THE UNIVERSITY OF NEW SOUTH WALES

SCHOOL OF MECHANICAL AND INDUSTRIAL ENGINEERING.

RESTORATION OF THE STEAM TUG 'WARATAH'.

by

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Dedicated to

'The Waratah'

and those who believed in her.

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PREFACE

The restoration of the 'Waratah', a Steam Tug built in 1902, was a major project which drew upon a wide range of maritime related actvities. The Sydney Maritime Museum, the organization which undertook the restoration, had no previous experience with restoration of this type or scale. As there was, at that time, no knowledge of similar projects around the world from which to draw experience; the 'Waratah's' restoration was undertaken with the Museum learning as the work progressed.

Initial investigations indicated that the 'Waratah' was in very poor condition and that commercial avenues of restoration would have been prohibitively expensive. The Museum was forced to look at alternative methods; this resulting in an ambitious solution; the recommissioning of an abandoned dry dock. With the 'Waratah' in dock, the scope of her restoration was able to widen because of the freedom which resulted from the utilization of an independent facility. The restoration of 'Waratah' was extensive, covering her hull, machinery and outfit. While this work progressed, the various concepts governing the methods of repair were evolved as experience was gained. These concepts varied from the general to the specific, together defining a restoration policy.

This thesis aims to provide a basis for the restoration of other vessels. Although restoration methods may differ from those used on the 'Waratah' it is hoped that the contents of this thesis will illustrate that; firstly, restoration and preservation are both technical and philosophical problems and that their solution requires careful thought particularly with regard to compromise and secondly, that a full committment to a vessel's restoration can yield results not possible from a lesser committment, this requiring ambitious approaches and confidence within the organization.

This thesis has concentrated upon the restoration of 'Waratah's' hull to illustrate the above. Hull restoration has tended to be the biggest problem among maritime museums, often having been guided by inadequate restoration concepts which have resulted in poor restoration techniques. The hull restoration is described from its first preliminary surveys to the actual restoration, including the recommissioning of a dry dock to allow its restoration to commence. Although, in doing this, much of 'Waratah's restoration is covered in a general way, this thesis is not a detailed record of the restoration.

The author's involvement in the 'Waratah's' restoration has been long and varied. Having joined the Sydney Maritime Museum in 1971, the author commenced working on the Museum's various vessels, gaining experience as time progressed. In 1974, together with another member, Andrew Munns, the author began to investigate the restoration of the 'Waratah' which, in time lead to a certain degree of lobbying for her restoration to be commenced. Since that time, the author has had the opportunity to be involved in her restoration in a wide variety of fields. This was mainly on a voluntary basis, although there was also a period of part-time employment on the project.

Experience was gained in tasks such as planning, surveying, design, corrosion control, management, boiler making, shipwright skills and quality control as well as having the responsibility for authenticity of the restoration. This provided a unique opportunity to observe the restoration from a number of points of view and hence enabled the author to have a more complete perspective of the restoration as a whole.

The author wishes to acknowledge the assistance of the following persons in the preparation of this thesis.

Firstly, the thesis supervisor, Mr. F. G. Bartlett for his assistance, encouragement and patience during the compilation of this thesis.

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CHAPTER 1

INTRODUCTION.

1.1 THE SYDNEY MARITIME MUSEUM.

The Sydney Maritime Museum, owners and restorers of the Steam Tug 'Waratah', was founded in 1965 to preserve the veteran Steam Yacht 'Lady Hopetoun', then due for disposal. Part of the original aims required that the 'Lady Hopetoun' remain operational as a 'live' exhibit so as to preserve the skills required to operate her. With this in mind, the museum members undertook the restoration of the 24 metre wooden vessel, and by 1970, she was again fully operational (See Plate 1).

During these five years however, many other fine steamships were scrapped, a result of their widespread and rapid replacement by motorships. The museum, showing considerable foresight, acquired two other steam vessels; the 32 metre Steam Tug 'Waratah' in 1968 and the 52 metre Pilot Steamer 'John Oxley' in 1970. Another addition was the 30 metre wooden topsail ketch 'Avanti'. At the time of acquisition, each of these three vessels was far beyond the museum's resources to maintain, let alone restore; but the organization had faith in its future and so accepted the risks. Delaying until funds were available would have resulted in a lost opportunity to preserve such fine examples. The two steamers were in operational (although poor) condition.

