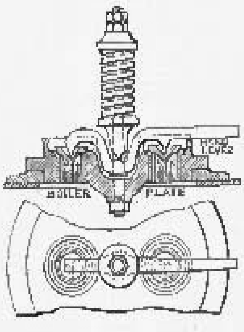
Tyler's Safety Valve, consisting of a disc, the seat for which is india-rubber, and the spring acting on the valve is formed by layers of india-rubber and metal. Patented in the year 1853.

Fig. 760.



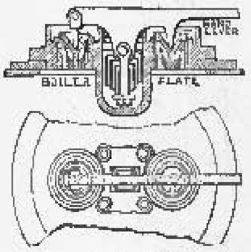
Ramsbottom's Safety Valves, consisting of two cones acted on by a hand lever in connection below with a coil spring situated between the seat pipes of the valves. Patented in the year 1855.

Fig. 761.



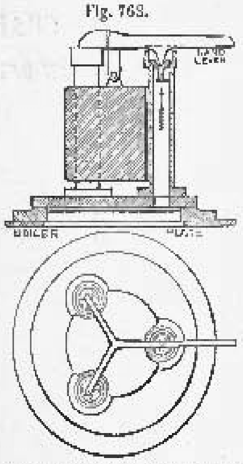
Ramsbottom's Safety Valves, consisting of two cones acted on by a hand lever in connection above with a coil spring that is adjusted with a cap and two nuts on the rod. Patented in the year 1855.

Fig. 762.



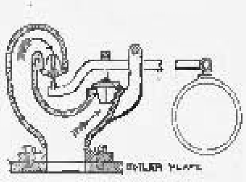
Ramsbottom's Safety Valves, consisting of two cones acted on by a hand lever in connection below with a volute spring that is secured in the recess between the valves. Patented in the year 1855.

Fig. 763.



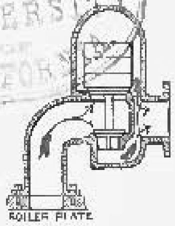
Ramsbottom's Safety Valves, consisting of three cones acted on by a hand lever in connection below with one direct weight situated between the seat pipes. Patented in the year 1855.

Fig. 764.



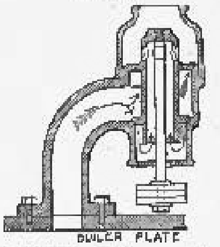
Johnson's Safety Valves, consisting of two valves opening up and down for the escape of the steam, and the "down" valve acts as the ordinary suspension pin for the lever. Patented in the year 1855.

Fig. 765.



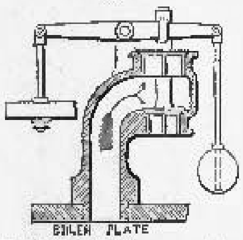
Holt's Safety Valves, consisting of two discs that, when rising, permit the escape of the steam under and over the seats, the weight being direct on the top valve. Patented in the year 1856.

Fig. 766.



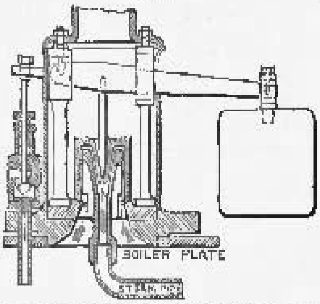
Holt's Safety Valves, consisting of two discs that, when rising, permit the escape of the steam under and over the seats, the weight being hung from the top valve. Patented in the year 1856.

Fig. 767.



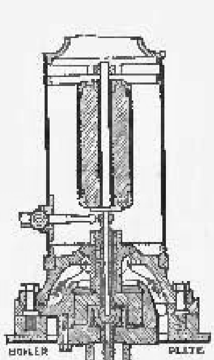
Holt's Safety Valves, consisting of two discs that, when rising, permit the escape of the steam under and over the seats; the lever is weighted at each end in proportion to the relative areas of the valves. Patented in the year 1856.

Fig. 768.



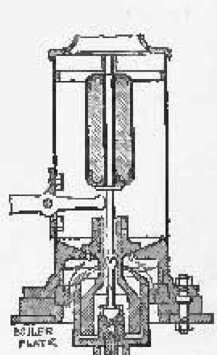
Bodmer's Safety Valves, consisting of a cup valve and weight lever in connection with a ball and socket regulating feed water valve. Patented in the year 1857.

Fig. 769.



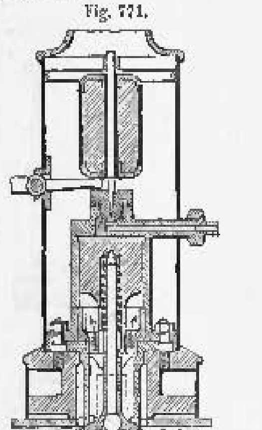
Bodmer's Combined Safety Valves, consisting of a ball and socket valve and piston valve for the water pressure and an annular valve for the escape of the steam. Patented in the year 1857.

Fig. 770.



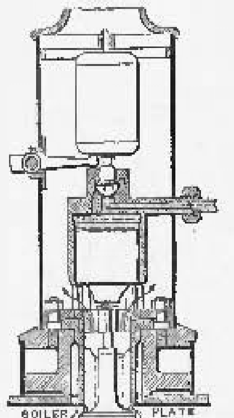
Bodmer's Combined Safety Valves, consisting of a ball and socket valve and piston valve for the water pressure and an annular valve for the escape of the steam. Patented in the year 1857.

Fig. 771.



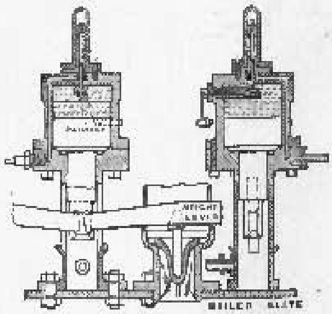
Bodmer's Combined Safety Valves, consisting of a ball and socket valve above the piston valve for the water pressure and a descending disc valve for the escape of the steam. Patented in the year 1857.

Fig. 772.



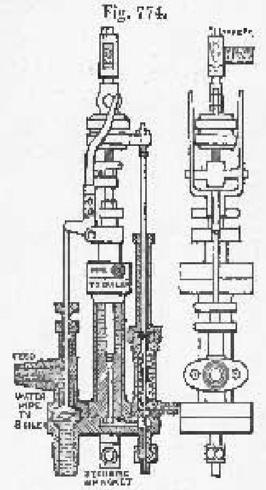
Bodmer's Combined Safety Valves, showing the steam escape valve opened. Patented in the year 1857.

Fig. 773.



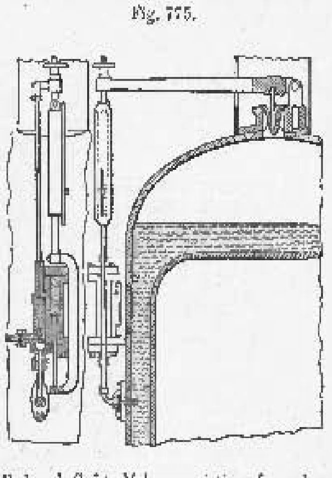
Bodmer's Regulating Feed Water Valves in connection with the weight levers of the steam escape valves. Patented in the year 1857.

Fig. 774.



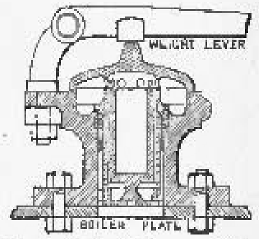
Bodmer's Regulating Feed Water Apparatus in connection with the spring levers of safety valves. Patented in the year 1857.

Fig. 775.



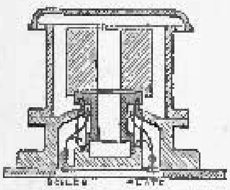
Bodmer's Safety Valve, consisting of a spring lever in connection with a feed water regulating piston valve and spring valve. Patented in the year 1857.

Fig. 776.



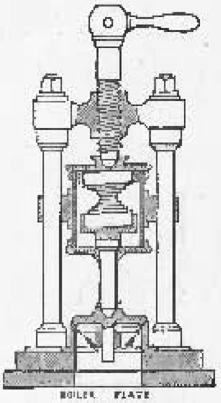
Haste's Safety Valves, consisting of a lever weight valve with two seats, and a cylinder formed within the smaller seat containing an independent direct weighted valve, so that the opening of the small valve will to some extent permit the steam to more readily open the large valve. Patented in the year 1858.

Fig. 777.



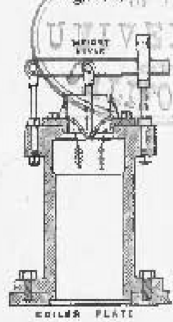
Illingworth's Safety Valve, consisting of a cylindrical valve with two seats, acted on by a direct weight; the steam escaping from the lower seat passes through the valve and weight. Patented in the year 1858.

Fig. 778.



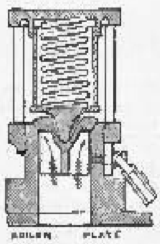
Smith's Safety Valve, consisting of a disc that is acted on by two volute spiral springs contained in a box, the adjustment being by a hand lever and screw stud, which raises or lowers the box. Patented in the year 1858.

Fig. 779.



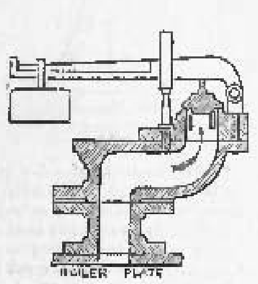
Hartnun's Safety Valve, consisting of a recessed cone portion below the seat for the lever rod to rest in, so that when the valve rises or falls it is free from the curve motion of the lever. Patented in the year 1859.

Fig. 780.



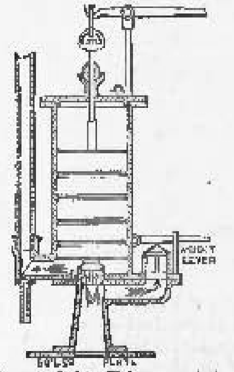
Clayton's Safety Valve, consisting of a recessed cone portion below the seat for the spring rod to rest in, so that when the valve rises or falls it is free from any side motion of the spring, which is contained in a box, and the adjusting casing padlocked. Patented in the year 1859.

Fig. 781.



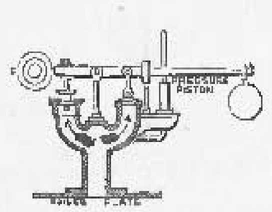
German Safety Valve, with a right angle branch for the passage of the steam. Used since the year 1860.

Fig. 782.



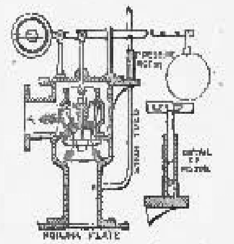
German Safety Valves, consisting of two separate discs acted on by a weight lever and a direct load. Used since the year 1860.

Fig. 783.



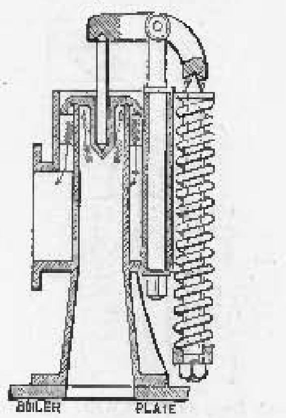
Galloway's Safety Valves, consisting of two valves closing and opening up and down, acted on by a lever in connection with a steam piston and rod which assist to open the valves as the pressure in the boiler increases. Patented in the year 1861.

Fig. 784.



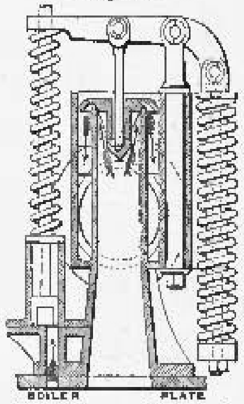
Galloway's Safety Valve, consisting of a double seat valve acted on by a lever in connection with a steam piston and rod which assist to raise the valve as the pressure in the boiler increases. Patented in the year 1861.

Fig. 785.



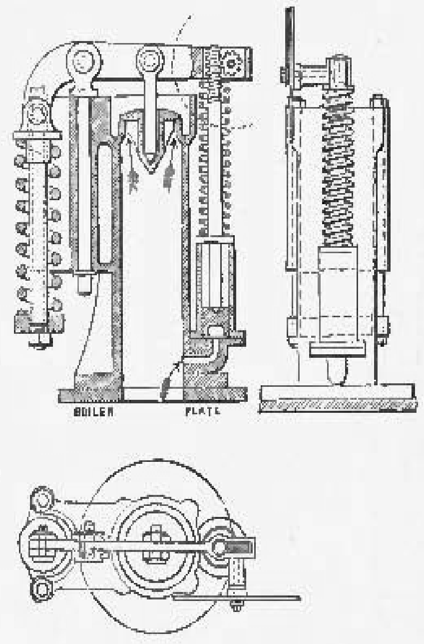
Naylor's Safety Valve, consisting of a disc with a deep recess for the lever rod to rest in, and the curved end of the lever is pressed up by the screw spring at the side of the casing. Patented in the year 1863.