PLATE I. S.L. "LADY HOPETOUN" b. 1902

PLATE II. S.S. "JOHN OXLEY" b. 1927
(G. Andrews)

The sailing vessel was not operational. With the passing of time, insufficient funds necessitated that the two steamers be laid up. The position with the 'Avanti' was even more serious and eventually she had deteriorated to such an extent that the museum was forced to scrap her.

In the early 1970's, the museum acquired the 55 metre Barque 'James Craig'. To meet the demands of the 'James Craig' project, the museums' structure was somewhat changed. With growing public interest in the museum, and the influx of funds through art unions, the museum felt that it could direct limited funding into one of its steamships.

'Waratah' was the ship chosen to receive these funds. There were two main reasons. Firstly the 'Waratah's' hull was suspected to be in a poorer condition than that of the 'John Oxley' and was therefore demanding more immediate attention. Secondly, it was felt that the limited funds available would go much further on the 'Waratah' than they would have on the much larger 'John Oxley'. (See Plate II)

1.2 THE WARATAH

1.2.1 Historical Significance.

The 'Waratah' is a good example of a late nineteenth century small steamship. Her elegant appearance and graceful proportions are distinctive when compared to the more utilitarian designs of this century. Even her antiquated construction and old fashioned steam reciprocating machinery are relics of an era past. (See Figure 1).

The 'Waratah' has had a long association with Australia's maritime history. She served as part of the N.S.W. Public Works Department fleet of dredges and attending plant (including tugs) which were charged with the responsibility of keeping the N.S.W. coastal ports navigable. Until relatively recently a large proportion of intrastate trade and transport along Australian coasts was handled by shipping; shipping which required safe ports. Many of these ports were often inland on coastal rivers which, without regular dredging, would have been unnaviagable. 'Waratah's' duties included the coastal towage of dredging plant as well as attending to the dredges within the various ports. She was also used for a wide variety of other duties. A fuller historical description appears in Appendix A and a technical description in Appendix B. Photographs taken during her career appear as Plates III, IV, V, VI, and VII.

1.2.2 Suitability as a Museum Ship.

The 'Waratah is quite unique amongst preserved vessels around the world. She is one of the very few nineteeth century steamers preserved; which was and could be again seagoing or at least operational. The majority of preserved nineteenth century steamers are inshore vessels

FIG I

IRON SINGLE SCREW STEAM TUG

"WARATAH"

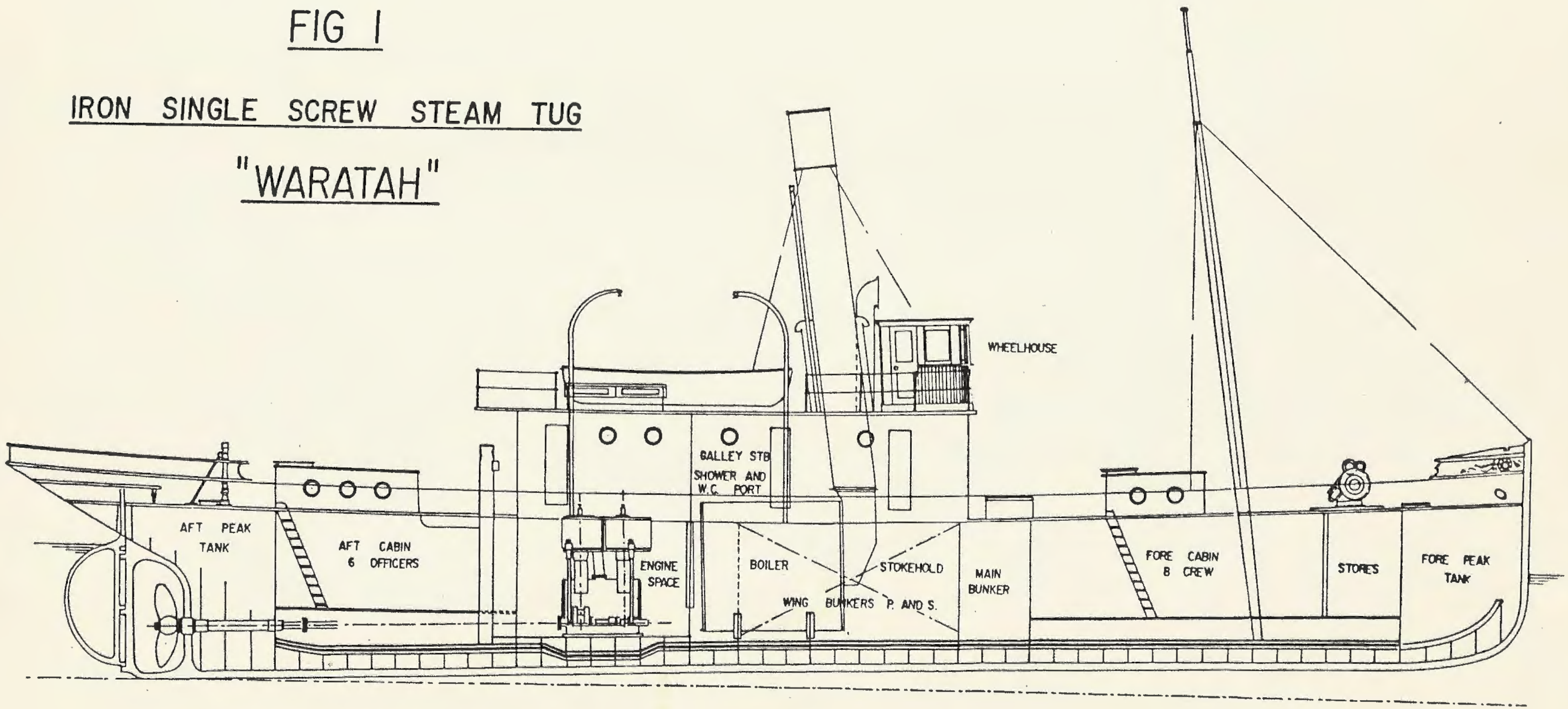


PLATE III. NEWCASTLE HARBOUR 1906
"WARATAH" ALONGSIDE WHARF
LEFT FOREGROUND.
(N.S.W. Govt Printer)

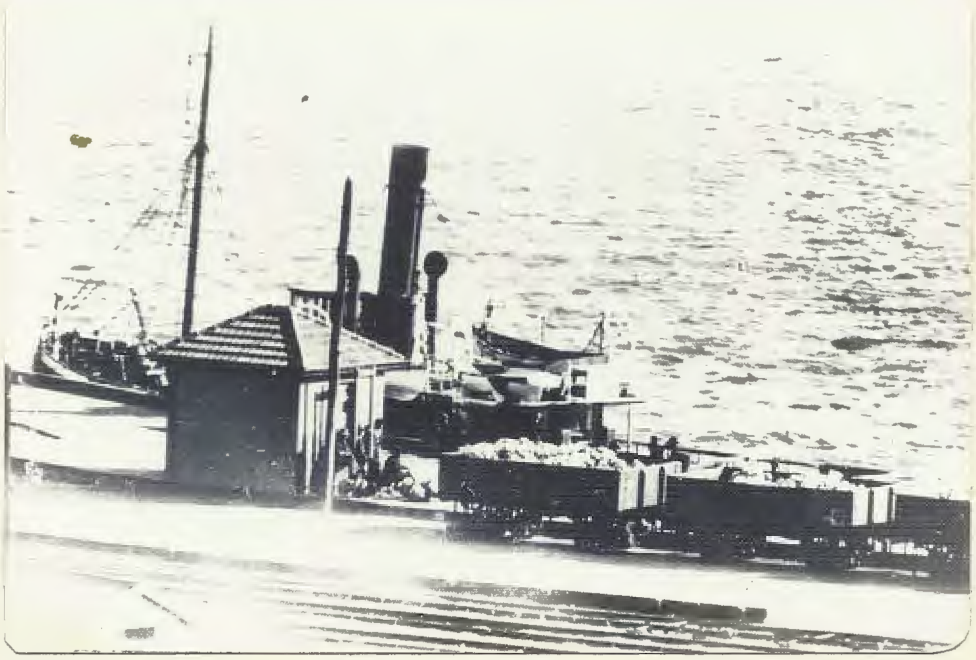


PLATE IV. ENLARGEMENT OF "WARATAH"
IN ABOVE PHOTOGRAPH

PLATE V. "WARATAH" IN THE 1930's
(C. Curran)

PLATE VI. (right)
"WARATAH" AFTER REFIT 1950's
(M. Dippy)

PLATE VII. (left)
"WARATAH" LEAVING NEWCASTLE
FOR SYDNEY 1968. (G. ANDREWS)

(ferries, harbour tugs, etc.), or are not operational.