Fig. 786.



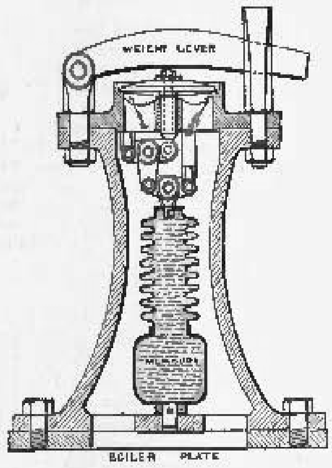
Naylor's Safety Valve, consisting of a disc with a deep recess for the lever rod to rest in; the curved end of the lever is pressed up by the screw spring, but the straight end is also pressed up by a screw spring acted on by a steam piston under it, so that the resistance is made more uniform. Patented in the year 1863.

Fig. 787.



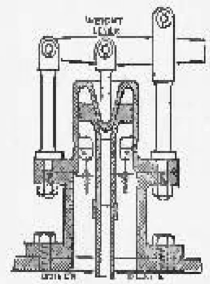
Naylor's Safety Valve, consisting of a disc with a deep recess for the lever rod to rest in; the curved end of the lever is pressed up by the screw spring, but the straight end is also pressed up by a screw spring acted on by a steam piston under it, so that the resistance is made more uniform; an indicator is also fitted. Patented in the year 1863.

Fig. 788.



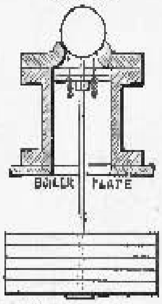
Nash's Safety Valve, consisting of a disc valve, over which is an ordinary weight lever, and under it a set of compound levers in connection with corrugated and drum cylinders filled with mercury, which expand and contract according to the surrounding temperature, and thus actuate the valve. Patented in the year 1863.

Fig. 789.



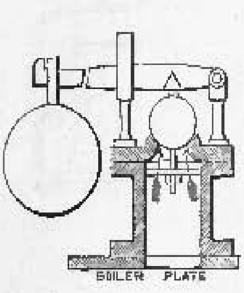
German Balance Piston Safety Valves, consisting of a piston seat for a cone that is formed with a cylinder in which the piston is fitted, the cylinder having a separate seat. Used since the year 1864.

Fig. 790.



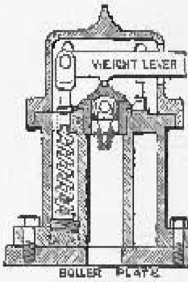
Baldwin's Safety Valve, consisting of a globe seated on an eccentric seat, so that when the valve rises the area of the opening is increased proportionately, the weight being suspended under the valve. Patented in the year 1866.

Fig. 791.



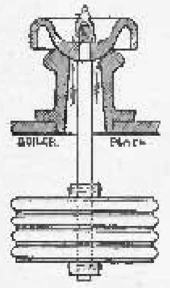
Baldwin's Safety Valve, consisting of a globe seated on an eccentric seat, so that when the valve rises the area of the opening is increased proportionately, the valve being acted on by a lever and weight. Patented in the year 1866.

Fig. 792.



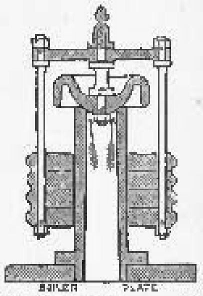
Swann's Safety Valve, consisting of a disc acted on by a weight lever that is connected at the back end to a spring rod, the action of the spring being to hold the lever down, as is the weight at the opposite end. Patented in the year 1866.

Fig. 793.



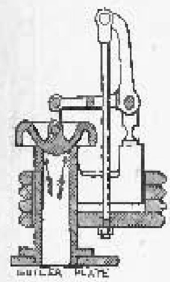
Parson's Safety Valve, consisting of a mushroom-sectioned disc having a weight suspended below it in the boiler, so that the weight and valve may oscillate without the steam escaping. Patented in the year 1867.

Fig. 794.



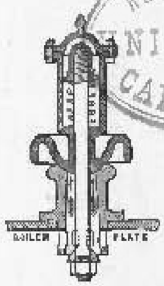
Parson's Safety Valve, consisting of a mushroom-sectioned disc having a cross bar above and two side rods suspending an annular weight below around the seating pipe above the boiler. Patented in the year 1867.

Fig. 795.



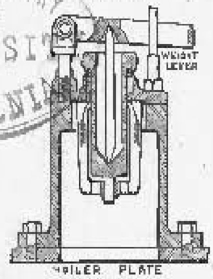
Parson's Safety Valve, consisting of a mushroom-sectioned disc acted on above by a bell-crank lever and suspended weight below. Patented in the year 1867.

Fig. 796.



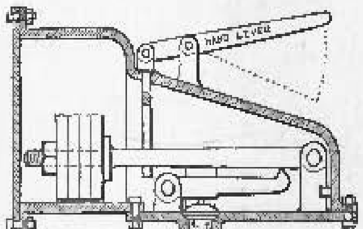
Parson's Safety Valve, consisting of a mushroom-sectioned disc formed with a box above containing a spring in connection with a fixed rod passing through the valve. Patented in the year 1867.

Fig. 797.



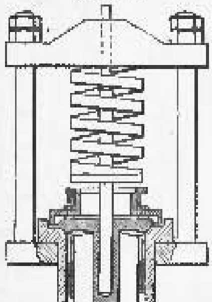
Cooke's Safety Valve, consisting of a deep cup valve with a knife edge seating and the lever rod pointed at each end, so that the action of the lever does not affect the valve. Patented in the year 1867.

Fig. 798.



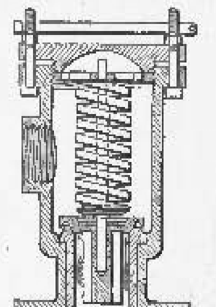
Cameron's Safety Valve, consisting of a disc acted on by two combined levers and a weight on the end of the upper and longer lever. Patented in the year 1867.

Fig. 799.



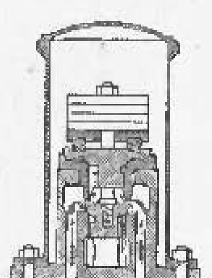
Richardson's Safety Valve, consisting of a disc fitted with an adjustable annular cap between the plate and the spring to cause a resistance to the escape of the steam independently of the action of the spring. Patented in the year 1867.

Fig. 800.



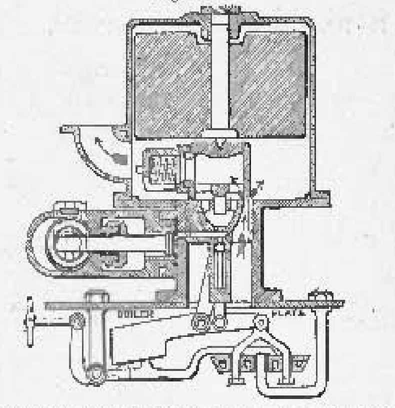
Richardson's Safety Valve, consisting of a disc formed with an inverted recess to cause a resistance to the escape of the steam independently of the action of the spring. Patented in the year 1867.

Fig. 801.



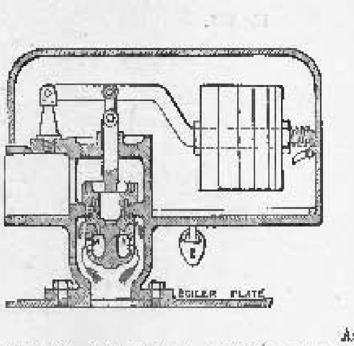
Sanders' Safety Valves, consisting of two discs of unequal diameters; and the top disc is fitted with a direct weight seated on four screw springs to counteract any vibration. Patented in the year 1868.

Fig. 802.



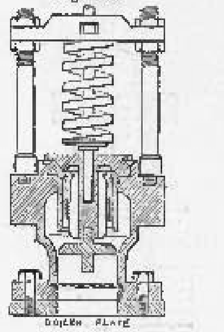
Church's Safety Valve, consisting of discs and piston valves having vertical and horizontal motions, and acted on by springs, weights, and levers. Patented in the year 1868.

Fig. 803.



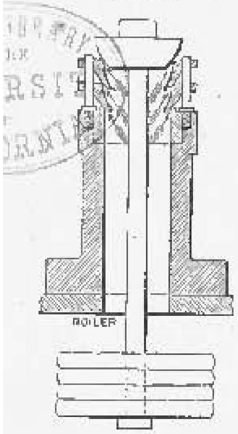
Ashcroft's Safety Valves, consisting of a cylinder with a top seat and two bottom seats, which are contained in a perforated box screwed in the casing, the valves being acted on by a weight lever above. Patented in the year 1868.

Fig. 804.



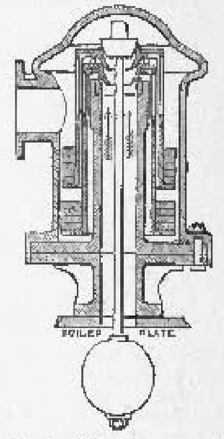
Ashcroft's Safety Valves, consisting of two discs above and below the seatings, the use of the lower disc being to prevent any water escaping with the steam and to close suddenly if the spring on the top disc breaks. Patented in the year 1868.

Fig. 805.



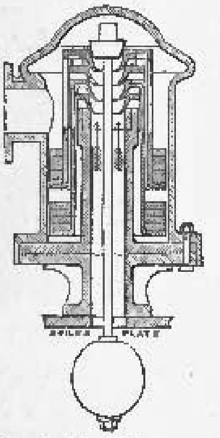
Hopkinson's Safety Valves, consisting of three cones, the upper cone being acted on directly by a heavy weight. Patented in the year 1870.

Fig. 806.



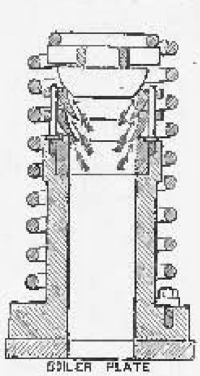
Hopkinson's Safety Valves, consisting of three cones; the top cone is acted on by a hung weight, and the other two cones by weights surrounding the cylinders of the cones. Patented in the year 1870.

Fig. 807.



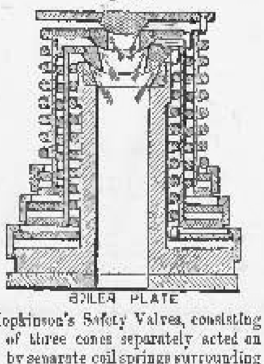
Hopkinson's Safety Valves, consisting of five cones; the top cone is acted on by a hung weight, and the second and third cones by weights surrounding the cylinders of the cones. Patented in the year 1870.

Fig. 808.



Hopkinson's Safety Valves, consisting of three cones, the upper cone being acted on by a coil spring surrounding the seat pipe. Patented in the year 1870.

Fig. 809.



Hopkinson's Safety Valves, consisting of three cones separately acted on by separate coil springs surrounding the seat pipe and the cylinder of each valve. Patented in the year 1870.

Fig. 810.

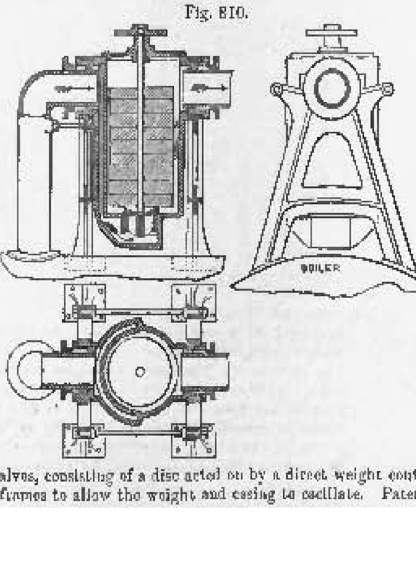
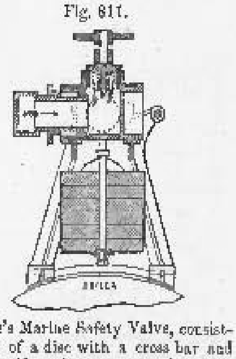


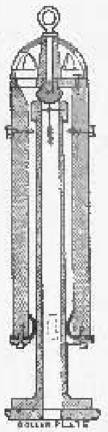
Fig. 811.



Wilke's Marine Safety Valve, consisting of a disc with a cross bar and two side rods to suspend the direct weight below the casing, which is hung in two side frames to allow the weight and casing to oscillate. Patented in the year 1871.

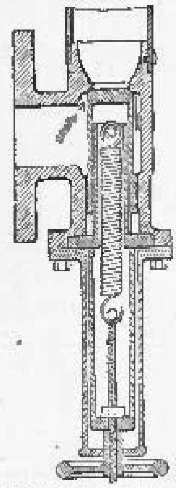
Wilke's Marine Safety Valves, consisting of a disc acted on by a direct weight contained in the casing, which is hung in two side frames to allow the weight and casing to oscillate. Patented in the year 1871.

Fig. 812.



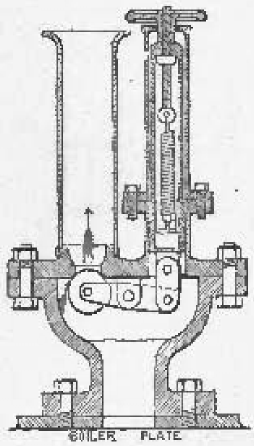
Cowburn's Safety Valve, consisting of a semispherical disc in connection with a dome casing attached to an annular weight that surrounds the seat pipe. Patented in the year 1871.

Fig. 813.



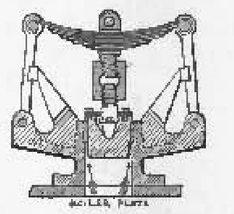
Mirchin's Safety Valve, consisting of a piston and cylinder seat valve in connection with a spring adjusted by a screw rod and hand wheel; the steam acting on the annular space of the piston causes the valve to open. Patented in the year 1871.

Fig. 814.



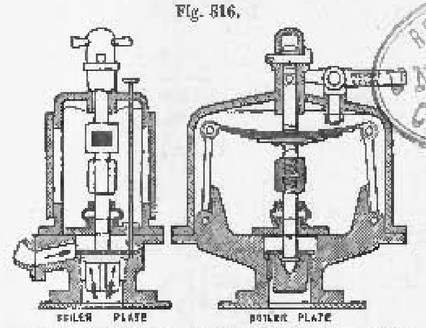
Mirchin's Safety Valve, consisting of a ball attached to a lever connected to a piston and spring above it; the steam acting on the annular space of the piston causes the valve to open. Patented in the year 1871.

Fig. 815.



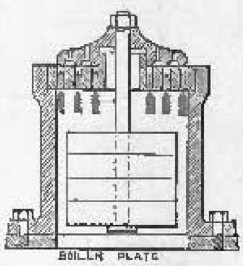
Taylor's Safety Valve, consisting of a disc acted on by a series of flat curved springs. Patented in the year 1871.

Fig. 816.



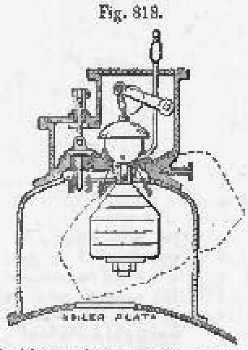
Taylor's Safety Valve, consisting of a disc fitted with a horizontal wheel and pinion for adjustment; and the valve is acted on by curved springs and a weight lever. Patented in the year 1871.

Fig. 817.



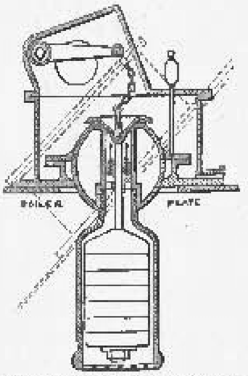
Lee's Safety Valve, consisting of a disc with three circular seats and three openings to correspond in it and the seating. Patented in the year 1871.

Fig. 818.



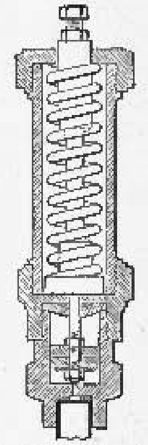
Watson's Marine Safety Valve, consisting of a hollow globe fitted with a cap and a seat having a groove in it to receive any lubricant; the small disc valve at the side forming no part of this invention. Patented in the year 1871.

Fig. 819.



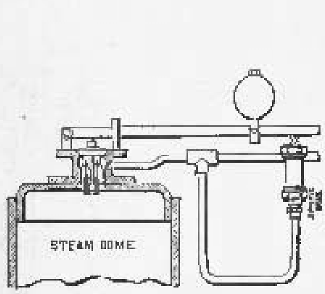
Watson's Marine Safety Valves, consisting of a hollow globe seated on a gland and packing; the top of the globe is formed with a seat, on which is a disc valve acted on by a hung weight contained in the casing attached to the globe. Patented in the year 1871.

Fig. 820.



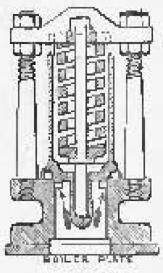
MacDonald's Spring and Piston Valve and Box, to assist the action of the lever of ordinary safety valves. Patented in the year 1872.

Fig. 821.



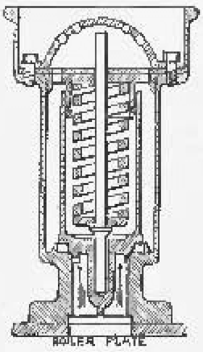
MacDonald's Safety Valve and Weight Lever in connection with the spring and piston valve and box to assist the action of the lever. Patented in the year 1872.

Fig. 822.



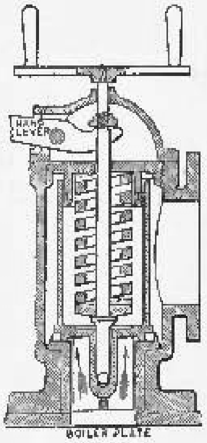
Giles' Land Safety Valve, consisting of a cylinder seated in a recessed seat, so that the steam, on the valve rising, is compelled to act on the outer edge, and thus compensate for the increasing resistance of the spring as it is compressed. Patented in the year 1872.

Fig. 823.



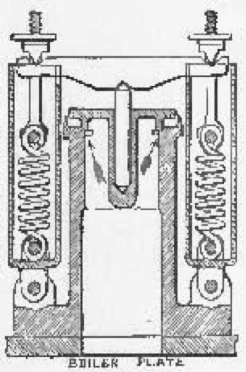
Giles' Locomotive Safety Valve, consisting of a cylinder seated in a recessed seat, so that the steam, on the valve rising, is compelled to act on the outer edge, and thus compensate for the increasing resistance of the spring as it is compressed. Patented in the year 1872.

Fig. 824.



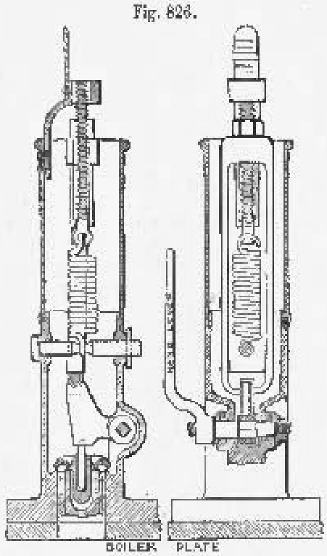
Giles' Marine Safety Valves, consisting of a cylinder seated in a recessed seating; the valve is turned on its seat by the twin handle lever, and a lift hand lever is also fitted to "ease" the valve. Patented in the year 1872.

Fig. 825.



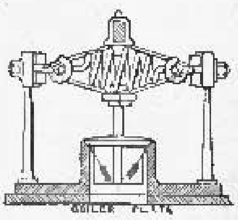
Giles' Safety Valve, consisting of a disc seated on a cylinder with a recessed seating; and two coil springs are used with a cross bar to act on the valve rod. Patented in the year 1872.

Fig. 826.



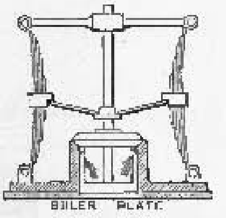
Field's Safety Valve, consisting of a disc having an annular seat and a recess for the hand lever rod to rest in, the upper part of the lever being in connection with the rods of a coil spring adjusted above by a screwed rod. Patented in the year 1871.

Fig. 827.



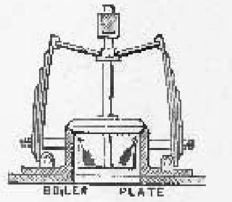
Turton's Safety Valve Springs, consisting of two pairs of struts in connection with two cross bars having between them two spiral springs. Patented in the year 1872.

Fig. 828.



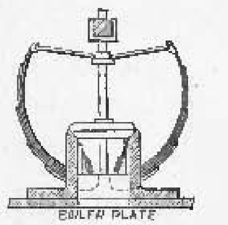
Turton's Safety Valve Springs, consisting of two struts in connection with a series of curved flat springs hinged and studded at each end, and the struts acting in the centre. Patented in the year 1872.

Fig. 829.



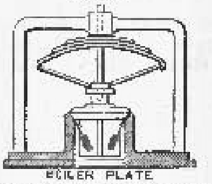
Turton's Safety Valve Springs, consisting of two struts in connection with a series of curved flat springs hinged on pins and adjusted by set studs and a bridle. Patented in the year 1872.

Fig. 830.



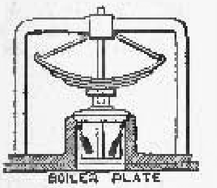
Turton's Safety Valve Springs, consisting of two struts in connection with a series of curved flat springs hinged at the centre line of the valve seat. Patented in the year 1872.

Fig. 831.



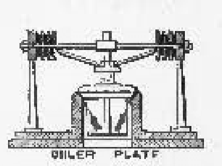
Turton's Safety Valve Springs, consisting of two struts in connection with a series of inverted curved flat springs suspended by the struts and bearing against the cross bar. Patented in the year 1872.

Fig. 832.



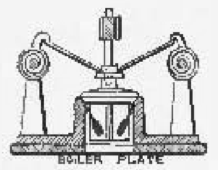
Turton's Safety Valve Springs, consisting of two struts in connection with a series of curved flat springs bearing on the collar above the valve. Patented in the year 1872.

Fig. 833.



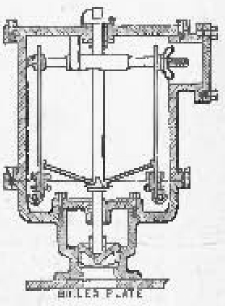
Turton's Safety Valve Springs, consisting of two struts in connection with india-rubber springs. Patented in the year 1872.

Fig. 834.



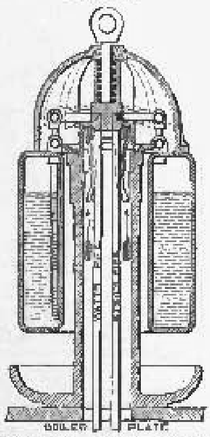
Turton's Safety Valve Springs, consisting of two struts in connection with two levers that are attached to two coil springs. Patented in the year 1872.

Fig. 835.



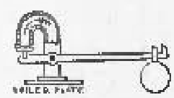
Turton's Safety Valve Springs, consisting of two struts in connection with two single bar springs looped under pins below the struts and adjusted above by a cross bar and set screw, the bar being suspended. Patented in the year 1872.

Fig. 836.



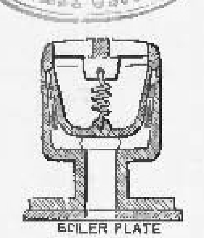
Lockwood's Safety Valves, consisting of a block and cylinder in connection with a water weight casing that is connected and regulated by pipes with the water in the boiler. Patented in the year 1872.

Fig. 837.



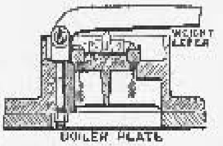
Cazier's Safety Valve, consisting of a disc opening downwards and the weight lever under the valve. Patented in the year 1872.

Fig. 838.



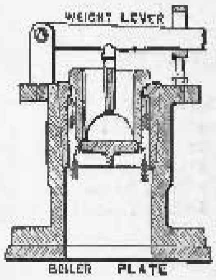
Safety Valve, consisting of an annular space for the steam to act up against a ring that bears on two seats; the ring is held down by a coil spring contained in the recess of the inner seat. Proposed by the "Engineer," October 18th, 1872.

Fig. 839.



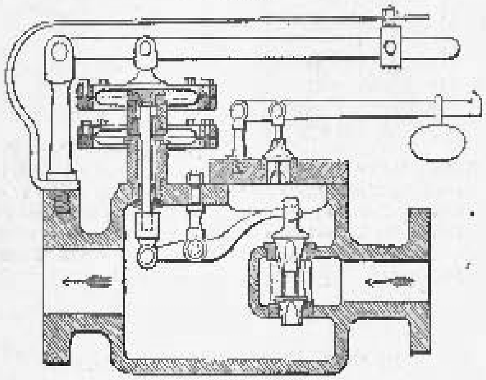
Annular Seat Safety Valve, Proposed in the "Engineer," November 8th, 1872.

Fig. 840.



Double Seat Safety Valve, Proposed in the "Engineer," November 8th, 1872.