Ships considered for preservation must not only be historically significant, but must also be practical within the scope of the particular organization preserving them. The 'Waratah's' historical qualifications have been stated, but there are other factors which had to be considered.

Size is an important factor of a preserved ship. 'Waratah' is sufficiently large to stimulate interest through her size and the associated amount of detail. She is also large enough to enable visitors to come aboard to inspect her without fear of overcrowding and congestion. She is not so large, however to need the same extensive workshops, equipment and labour to restore and maintain her that a larger ship would require. This reduces both the short term and long term commitment.

From an operational point of view, 'Waratah' is of a handy size as she is large enough to carry a reasonable number of passengers, and possibly, venture out to sea (without passengers), yet she is small enough to be comparitively economical to operate. She differs markedly from other preserved tugs of a similar size as she is equipped with a remarkably low powered engine to drive her fine hull. This is distinct from the usual tug combination of a large powered engine driving a full hull. Not only is she economical on power;she has the advantage of being coal fired and relies on higher priced oil products for lubrication only.

The 'Waratah' is heavily constructed. This combined with her simple operation, makes her very suitable as a training ship, preserving the skills of seamanship and steam engineering.

On the negative side was her initially poor condition and the need to carry out a major restoration before she could be effectively displayed. Complicating the matter was the pressing need to carry out short term repairs to prevent her sinking.

1.3 THE PROBLEM

The 'Waratah' was in very poor condition. Her last major refit had been in 1956 and even this was only sufficient for her to be fit for harbour duties. In the years following this refit, the Public Works Department spent as little as possible to keep her operational. Those repairs which were necessary were done in a temporary manner and at minimum expense. By 1968, when the museum acquired her, she sorely needed major repairs. Although operational when acquired, she was laid up in 1972 for fear that she might become holed while steaming. For eight years after her acquisition, the museum did not have sufficient resources to carry out any meaningful maintenance or restoration. She steadily deteriorated until the mid 1970's when the fear that she would sink at her moorings and become a major liability forced the museum to make a decision regarding her future. The question was whether it would be feasible to preserve 'Waratah' in view of the possible short term and long term costs and given the museum's limited resources. Implicit in any positive decision to preserve her was the immediate commitment to carry out sufficient repairs to keep her watertight, even if these repairs were only of a temporary nature. The financial burden of restoration and preservation had to be weighed against the desirability of the 'Waratah' as a museum ship. This financial burden depended upon:

a) The condition of the 'Waratah' determing the work necessary for both the immediate and long term future.

b) The museum's commitment to authenticity of its exhibits.

c) Modus operandi of the repairs and restoration depending upon -

- site of dry berthing and/or repair
- workforce - union, contract and/or volunteer
- capital equipment
- competance of management
- extent of donations
- others.

d) Returns, if any, from expenditures on 'Waratah' such as those donations from increased public interest, public inspections, etc. These would be largely dependant upon the extent of visible results from expenditure on restoration.

The first stage of the 'Waratah' restoration investigated the factors listed so that a decision could be made. The factors of authenticity and return were only vaguely covered in these initial investigations, partly because of the pressing immediate problems of keeping 'Waratah' afloat and partly because their significance was not yet clearly understood. Chapter 4 deals with the investigations which led to the decision that preservation (and later restoration) was feasible.

Once the decision to preserve 'Waratah' was made the Museum had to deal with the technical problems associated with carrying out the work. Descriptions of the work carried out to recommission the dry dock and restore the hull appear in Chapters 5 and 7 respectively. Unfortunately limits of time and space available for this thesis did not allow similar chapters covering restoration of machinery and outfit. Although these chapters were not included, their significance as part of the total project should not be underestimated. Their exclusion does not seriously effect this thesis, however, as similar machinery and outfit restorations have been carried out on a number of museum ships in the past; while the restoration of the hull, by comparison, is more unique as there have been few major hull restorations of metal hulled ships.

Once the restoration was begun, it was found that it was not only a technical problem, but also a philosophical one. Significance of the terms 'restoration' and 'preservation' became apparent as the restoration progressed, not only changing the concepts underlying the methods of repair, but also defining definite responsibilities of a museum-type organization with respect to its exhibits. These concepts are believed to be key to the long term success of a preservation. The philosophies of museums, restoration and preservation are evolved in Chapters 2 and 3 and specific concepts relating to 'Waratah' are discussed in Chapter 6.