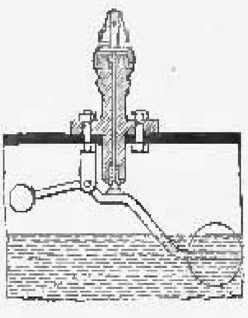
Fig. 841.



Pollard's Safety Valves in combination with valves, levers, and springs for the regulation of the steam pressure when passing from the boiler to the engine. Patented in the year 1867.

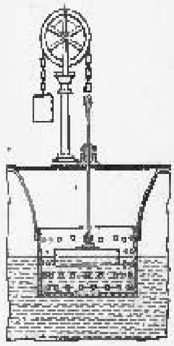
BOILER ALARM SAFETY VALVES AND GEAR.

Fig. 842.



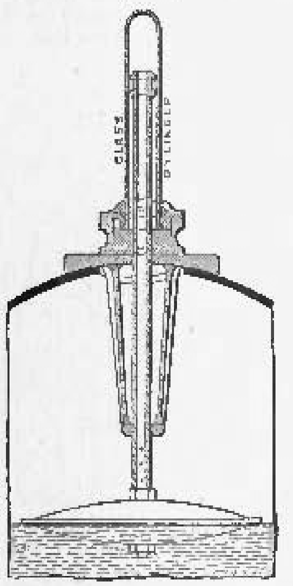
Alarm Whistle Valve, Float, Lever, and Balance. Used since the year 1840.

Fig. 843.



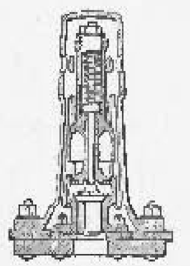
Alarm Float Chain-wheel Balance and Indicator. Used since the year 1840.

Fig. 844.



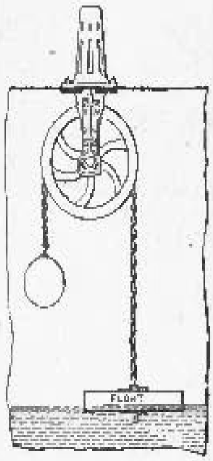
Johnson's Indicating Alarm Float, by means of a piston moving in a glass cylinder, secured on the top of the boiler. Patented in the year 1852.

Fig. 845.



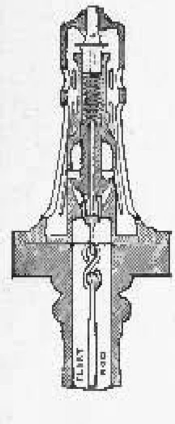
Tayler's Alarm Safety Valve, consisting of a disc and rod acted on by a coil spring contained in a whistle box; the whistle being situated between the valve and the spring. Patented in the year 1858.

Fig. 846.



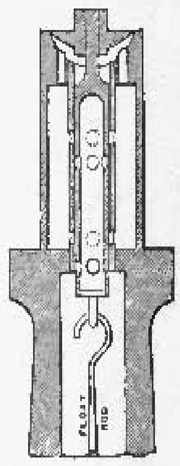
Tayler's Alarm Safety Valve Apparatus, inside the boiler, consisting of a disc float, chain, wheel, and counterbalance, in connection with the valve shown by Fig. 845. Patented in the year 1853.

Fig. 847.



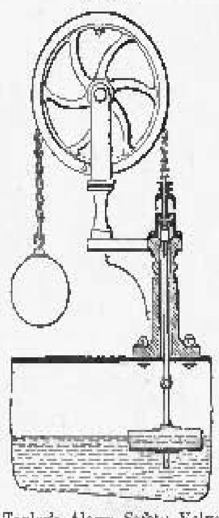
Tayler's Alarm Safety Valve, Whistle and Spring. The valve opens downwards and is connected direct to the float. Patented in the year 1853.

Fig. 848.



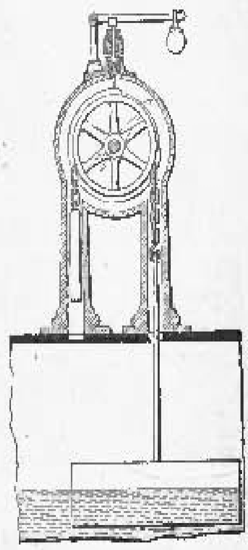
Tayler's Alarm Safety Valve, consisting of a sliding tube contained in a fixed tube, and both tubes perforated. Patented in the year 1853.

Fig. 849.



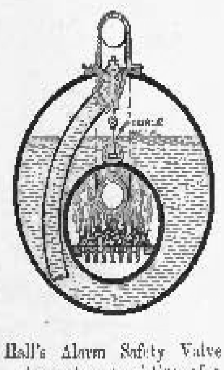
Tayler's Alarm Safety Valve Apparatus, outside the boiler, consisting of a disc float, chain, wheel, counterbalance, and whistle. Patented in the year 1853.

Fig. 850.



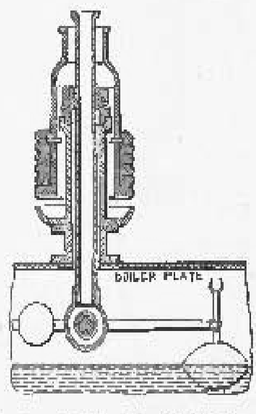
Tayler's Alarm Safety Valve Apparatus, outside the boiler, consisting of an eccentric rimmed wheel with a safety valve rod acting on it and a steam whistle to indicate when the valve is lifted. Patented in the year 1853.

Fig. 851.



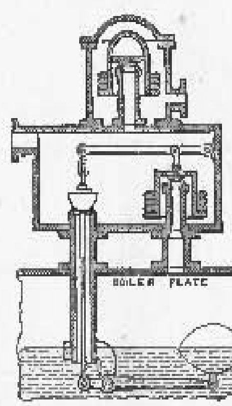
Ball's Alarm Safety Valve Apparatus, consisting of a disc connected to a fusible plug on the fire box plate and a water pipe under and over the valve which, when lifting, admits water in the fire box besides through the plug casing. Patented in the year 1855.

Fig. 852.



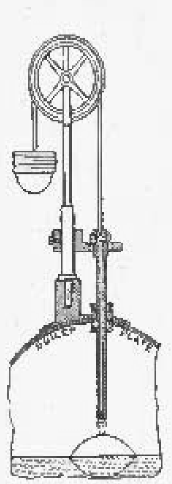
Cowburn's Water Level Float, Lever, and Counterbalance, in connection with a direct loaded safety valve, the hollow rod of which suspends the float lever. Patented in the year 1855.

Fig. 853.



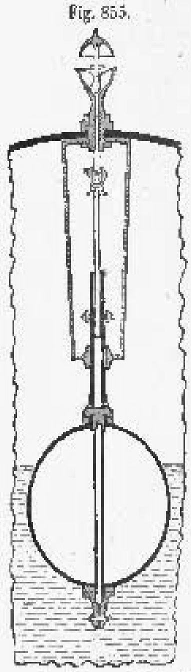
Cowburn's Water Level Float and Lever, in connection with a safety valve and lever, on the casing of which is a direct loaded safety valve. Patented in the year 1855.

Fig. 854.



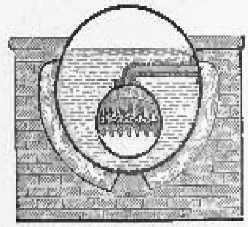
Cowburn's Water Level Float, Wheel, Chain, and Counterbalance, outside the boiler. Patented in the year 1856.

Fig. 855.



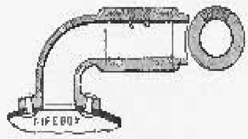
Johnston's Alarm Safety Valve Apparatus, consisting of a ball float that is directly connected to a spindle valve that descends to admit steam to the whistle above. Patented in the year 1856.

Fig. 856.



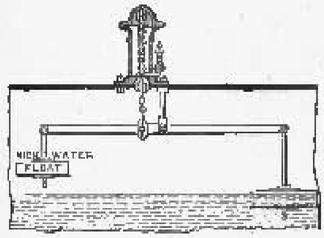
Routledge's Alarm Flame Tube, fitted with fusible plugs inside the boiler. Patented in the year 1856.

Fig. 857.



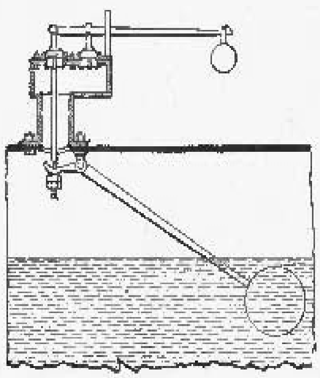
Routledge's Alarm Flame Tube, fitted with fusible plugs. Patented in the year 1856.

Fig. 858.



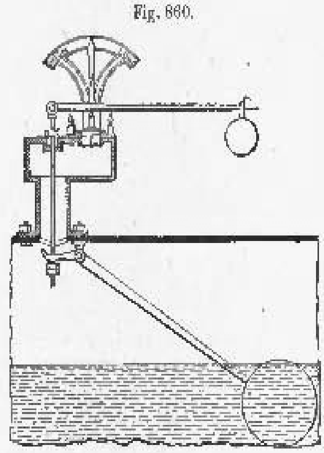
York's Alarm Safety Valve Apparatus, outside the boiler, consisting of two floats and a disc valve acted on by a spring; at the side of the casing is a whistle to indicate when the valve opens. Patented in the year 1856.

Fig. 859.



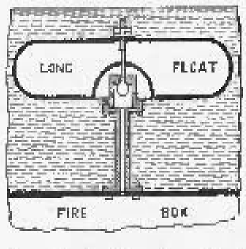
Knowelden's Alarm Safety Valve Apparatus, consisting of two safety valves; one being held down by a float lever inside the boiler, and the other acted on by the weight lever. Patented in the year 1856.

Fig. 860.



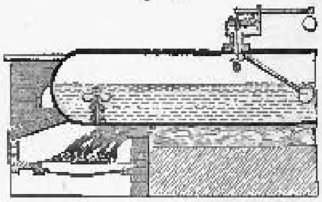
Knowelden's Alarm Safety Valve Apparatus, consisting of a float and lever that is connected to a weight lever which acts on a disc valve; the motion of the lever is indicated by a hand pointer and recording quadrant. Patented in the year 1856.

Fig. 861.



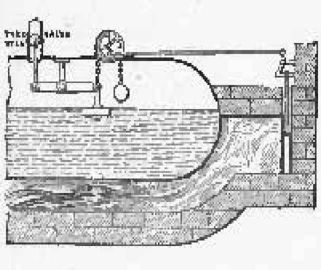
Knowelden's Alarm Low Level Safety Valve Apparatus, consisting of a ball connected to a long float that, when descending, admits the water in the boiler in the fire box. Patented in the year 1856.

Fig. 862.



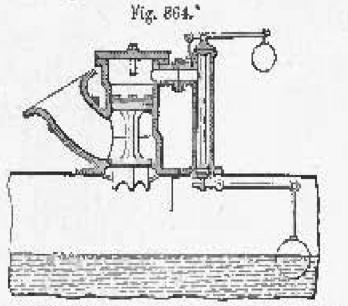
Knowelden's High and Low Level Alarm Safety Valve Apparatus, fitted to an egg-end boiler. Patented in the year 1856.

Fig. 863.



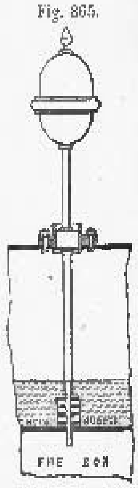
Walley's Alarm Safety Valve Apparatus, consisting of a float and lever in connection with the engine steam pipe throttle valve and a chain wheel that is connected to the flue damper. Patented in the year 1856.

Fig. 864.



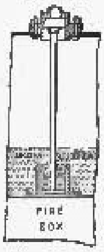
Horton's Safety Valves in connection with a water level float and lever, the action of the float and small valves being to regulate the pressure of the steam on the top of the piston of the large valve. Patented in the year 1857.

Fig. 865.



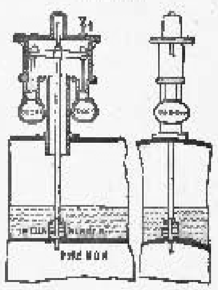
Parson's Safety Piston Valve in connection with a series of metal and india-rubber rings that are secured on the roof of the fire box; and the melting of the india-rubber permits the valve to fall and the steam to escape. Patented in the year 1858.

Fig. 866.



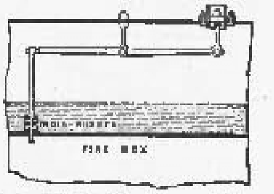
Parson's Safety Piston Valve in connection with a cylinder of india-rubber fixed in a casing on the roof of the fire box; and the melting of the india-rubber permits the valve to rise and the steam to escape. Patented in the year 1858.

Fig. 867.



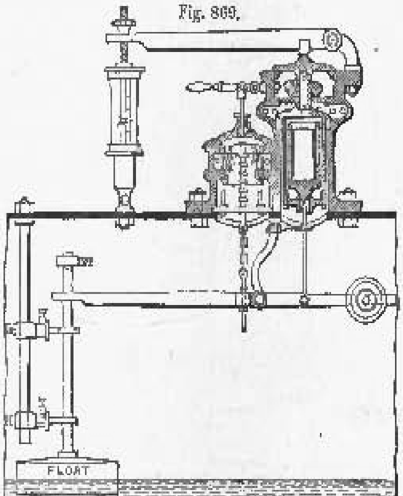
Parson's Twin Safety Piston Valves in connection with a series of metal and india-rubber rings that are secured on the roof of the fire box, for the same purpose as for Fig. 866. Patented in the year 1858.

Fig. 868.



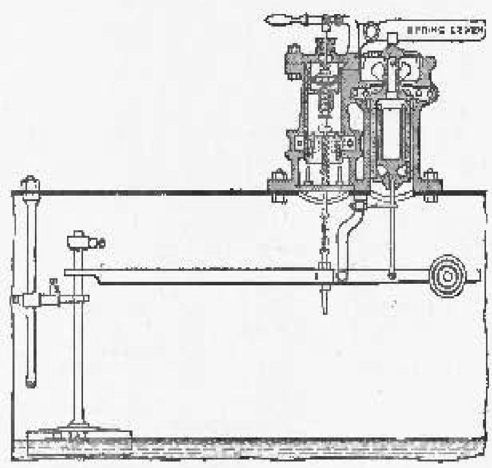
Parson's Safety Plug Valve and India-rubber Rings, for the same purpose as for Fig. 866, connected by a lever. Patented in the year 1858.

Fig. 869.



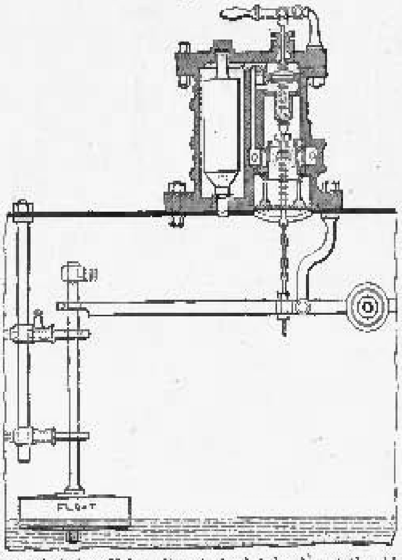
Haste's Safety Valves, acted on by a spring lever and a direct weight respectively; the weight valve is raised by the float lever, which also is in connection with a cylindrical safety valve that is lowered to open when the water is low in the boiler. Patented in the year 1858.

Fig. 870.



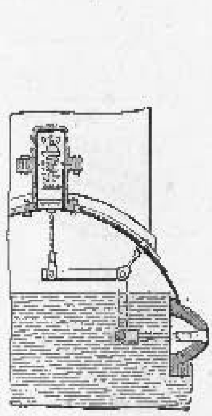
Haste's Safety Valves, acted on by a spring lever and a direct weight respectively; the weight valve is raised by the float lever, which is also in connection with a cylindrical safety valve that is lowered to open when the water is low in the boiler. Patented in the year 1856.

Fig. 871.



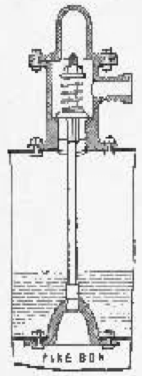
Haste's Safety Valve, directly loaded, having at the side a cylindrical safety valve in connection with a float lever that lowers the valve when the water is low in the boiler. Patented in the year 1858.

Fig. 872.



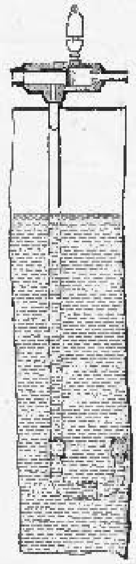
Parson's Alarm Valve in connection with lever gear in the boiler and a fusible plug at the side open to the flue. Patented in the year 1858.

Fig. 873.



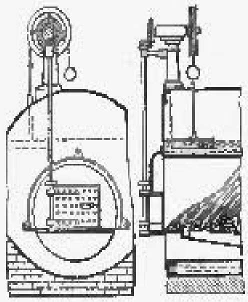
Parson's Alarm Valve in connection with a fusible plug on the roof of the fire box. Patented in the year 1858.

Fig. 874.



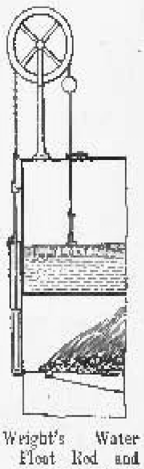
Parson's Feed Water Whistle Alarm, consisting of a piston working by the steam on one side and feed water on the other; and the whistle indicates when more feed is required. Patented in the year 1858.

Fig. 875.



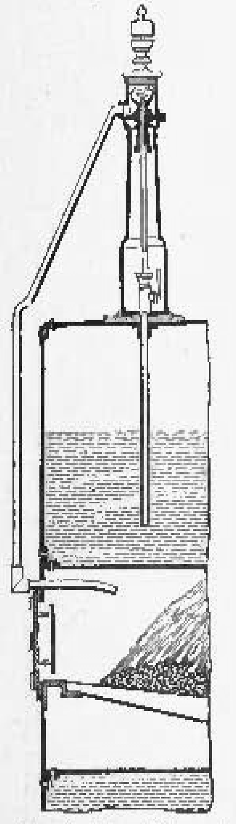
Wright's Water Float, Rod, Chain Wheel, Bevel Gearing, and Perforated Fire Door, for indicating the water level and regulating the draught. Patented in the year 1858.

Fig. 876.



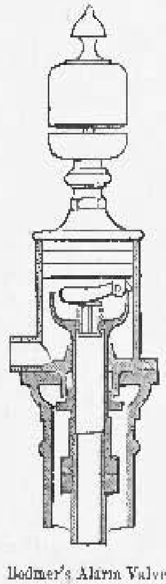
Wright's Water Float Rod and Chain Wheel in connection with the sliding furnace door. Patented in the year 1858.

Fig. 877.



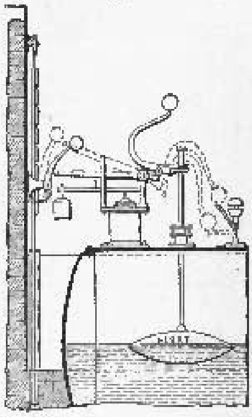
Bodmer's Alarm Valve and Pipes inside and outside the boiler, to indicate when the water is below the inside pipe. Patented in the year 1858.

Fig. 878



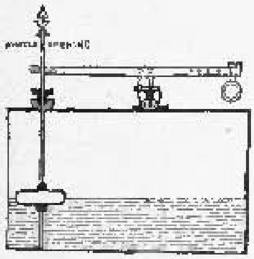
Bodmer's Alarm Valve and Whistle in connection with the apparatus shown by Fig. 877. Patented in the year 1858.

Fig. 879.



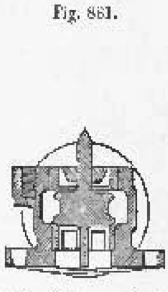
Normanday's Alarm Valve and Apparatus, consisting of a float and lever gear outside the boiler in connection with the damper and a whistle. Patented in the year 1858.

Fig. 880.



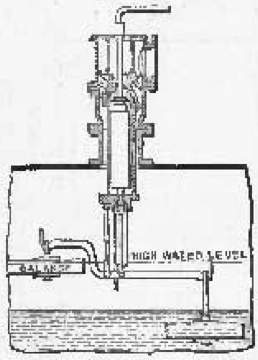
Archer's Alarm Valve Apparatus, consisting of a float, outside lever, safety valve, and steam whistle. Patented in the year 1858.

Fig. 881.



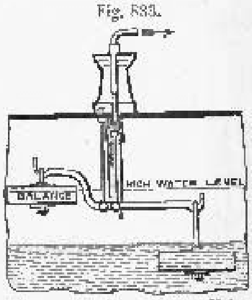
Archer's Reverse Seats Safety Valves in connection with the apparatus shown by Fig. 880. Patented in the year 1858.

Fig. 882.



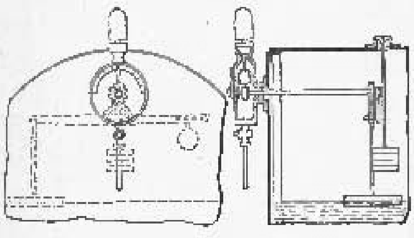
Illingworth's Alarm Safety Valve Apparatus, consisting of a cylindrical double seat valve with a direct weight under it, and below that a cone valve in connection with a lever float and balance weight: the central pipe over the disc valve being connected under a steam whistle. Patented in the year 1858.

Fig. 883.



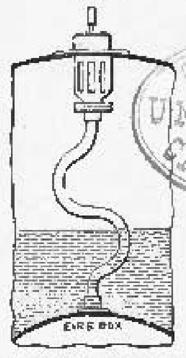
Illingworth's Alarm Safety Valve in connection with a lever, float, and balance weight inside the boiler. Patented in the year 1858.

Fig. 884.



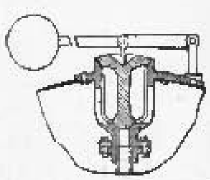
Walker's Alarm Safety Valve and Apparatus, consisting of a valve underhung with a weight, the rod being in connection with a float lever that, by a pinion and toothed quadrant, causes a whistle and hand pointer to indicate when the water is low in the boiler. Patented in the year 1859.

Fig. 885.



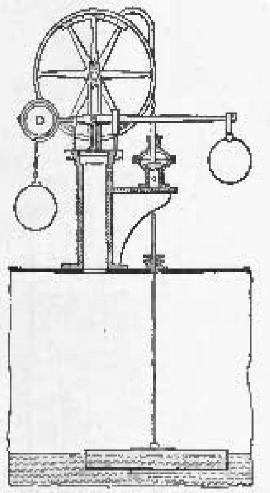
Davies' Alarm Safety Valve and Curved Pipe, connecting the valve casing to the fire box, so that on the valve rising the steam enters therein. Patented in the year 1860.

Fig. 886.



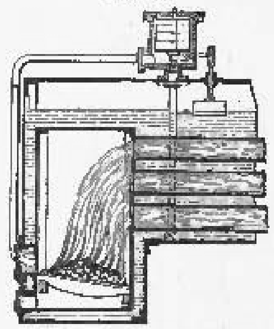
Davies' Double Seat Alarm Safety Valve and Casing, as shown with the curved pipe in Fig. 885. Patented in the year 1860.

Fig. 887.



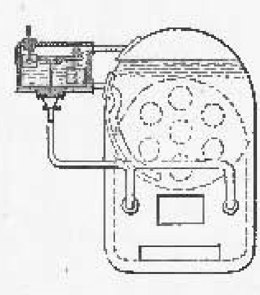
Galloway's Alarm Valve Apparatus, consisting of float rod in connection with a chain wheel shaft that is formed as a plug cock to admit steam under the diaphragm valve that acts on the lever of the safety valve. Patented in the year 1861.

Fig. 888.



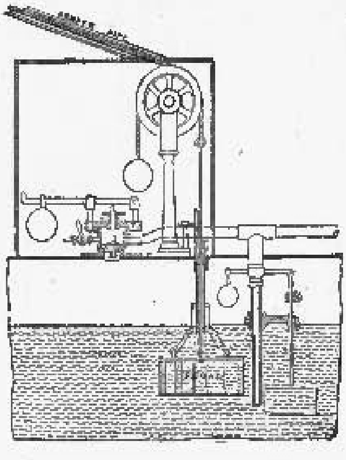
McCarthy's Alarm Safety Valve and Apparatus, consisting of a direct weighted valve outside the boiler connected by a lever and rod to the float in the boiler; when the float lever raises the valve, the water in the boiler also flows through the inside and outside pipes to the fire box. Patented in the year 1862.

Fig. 889.



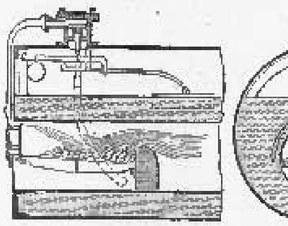
McCarthy's Alarm Safety Valve Float Lever Apparatus, contained in a box outside the boiler and connected to it by pipes. Patented in the year 1862.

Fig. 890.



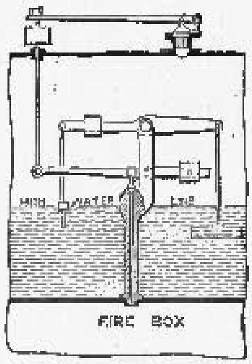
Turner's Alarm Safety Valve and Apparatus, consisting of a float, wheel, and counterbalance, also a float lever in connection with a throttle steam valve; and an ordinary safety valve. Patented in the year 1863.