1.4 SEQUENCE OF EVENTS

This thesis has been written in a logical order as distinct from a chronological one. The reason is to obtain some continuity within the text rather than a disjointed assembly of ideas. As such it must be remembered that:

a) Work did not necessarily proceed in the order given in the text. A number of jobs were worked on concurrently and some individual jobs were drawn out over a period of some months. The continuity and order of work was determined by factors such as its priority, the cash flow situation, material stocks and availability of equipment and labour. As such, many jobs overlapped each other chronologically.

b) Concepts were developed as the restoration work prgressed and were often not known before restoration started. Many of the concepts and philosophies have been discussed prior to description of the restoration as it is necessary to understand them to understand the direction of the restoration.

FIG 2

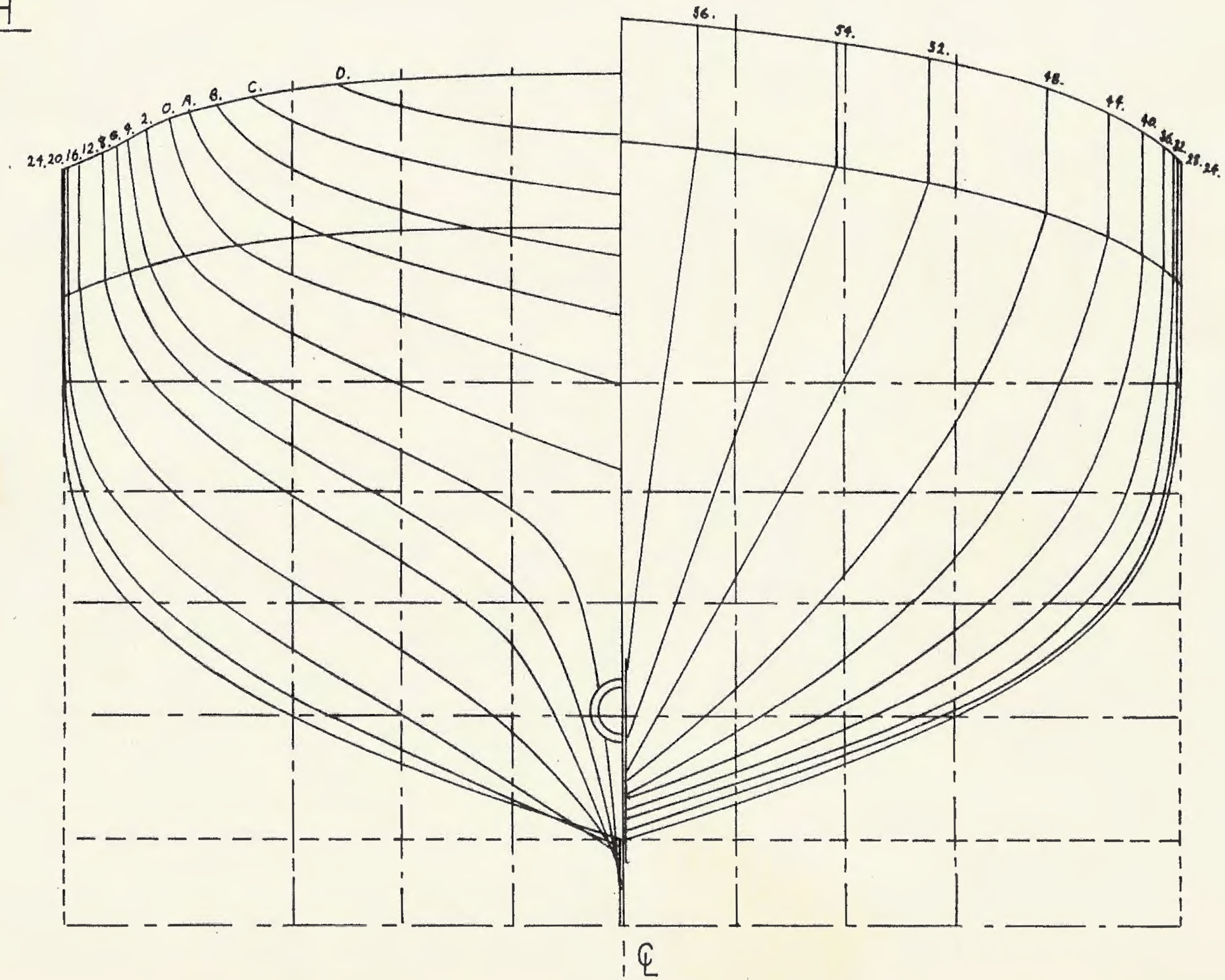
G 2.