Fig. 891.



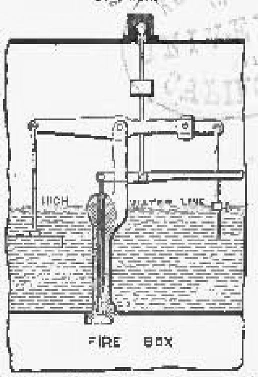
Hackett's Alarm Safety Valve and Apparatus, consisting of a valve in connection with a weight lever, float lever, and two water pipes, that, on the valve rising, conduct some of the water in the boiler to the fire box. Patented in the year 1866.

Fig. 892.



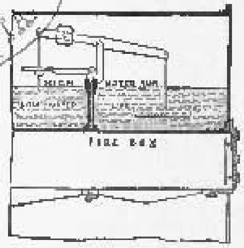
Bray's Alarm Safety Valve Apparatus, inside the boiler, consisting of a tube seating, on which is a cone acted on by a weight lever in connection with a weight connected to the lever of the safety valve outside the boiler; the tube also supports a float lever that, when in contact with the cone lever, admits the steam through the tube into the fire box. Patented in the year 1866.

Fig. 893.



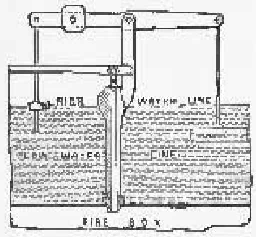
Bray's Alarm Safety Valve Apparatus, inside the boiler, consisting of a cone at the bottom of the tube secured on the roof of the fire box, and the action of the gear as in Fig. 893. Patented in the year 1866.

Fig. 894.



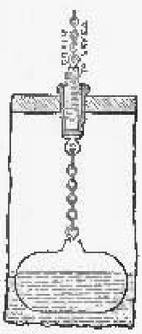
Bray's Alarm Safety Valve Apparatus, inside the boiler, consisting of the float and lever in connection with the lever and safety valve that admits steam into the fire box when the water is low. Patented in the year 1866.

Fig. 895.



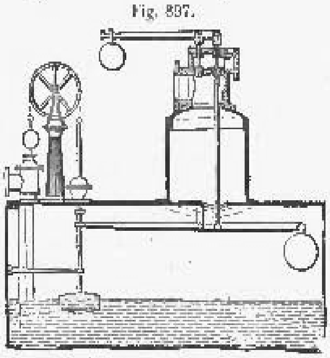
Bray's Alarm Safety Valve Apparatus, inside the boiler, showing the levers on the horizontal line in connection with Fig. 894. Patented in the year 1866.

Fig. 896.



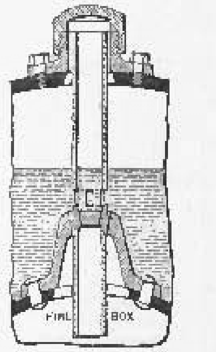
Swann's Alarm Valve in connection with a float and chain direct. Patented in the year 1866.

Fig. 897.



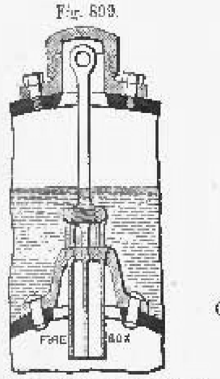
Macpherson's Alarm Safety Valves and Apparatus, consisting of two valves, one acted on by a weight lever and the other by a rod connected to a float lever inside the boiler; the float is also connected to a chain wheel and feed water valve. Patented in the year 1867.

Fig. 898.



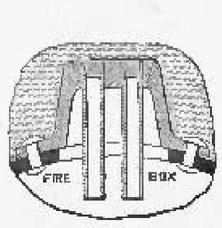
Cowburn's Alarm Fusible Plug, that when melted admits the steam and water in the boiler through the removable tube into the fire box. Patented in the year 1867.

Fig. 899.



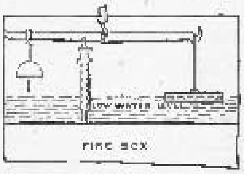
Cowburn's Alarm Fusible Plugs, that when melted admits the water in the boiler through the removable tube into the fire box. Patented in the year 1867.

Fig. 900.



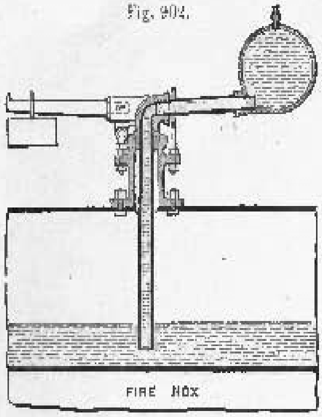
Cowburn's Alarm Fusible Plugs, that when melted admits the water in the boiler in the fire box. Patented in the year 1867.

Fig. 901.



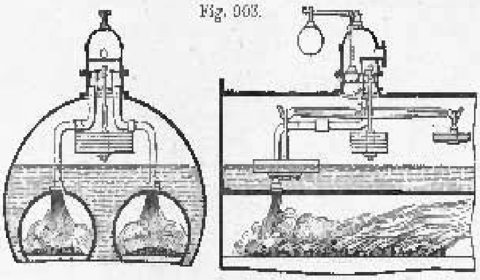
Renyon's Alarm Safety Valve and Apparatus, inside the boiler, consisting of a tube secured to the fire box, having a valve on the top with a larger tube connected to a lever float and counterbalance; the lifting of the valve permits the water to enter the fire box. Patented in the year 1867.

Fig. 902.



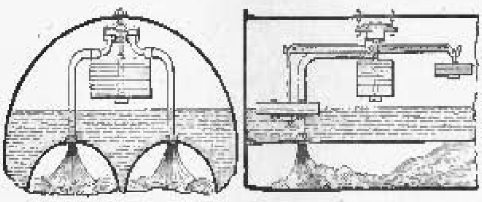
Benson's Alarm Safety Valve Water Pipe, consisting of a pipe vertical in the boiler and horizontal outside, with a hollow ball in connection with a lever weighted safety valve, which rises when the water is out of the pipe, to indicate the water is low in the boiler. Patented in the year 1868.

Fig. 903.



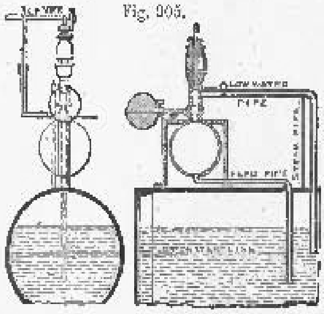
Hugh's Alarm Safety Valve and Apparatus, consisting of a lever weight safety valve and, also a direct underhung weight valve, the weight being in the boiler and the rod in connection with a lever float and counterbalance, and when that valve is lifted by the lever float the water in the boiler flows through the pipes into the fire box. Patented in the year 1869.

Fig. 904.



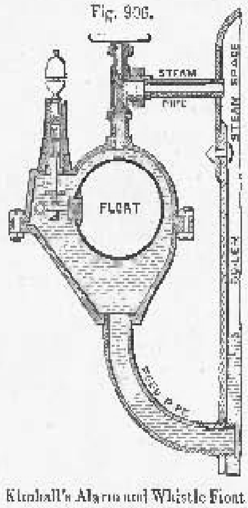
Hugh's Alarm Safety Valve and Apparatus, consisting of a valve and box, underhung weight float lever and counterbalance, and alarm water pipes. Patented in the year 1869.

Fig. 905.



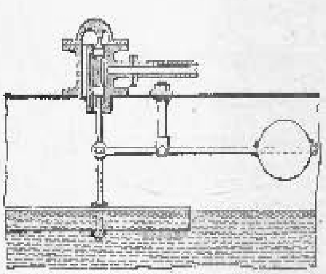
Pratt's Alarm Valve Whistle, Water Globe, and Safety Valve combined; a quantity of water in the boiler, being in connection with the water in the globe, regulates the action of the safety valve and whistle. Patented in the year 1870.

Fig. 906.



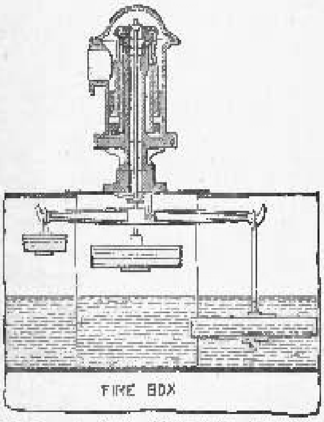
Kimball's Alarm and Whistle Float Apparatus, situated outside the boiler front; the float rises and falls as the water in the boiler actuates when the steam valve is open. Patented in the year 1870.

Fig. 907.



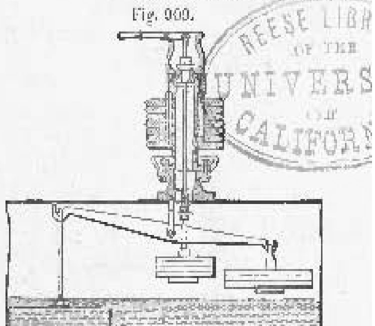
Langlet's Alarm Valve, Weight Lever, and Float, inside the boiler; the lowering of the float causes valve to descend and the steam to pass out through the casing pipe. Patented in the year 1870.

Fig. 908.



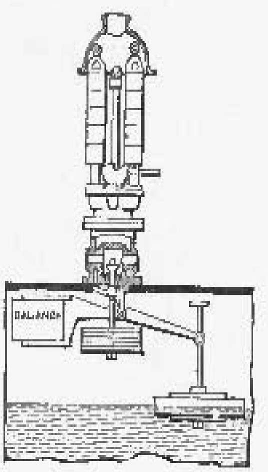
Hopkinson's Alarm Safety Valve Apparatus, consisting of two valve cylinders with weights surrounding the lower parts and a central valve with a hung weight in the boiler, there, in connection with a lever float and counterbalance, the central valve is lifted by the lever when the water is low in the boiler. Patented in the year 1870.

Fig. 909.



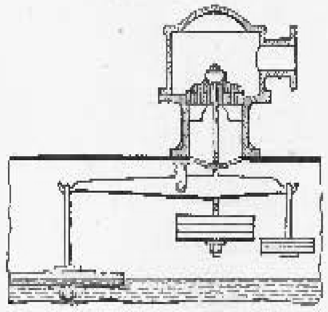
Adamson's Alarm Safety Valve Apparatus, consisting of one valve cylinder with weights surrounding the lower part and a central valve with a hung weight in the boiler, there, in connection with a lever float and counterbalance; the central valve is lifted by the float lever when the water is low in the boiler. Patented in the year 1871.

Fig. 910.



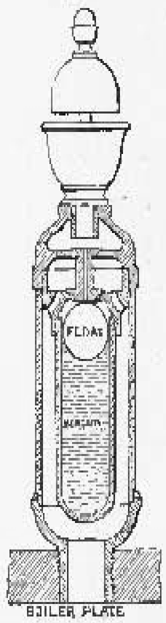
Cowburn's Alarm Safety Valve and Apparatus, inside the boiler, consisting of a direct weighted valve in connection with a float lever and balance; the lowering of the float assists to raise the valve. Patented in the year 1871.

Fig. 911.



Lee's Alarm Safety Valve and Apparatus, consisting of a perforated valve and seat and a central curved valve underhung with a weight in connection with a lever, float, and counterbalance. Patented in the year 1871.

Fig. 912.



Kirk's Alarm Valve and Float in Mercury; the expansion of the mercury causes the float to lift the valve, and the steam blows the whistle above. Patented in the year 1871.

APPENDIX C:

RECONSTRUCTION OF SAFETY VALVE

The attached DVD provides a photographic chronology showing the reconstruction of *Xantho*'s safety valve from start to finish (Table C-1). Although labour intensive the reconstruction of this device was critical for understanding how *Xantho*'s propulsion machinery operated. This object is on permanent display in the 'Steamships to Suffragettes Gallery', located at The Western Australian Museum (WAM) Shipwreck Galleries, Fremantle.

Also included is the de-concretion of the isolating valve recovered from the wreck site in June 2012 (Table C-2). This device will be consolidated with the safety valve once it has been desalinated and stabilised.

Table C-1 Photographic chronology of safety valve (XA339) reconstruction.