.T. "WARATAH"

ARATAH"

BODY PLAN

PLAN

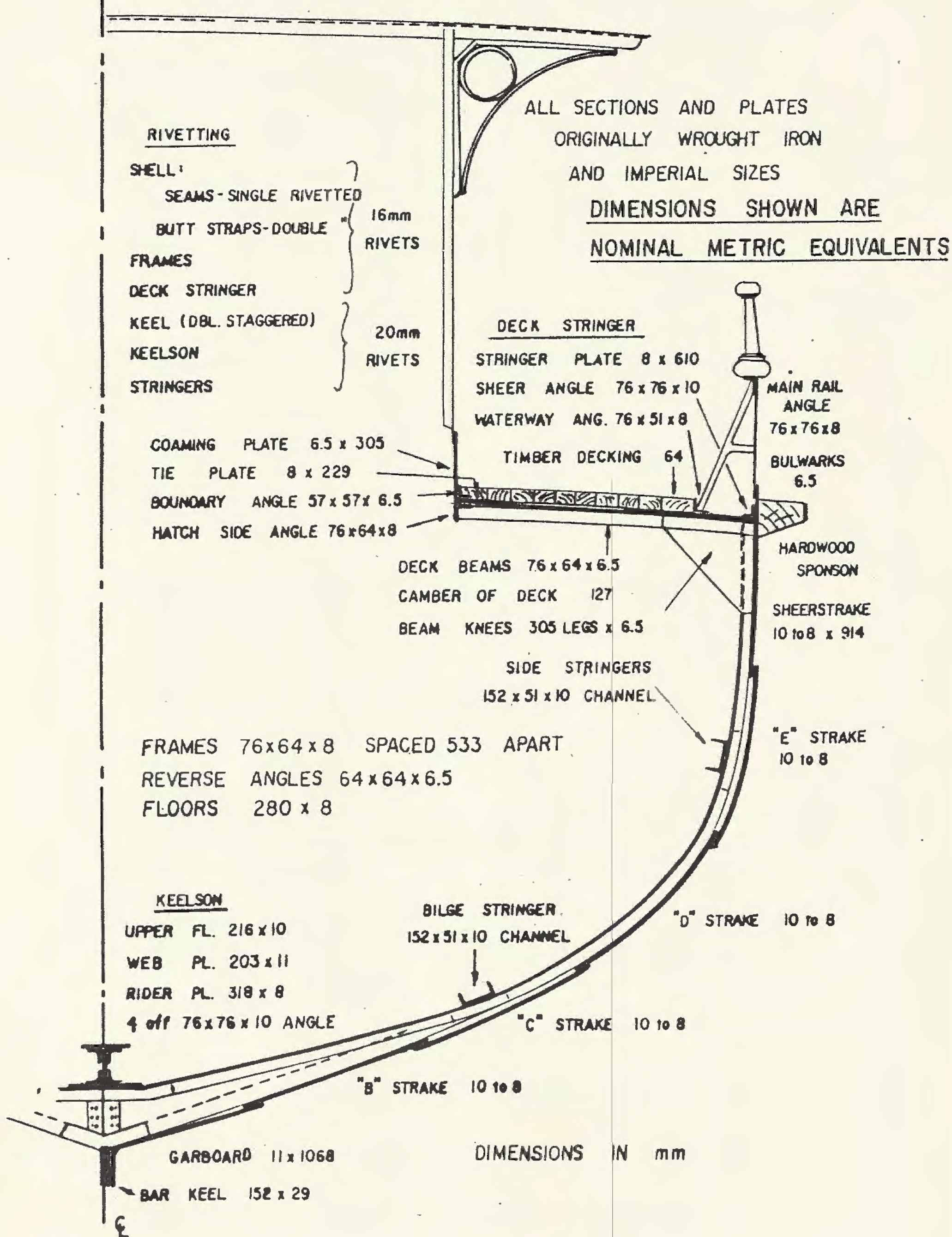


PRINCIPAL	DIMENSIONS
LOA	33·08 m
LBP	30·48 m
BEAM (mld)	6·15 m
DEPTH (mld)	2·98 m

FIG 3

S.T. WARATAH

MIDSHIP SECTION (as built)



CHAPTER 2

BASIC PHILOSPHIES.

2.1 NEED FOR A POLICY

When first considered, the concepts associated with the terms museum, preservation and restoration appear obvious, but when they are applied to a project such as the restoration of 'Waratah' this is far from true. Complications arise because these concepts are open to interpretation and the individual interpretations can, and often do differ greatly. The following is a statement of a basic long term aim of the museum.

RESTORATION of the 'Waratah' and her PRESERVATION as a MUSEUM ship.

This basic statement can be interpreted in dozens of different ways, each leading to a different technical solution and giving differing end results. How can an object which has its form and features fixed in the past have so many different versions in a preserved condition? The answer is in the differing interpretations of the concepts and aims. Obviously, it is undesirable for such variations to exist because they indicate inaccuracies.

Unfortunately, many such interpretations are based upon the preconceived ideas of the individual people in control.

These are, more often based upon personal bias rather than philosophical, technical and financial arguments. Whatever the methods of restoration and preservation, they must be such that they can be justified, not only in terms of bare cost but also in terms of their total effectiveness. It should be remembered that the stringencies of a tight budget are not always adequate justification for inferior methods when the project is viewed critically in the long term. Work done to a definite policy evolved from considerations of the various aims, will be in a better position to be justified, both in the short and long term. It has to be conceded that very few restorations can be exactly authentic, but the significance of any deviation from complete authenticity can be better gauged and accounted for when within the guidelines of such a policy. Another advantage is the resulting greater consistency within the restoration which helps to determine a level of creditability.

Such a restoration policy will be evolved by first discussing the concepts and aims of museums generally in Chapter 2 followed by the more specific concepts regarding museum ship preservation in Chapter 3.

2.2. GENERAL DISCUSSION OF MUSEUMS

2.2.1 The effects of progress.

In recent times society has undergone rapid and extensive changes; so much so that, within a single generation, whole industries have been all but lost and completely new ones evolved. Often an unfortunate consequence of these rapid changes has been the unquestioned destruction of the past due to the overwhelming forces of progress.

Fortunately, there is currently a world-wide resurgence of interest in the past. The reasons for this may be many and varied; a few possible reasons being:

a) Security.

Individual people have, within a single generation, experienced many dramatic changes to their way of life. Change has been so rapid that the world in which many people were brought up in bears little relation to the world today. Preservation of the past provides something to relate to in a world where an individual's skills, views, and whole lifestyle may be considered obsolete within only a few decades. The past, to these people, is fixed and secure. The future, with its rapid changes, is often variable and uncertain.

b) Comparison.

Just as there is a trend to preserve the past, there is also a trend to question our current values. An insight into the past can provide a reference from which to gauge the appropriateness of these current values. Not only did life in past generations have advantages and disadvantages, but also many of the improvements to modern man's 'standard of living' have been made at the cost of other components of his environment and lifestyle. History is a record of life in the past, and provides an insight into these past lifestyles. For example, history can provide an insight into life during war, prosperity, or in the dark past before man's reliance on technology. Through history an understanding of the basis of our present values will become clearer and this may assist to determine an appropriate direction for the future.

c) Source of Experience.

Associated with the tremendous changes which have accompanied our progress, there has been a loss of certain skills and knowledge. Those areas of human endeavour which are presently considered obsolete will not be passed on to future generations unless some conscious effort is made to preserve them. It is ironic that, in an era where there is such a quest for knowledge, hundreds of years of accumulated experience which has been amassed within the redundant trades should be endangered. A knowledge of the technology of the past widens the resources available for dealing with the future. Good examples of this are some of the proposed technologies for dealing with future fuel shortages, these including the use of wind propulsion, coal as an energy source for transport and electric vehicles.

Whatever the reason for an individual's interest in the past, a conscious effort has to be made to preserve it. The most widespread method is through the institutions known as museums.

2.2.2 The Role of Museums.

2.2.2.1 Combined Educators and Entertainers.

Key to any formulation of a preservation/restoration policy is an understanding of the basic role of Museums.

The role of Museums can be divided into two major components:

a) As a centre for the preservation of objects and information of historical significance. This covers the acquisition, restoration and maintenance of these objects and information.

b) As a source for historical information dissemination. This covers library, display, educational and entertainment functions.

A Museum's responsibilities do not only include preservation, but also include a high degreee of interaction with the public.