Date	CD folio reference	No. of images	Description of work undertaken
January 10, 1994	01	1	XA339 safety valve as recovered from wreck site, prior to de-concretion
June 24, 2010	02	10	Removal of valves from remnants of casing
July 13, 2010	03	15	XA339 rebuilding valve casing in an upside down position. Treatment of fragments with rust convertor 'Rusticide'.to stabilise iron fragments
July 14, 2010	04	7	XA339 rebuilding valve casing using masking tape to hold pieces in place until B44 adhesive cured
July 20, 2010	05	15	Use of wooden supports to hold flanges in place until B44 adhesive cured
July 22, 2010	06	2	Use of metal support frame to hold underneath of flange
July 23, 2010	07	14	XA339 rebuilding of casing and flange
July 25, 2010	08	7	XA339(i) Lever weighted valve after treatment with 'Senson Full Spectrum', a vinyl-copolymer in an isopropanol base with vapour phase inhibiters
July 27, 2010	09	6	Fitting heavy duty wooden support frames to hold steam flange in place
August 2, 2010	10	6	XA339F Oblong deadweight before reconstruction
August 5, 2010	11	16	XA339 during reconstruction
August 10, 2010	12	4	XA339 rebuilding of casing and flange
August 20, 2010	13	6	XA339 rebuilding of casing and flange
August 22, 2010	14	18	XA339 rebuilding of casing
August 25, 2010	15	2	XA339D circular deadweight before reconstruction
August 25, 2010	16	2	XA339E oblong deadweight before reconstruction
August 25, 2010	17	3	XA339C circular deadweight before reconstruction
August 26, 2010	18	1	XA339C circular deadweight during reconstruction
August 26, 2010	19	6	XA339 rebuilding of casing and flange
August 26, 2010	20	2	XA339E oblong deadweight during reconstruction. Use of tape to hold pieces in place

Table C-1 Photographic chronology of safety valve (XA339) reconstruction (continued).

Date	CD folio reference	No. of images	Description of work undertaken
August 27, 2010	21	4	XA339 reconstruction of flange
September 2, 2010	22	2	Workshop where treatment and reconstruction was undertaken
September 2, 2010	23	4	XA339 reconstruction of blow down flange
September 4, 2010	24	9	XA339A boiler mounting flange before treatment
September 5, 2010	25	8	XA339D circular deadweight before reconstruction
September 6, 2010	26	5	XA339D circular deadweight during reconstruction
September 8, 2010	27	6	XA339 during reconstruction. Use of tape and wooden supports to hold pieces in place
September 22, 2010	28	31	XA339 during reconstruction. Photographs XA339-21-22 September 2010 and XA339-22-22 September 2010 show curator Michael McCarthy with artefact.
October 1, 2010	29	5	XA339 during reconstruction
October 4, 2010	30	6	XA339 during reconstruction
October 5, 2010	31	10	XA339 during reconstruction
October 11, 2010	32	10	XA339F oblong deadweight after reconstruction
October 11, 2010	33	8	XA339E oblong deadweight after reconstruction
October 11, 2010	34	6	XA339D circular deadweight after reconstruction
October 11, 2010	35	5	XA339C circular deadweight after reconstruction
October 18, 2010	36	1	XA339 lifting off table to place artefact in an upright position
October 18, 2010	37	29	XA339 testing to see how artefact fits on support saddle designed and manufactured by Don Cockrell
October 19, 2010	38	2	XA339B replication of gasket for safety valve plate
October 19, 2010	39	20	XA339B safety valve plate before reconstruction
October 19, 2010	40	2	XA339C, XA339D, XA339E, and XA339F deadweights returned to Maritime Archaeology for accession numbers to be written on artefact

Table C-1 Photographic chronology of safety valve (XA339) reconstruction (continued).

Date	CD folio reference	No. of images	Description of work undertaken
October 21, 2010	41	6	Manufacturing of template for testing theory how safety valve was fitted to steam dome
October 21, 2010	42	4	Testing installation theory of how safety valve was fitted to steam dome
October 28, 2010	43	7	Painting of support saddle
October 28, 2010	44	6	Staining of support saddle
November 1, 2010	45	16	Staining of support saddle
November 1, 2010	46	11	XA339B safety valve plate after reconstruction
November 3, 2010	47	10	XRF tested areas on valves
November 5, 2010	48	7	XA339 on display in artefact preparation room
November 6, 2010	49	1	XA339 on display in artefact preparation room
November 7, 2010	50	13	XA339A rebuilding steam dome safety valve mounting
November 8, 2010	51	4	XA339C, XA339D, XA339E, and XA339F replication of deadweights out of light foam
November 8, 2010	52	34	XA339A during reconstruction
November 9, 2010	53	5	XA339A during reconstruction
November 12, 2010	54	7	Replication of lever weighted arm
December 31, 2010	55	11	XA339 after reconstruction with replica weight in artefact preparations room
February 4, 2011	56	10	XA339 moving safety valve to Xantho Gallery
February 21, 2011	57	13	XA339 safety valve on display in Xantho gallery
July 25, 2012	58	9	XA260 steam pipe from engine before reconstruction
August 15, 2012	59	4	XA339(i) deadweight safety valve after treatment
November 6, 2012	60	11	XA339G XA339H oblong deadweight after desalination but before reconstruction.
November 6, 2012	61	12	XA339H oblong deadweight after desalination but before reconstruction

Table C-2 Photographic chronology of isolating valve (XA5758) de-concretion process.

Date	CD folio reference	No. of images	Description of wok undertaken
June 10, 2012	62	37	XA5758 isolating valve as recovered from wreck site, prior to de-concretion.
August 15, 2012	63	10	XA5758 isolating valve during de-concretion
August 30, 2012	64	12	XA5758 isolating valve after de-concretion
September 6, 2012	65	7	Dismantling of steam pipe
September 7, 2012	66	53	Dismantling of steam pipe
September 27, 2012	67	17	Amalgamation with safety valve

APPENDIX D:

BOARD OF TRADE RULES

The documentation presented in this appendix has been extracted from Seaton and Rounthwaite (1894 260–267) and refers to the Board of Trade rules for the use of safety valves on steam-ships.

The Board of Trade Rules referring to Safety-Valves are as follows:—

123. The Engineer Surveyor shall declare, amongst other things, the limits of the weight to be placed on the safety-valves; that the safety-valves are such, and in such condition as required by the Act, and that the machinery is sufficient for the service for the time he fixes, and is in good condition for that time.

The locked-up valves, *i.e.*, those out of the control of the engineer when steam is up, should have an area not less, and a pressure not greater, than those which are not locked up, if any such valves are fitted.

Cases have come under the notice of the Board of Trade in which steamships have been surveyed and passed by the Surveyors, with pipes between the boilers and the safety-valve chests. Such arrangement is not in accordance with the Act, which distinctly provides that the safety-valves shall be upon the boilers.

The Surveyors are instructed that in all *new boilers*, and whenever *alterations can be easily made*, the valve chest should be placed directly on the boiler; and the neck, or part between the chest and the flange which is bolted on to the boiler, should be as short as possible, and be cast in one with the chest.

The Surveyors should note that it is not intended by this instruction that vessels with old boilers which have been previously passed with such an arrangement should be detained for the alterations to be carried out.

Of course, in any case in which a Surveyor is of opinion that it is positively dangerous to have a length of pipe between the boilers and the safety valve chest, it is his duty at once to insist on the requisite alterations being made before granting a declaration.

If any person place an undue weight on the safety-valve of *any* steamship, or in the case of steamships surveyed under the Act, increase such weight beyond the limits fixed by the Engineer Surveyor, he shall, in addition to any other liabilities he may incur by so doing, incur a penalty not exceeding one hundred pounds.

124. The area per square foot of fire grate surface of the locked-up safety-valves should not be less than that given in the following Tables opposite the boiler pressure intended, but in no case should the valves be less than two inches in diameter. This applies to new vessels or vessels which have not received a passenger certificate.

When, however, the valves are of the common description, and are made in accordance with the Tables, it will be necessary to fit them with springs having great elasticity, or to provide other means to keep the accumulation within moderate limits; and as boilers with forced draught may require valves considerably larger than those found by the Tables, the design of the valves proposed for such boilers, together with the estimated coal consumption per square foot of fire-grate, should be submitted to the Board for consideration.

In ascertaining the fire-grate area, the length of the grate should be measured from the inner edge of the dead plate to the front of the bridge, and the width from side to side of the furnace on the top of the bars at the middle of their length.

In the case of vessels that have not had a passenger certificate, if there is only one safety-valve on any boiler, the Surveyor should not grant a declaration without first referring the case to the Board for special instructions.

Safety-Valve Areas (Board of Trade).

Boiler Pressure.	Area of Valve per square foot of Fire-grate.	Boiler Pressure.	Area of Valve per square foot of Fire-grate.	Boiler Pressure.	Area of Valve per square foot of Fire-grate.
15	1·250	54	·543	93	·347
16	1·209	55	·535	94	·344
17	1·171	56	·528	95	·340
18	1·136	57	·520	96	·337
19	1·102	58	·513	97	·334
20	1·071	59	·506	98	·331
21	1·041	60	·500	99	·328
22	1·013	61	·493	100	·326
23	·986	62	·487	101	·323
24	·961	63	·480	102	·320
25	·937	64	·474	103	·317
26	·914	65	·468	104	·315
27	·892	66	·462	105	·312
28	·872	67	·457	106	·309
29	·852	68	·451	107	·307
30	·833	69	·446	108	·304
31	·815	70	·441	109	·302
32	·797	71	·436	110	·300
33	·781	72	·431	111	·297
34	·765	73	·426	112	·295
35	·750	74	·421	113	·292
36	·735	75	·416	114	·290
37	·721	76	·412	115	·288
38	·707	77	·407	116	·286
39	·694	78	·403	117	·284
40	·681	79	·398	118	·281
41	·669	80	·394	119	·279
42	·657	81	·390	120	·277
43	·646	82	·386	121	·275
44	·635	83	·382	122	·273
45	·625	84	·378	123	·271
46	·614	85	·375	124	·269
47	·604	86	·371	125	·267
48	·595	87	·367	126	·265
49	·585	88	·364	127	·264
50	·576	89	·360	128	·262
51	·568	90	·357	129	·260
52	·559	91	·353	130	·258
53	·551	92	·350	131	·256

Safety-Valve Areas (Board of Trade)—*continued.*

Boiler Pressure.	Area of Valve per square foot of Fire-grate.	Boiler Pressure.	Area of Valve per square foot of Fire-grate.	Boiler Pressure.	Area of Valve per square foot of Fire-grate.
132	·255	155	·220	178	·194
133	·253	156	·219	179	·193
134	·251	157	·218	180	·192
135	·250	158	·216	181	·191
136	·248	159	·215	182	·190
137	·246	160	·214	183	·189
138	·245	161	·213	184	·188
139	·243	162	·211	185	·187
140	·241	163	·210	186	·186
141	·240	164	·209	187	·185
142	·238	165	·208	188	·184
143	·237	166	·207	189	·183
144	·235	167	·206	190	·182
145	·234	168	·204	191	·181
146	·232	169	·203	192	·181
147	·231	170	·202	193	·180
148	·230	171	·201	194	·179
149	·228	172	·200	195	·178
150	·227	173	·199	196	·177
151	·225	174	·198	197	·176
152	·224	175	·197	198	·176
153	·223	176	·196	199	·175
154	·221	177	·195	200	·174

125. The Surveyor, in his examination of the machinery and boilers, is particularly to direct his attention to the safety-valves, and whenever he considers it necessary, he is to satisfy himself as to the pressure on the boiler by actual trial.

The Surveyor is to fix the limits of the weight to be placed on the safety-valves, and the responsibility of issuing a declaration before he is fully satisfied on the point is very grave. The law places on the Surveyors the responsibility of "declaring" that the boilers are in his judgment sufficient with the weights he states.

The Surveyor is to examine the whole of the valves, weights, and springs at every survey.

The responsibility of seeing to the efficiency of the mode by which the valves are fitted so as to be out of the control of the engineer when steam is up rests with the Surveyor, as long as it is efficient, and the method adopted is approved of by the Board of Trade.

The safety-valves should be fitted with lifting gear, so arranged that the two or more valves on any one boiler can at all times be eased together, without interfering with the valves on any other boiler. The lifting gear should in all cases be arranged so that it can be worked by hand either from the engine-room or stoke-hole.

Care should be taken that the safety-valves have a lift equal to at least one-fourth their diameter; that the openings for the passage of steam to and from the valves, including the waste-steam pipe, should each have an area not less than the area of valves required by clause 124; and that each valve box has a drain pipe fitted at its lowest part. In the case of lever-valves, if the lever is not bushed with brass, the pin must be of brass; iron and iron working together must not be passed. Too much care cannot be devoted to seeing that there is proper lift, and free means of escape of waste steam, as it is obvious that unless the lift and means for escape of waste steam are ample, the effect is the same as reducing the area of the valves or putting on an extra load. The valve seats should be secured by studs and nuts.

The Surveyors are, as far as in their power, to make the opinion of the Board on these points generally known to the owners of passenger steamers.

126. When the Surveyor has determined the amount of pressure he is to see the valves weighted accordingly, and the weights or springs fixed in such a manner as to preclude the possibility of their shifting or in any way increasing the pressure. The limits of the weight on the valves is to be inserted in the declaration, and should it at any time come to a Surveyor's knowledge that the weights or the loading of the valves have been shifted, or otherwise altered, or that the valves have been in any way interfered with, so as to increase the pressure, without the sanction of the Board of Trade, he is at once to report the facts to the Board of Trade.

127. If the following conditions are complied with the Surveyor need raise no question as to the substitution of spring loaded valves for dead weighted valves:—

(1.) That at least two valves are fitted to each boiler.

(2.) That the valves are of the proper size, as by clause 124.

(3.) That the springs and valves are so cased in that they cannot be tampered with.

(4.) That provision is made to prevent the valves flying off in case of the springs breaking.

(5.) That the requisite safety-valve area is cased in and locked up in the usual manner of the Government valves.

(6.) That screw lifting gear is provided to ease all the valves, as by clause 125.

(7.) That the size of the steel of which the springs are made is in accordance with that found by the following formula:—

$$\sqrt[3]{\frac{s \times D}{c}} = d:$$

s = the load on the spring in lbs.
D = the diameter of the spring (from centre to centre of wire) in inches.
d = the diameter, or side of square, of the wire in inches.
c = 8000 for round steel.
c = 11,000 for square steel.

(8.) That the springs are protected from the steam and impurities issuing from the valves.

(9.) That when valves are loaded by direct springs, the compressing screws abut against metal stops or washers, when the loads sanctioned by the Surveyor are on the valves.

(10.) That the springs have a sufficient number of coils to allow a compression under the working load of at least one quarter the diameter of the valve.

128. In no case is the Surveyor to give a declaration for spring-loaded valves, unless he has examined them and is acquainted with the details of their construction, and unless he has tried them under full steam, and full firing, for at least 20 minutes with the feed-water shut off and stop-valve closed, and is fully satisfied with the result of the test. In special cases, or when the valves are of novel design, the results of the tests under full steam should be reported to the Board, but if the Surveyors are fully satisfied with the results of the tests they need not delay the granting of the declaration for the vessel subject to approval of the Board. If the accumulation of pressure exceed 10 per cent. of the loaded pressure, he should not give his declaration without first reporting the case to the Board of Trade, accompanied by a sketch, and full particulars of the trial and the strength pressure of the boilers.

129. In the case of valves, of which the principle and details have already been passed by the Board of Trade, the Surveyor need not require plans to be submitted so long as the details are unaltered, of which he must fully satisfy himself; but in any new arrangement of valves, or in any case in which any detail of approved valves is altered, he should, before assuming the responsibility of passing them, report particulars, with a drawing to scale, to the Board of Trade. He can make this drawing himself from the actual parts of the valves fitted, but in order to save time, and to facilitate the survey, the owners or makers of engines may prefer to send in tracings of their own, before the valves are placed on the boiler. If they do this the survey can be more readily made, and delay and expense may be saved to owners, as the Surveyor will not then have to spend his time, and delay the ship, in preparing drawings and comparing them with the valves.

The tracings of new safety-valve designs should, if possible, be transmitted to the Board of Trade for consideration before the construction of the safety-valves is commenced.

In some spring valves the accumulation of pressure has reached cent. per cent., and therefore if the Surveyor had not required a trial, he would have passed valves which would have caused a pressure on the boiler double that intended by him. And in some cases in which the increase of pressure has not been great, defects that would have rendered the valves highly dangerous have been discovered on an examination of drawings.

The Surveyors should arrange with manufacturers so that the Surveyors may have the designs of valves which the manufacturers intend to use. An easy method of facilitating this matter is for the manufacturer to leave in the local Surveyor's office a plan or plans of his valve or valves when once agreed to, and then afterwards to inform the Surveyor that the valves fitted are according to drawing A, B, or C, as the case may be. By this means, when once a design has been agreed upon, and is adhered to, all subsequent questions and delays will be prevented.

131. It is clearly the duty of the masters and engineers of vessels to see, in the intervals between the surveys, that the locked-up safety-valves, as well as the other safety-valves and the rest of the machinery, are in proper working order. There is no provision in the Merchant Shipping Act, 1854, exempting the owner of any vessel, on the ground that she has been surveyed by the Board of Trade Surveyors, from any liability, civil or criminal, to which he would otherwise be subject. The Act of Parliament requires the Government safety-valves to be out of the control of the engineer when the steam is up; this enactment, far from implying that he is not to have access to them, and to see to their working, at proper intervals when the vessel is in port rather implies the contrary; and the master should take care that the engineer has access to them for that purpose. Substantial locks that cannot be easily tampered with, and as far as possible weather-proof, should be used for locking up the safety-valve boxes.

132. In witnessing the hydraulic tests of boilers, &c., and in witnessing all safety-valve tests for accumulation of pressure, the Surveyors are to use the pressure gauges supplied by the Board of Trade for the purpose. The steam gauge should not be used without a syphon filled with water between it and the boiler, and in all cases in which the Surveyors have to adjust the safety-valves of passenger steamships they should state in the Remarks column of their declarations which of the Board's gauges was used in making the adjustment of each set of valves.

The rules relating to feed check valves and feed pipes have already been given at the end of the section on "Feed pumps, &c." (page 143), and those relating to blow-off cocks and pipes at end of section on "Sea valves" (page 192).

Lloyd's rules relating to boiler mountings, &c., are as follows:—

17. Two safety-valves are to be fitted to each boiler, and loaded to the working pressure in the presence of a Surveyor. In the case of boilers of greater working pressure than 60 lbs. per square inch, the safety-valves may be loaded to 5 lbs. above the working pressure. If common valves are used, their combined areas are to be at least half a square inch to each square foot of grate surface. If improved valves are used, they are to be tested under steam in the presence of the Surveyor; the accumulation is in no case to exceed 10 per cent. of the working pressure.

18. An approved safety-valve is also to be fitted to the superheater.

19. In winch boilers one safety-valve will be allowed, provided its area is not less than half a square inch per square foot of grate surface.

20. Each valve is to be arranged so that no extra load can be added when steam is up, and must be fitted with easing gear which lifts the valve itself. All safety-valve spindles are to extend through the covers, and are to be fitted with sockets and cross handles, so that the valves can be lifted and turned round in their seats, and their efficiency tested at any time.

21. Stop valves are to be fitted so that each boiler can be worked separately.

22. Each boiler is to be fitted with a separate steam gauge, to accurately indicate the pressure.

23. Each boiler is to be fitted with a blow-off cock, independent of that on the vessel's outside plating.

APPENDIX E: MATERIALS SALVAGED FROM SS *XANTHO*

This compilation of newspaper articles from *The Inquirer & Commercial News* and *The Herald* provides a comprehensive listing of materials salvaged from *Xantho* by agents operating under the direction of Charles Broadhurst. Most of these items appear to have been salvaged from locations above deck, perhaps indicating how difficult it was to work at the site. With the exception of the 'copper hose branch' believed to be the blow down pipe connected to the safety valve, little of *Xantho*'s propulsion system was salvaged. Although the engine and boiler eventually were put to auction, they failed to gain much interest from prospective buyers and ultimately were abandoned.

This Day!

Important Sale by Auction.

WEDNESDAY, 5TH FEBRUARY.

S. S. XANTHO.

JAMES W. HUMPHRY

Has received instructions from Capt Denicke, (the master,) to sell by auction, at his Sale Room, High Street, Fremantle, on WEDNESDAY, the 5th February, WITHOUT RESERVE,

THE wreck of the above vessel, now lying in about 12 feet of water at Port Gregory, inside the reef, together with her furniture, tackle, and rigging.

ALSO,—

The following articles, stowed in a warehouse on shore:—

1 complete set of Sails, with running gear; 1 Lower Yard, Topsail Yard, Fore Gaff, and Main Boom and Gaff, with gear complete.

ALSO,—

1 bower anchor, 1 stream do., 61 fathoms chain, winch do., 2 boats' davits, 1 fish do., 2 life buoys, 2 boats' covers, manilla 3in. line, coir warp, aneroid barometer, 2 thermometers, 3 clinometers, masthead and side lights, 4 cork fenders, rigging screw, 1 copper pump, 1 do. hose branch, assorted blocks, gun cartridges, and blue lights, large ship's bell, portable forge, anvil, &c.; Azimuth compass and tripod, 2 steering compasses, 1 patent log, engine room tools, 2 clocks, lamps, spy glass, complete set flags; new cooking apparatus, English flag and jack, 3 awnings, 1 thirteen-feet dingy, &c., &c.

ALSO,—

At Fremantle,—1 first class ship's chronometer by McGregor, Glasgow, and some maps.

N.B.—The engines are 35-horse power, made by Penn & Son for the English Government, and only put in the *Xantho* about 12 months ago.

Sale to commence at 12 o'clock.

TERMS—LIBERAL.

Further particulars may be obtained on application to the Auctioneer, or to Mr. Sept. Burt, Solicitor, Perth.

Fremantle, Jan. 26, 1873.

Source: ***The Inquirer & Commercial News*, February 5, 1873**

IMPORTANT

Sale by Auction.

Wednesday, 5th February.

S. S. 'Xantho.'

JAMES W. HUMPHRY

HAS received instructions from Capt. DENICKE, (the master) to sell by Auction at his Sale Room, High Street, Fremantle, on WEDNESDAY, the 5th February:—

Without Reserve!

THE wreck of the above vessel, now lying in about 12 feet water at Port Gregory, inside the reef, together with her furniture, tackle and rigging.

ALSO,—

The following articles stowed in a warehouse on shore:—

1 complete set of sails with running gear. 1 lower yard, topsail yard, fore gaff, and main boon and gaff, with gear complete.

ALSO,—

1 Bower Anchor
1 Stream do.
81 Fathoms Chain
Winch do.
2 Boats Davits
1 Fist do.
2 Life Buoys
2 Boats Covers
Manilla 3in. Line
Coir Warp
Aneroid Barometer
2 Thermometers
3 Salinometers
Masthead and Side Lights
4 Cork Fenders
Rigging Screw
1 Copper Pump
1 Do. Hose Branch
Assorted Blocks
Gun, Cartridges and Blue Lights
Large Ship's Bell
Portable Forge, Anvil, &c.
Azemuth Compass & Tripod
2 Steering Compasses
1 Patent Log
Engine Room Tools
2 Clocks, Lamps, Spy Glass
Complete set Flags—new
Cooking Apparatus
English Flag and Jack
3 Awnings
1 Thirteen ft. Dingy
&c., &c. &c.

ALSO,—

At Fremantle,—1 first-class ship's Chronometer, by McGregor Glasgow, and some Maps.

N.B.—The Engines are 35 horse power, made by Penn and Son for the English Government, and only put into the "Xantho" about 12 months ago.

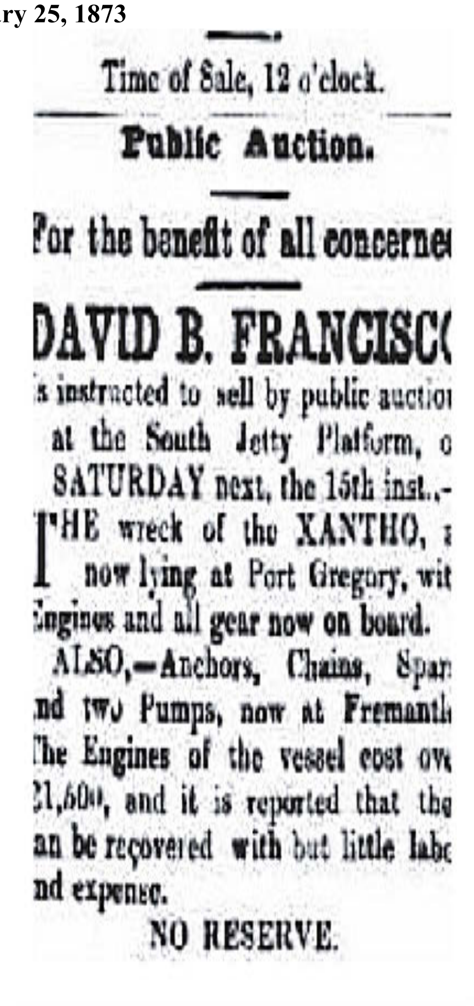
Sale to commence at 12 o'clock.

TERMS—LIBERAL.

Further particulars may be obtained on application to the Auctioneer, or to Mr. Sept. Burt, Solicitor Perth

Fremantle, Jan. 20, 1873.

Source: ***The Herald*, January 25, 1873**



Time of Sale, 12 o'clock.

Public Auction.

For the benefit of all concerne

DAVID B. FRANCISC

s instructed to sell by public auctio
at the South Jetty Platform, o
SATURDAY next, the 15th inst.,-
THE wreck of the XANTHO, a
now lying at Port Gregory, wit
Engines and all gear now on board.
ALSO,—Anchors, Chains, Spar
nd two Pumps, now at Fremantl
The Engines of the vessel cost ove
£1,600, and it is reported that the
an be recovered with but little labo
nd expense.

NO RESERVE.

Source: ***The Inquirer & Commercial News*, November 12, 1873**