From a financial point of view, most Museums depend upon public support, either by direct funding through gate monies, or indirectly through governments or company contributions. As the future of a Museum is, at least in part, tied to the degree of the public support, Museums must see that they provide some worthwhile service to the public.

A dispassionate look at the reasons why the majority of the general public go to Museums would, more than likely, reveal that they are seeking entertainment. Few would be consciously visiting a Museum for specific information or to be educated. In view of this how do the points raised in Section 2.2.1 relate to the typical visitor to a Museum? The answer is that they relate subconsciously through the medium of entertainment.

Entertainment can be regarded as the result of a favourable interaction between an entertainer and the people being entertained. A similar interaction is also a necessary part of any educating process. Education and entertainment are both closely related and when skillfully handled, can be used together to enhance the achievement of an end result. The entertainment value of a Museum can be regarded as the result of a successful educating process that reveals the previously unknown and the distantly reminiscent in an absorbing manner. The very nature of the history makes entertainment through education possible, but it should be remembered that sensitive and imaginative displays are required to make this practical.

Not only can education lead to entertainment, but also visa-versa. It must be assumed that people who come to a Museum have some sort of interest to have taken the trouble. By appealing to this interest and expanding on it, the educating possibilities are greatly increased. It has been found that Museums which are successful in entertaining tend to receive the support of the public (Smith, 1972, p.69).

2.2.2.2 Ivory Tower or Fun Palace?

These two terms decribe two extremes found among Museums.

a) Ivory Tower.

Some Museums, especially in the past, have had reputations as pompous, remote bodies which cater only for a narrow section of society. In such organizations, dubbed as 'Ivory Towers', attention is focused on remote scholarly pursuits and individual projects rather than on the needs of the public en masse. 'Ivory Towers' can rarely exist in a direct funding situation. The critical evaluation of the public at the turnstyles prevents their continued survival. Often, though, such organizations have an independent source of income which is not tied directly to public interest, examples being some government institutions. As there is no need for interaction with the public, such organizations can easily loose sight of their direction and, because of their independence, they can afford to continue doing so. A Museum has a responsibility not only to preserve information, but also to make it available to all interested levels of society, from school child to historian. Not only is this a responsibility, but a necessity if a Museum is to exist on public support.

b) Fun Palace.

The other extreme is the Fun Palace in which the acquisition of gate monies takes precedence. A temptation for Museums is to compromise the aims of preserving history for short term gains by obtaining public support at a lower cost. Such actions cover a wide range of ills from condoning popular misconceptions to exhibiting frauds. Truth is an inherent part of education and it is a Museum's responsibility to be as accurate as possible. Any deviations from this must reduce a Museum's creditability as an educational institution. It is true that a museum must always consider the various entertainment aspects, but this entertainment must be a result of successful education and not deceit. Museums are really guardians of the past and any inaccuracies presently existing, if not disputed or recorded, will be carried on into the future where they will be regarded as fact, distorting the future knowledge of history. There must, therefore, be some sort of integrity of purpose associated with Museums.

It is for this reason that an organization must decide whether it is prepared to uphold this integrity and accept the responsibilities of a Museum or whether it wishes to become an amusement centre. Those latter type organizations operating under the pretence of a Museum, reduce the creditability of all bona fide Museums as a whole and should be scorned.

Somewhere between the two extremes illustrated lie successful Museums. The aim of preserving history can only be fulfilled when a Museum through its success can continue its operations. This concept is quite different to the undesirable one of being successful through a blatant exploitation of history.

2.2.3 Exhibits.

Before a restoration/preservation policy can be formulated, there must be a basic understanding of those things which make an exhibit historically significant and effective as a display piece. The term exhibit is used in this thesis in a manner which includes the total concept of a finished display, not only the central component, but also the associated methods of display and labelling. Few artifacts are, when in isolation, successful exhibits. They require careful preparation to be properly utilized. Exhibits in Museums can be in many forms; some large, some small, some artifacts others intangibles such as skills. There are few limits on the form of an exhibit, the major one being the return for the necessary expenditure.

2.2.3.1 Types of Historical Significance.

To assist in determining the particular features which make an exhibit historically significant, three types of significance can be considered. It should be noted that these three types relate to history involving human beings.

Natural history might well have its own equivalents.

a) Signifcance Relating to Events.

History is a progression of events, each of which has its own influence, large or small, on the total chronicle. An exhibit can have a significance which is related to an event in history. This relationship can be used to illustrate a particular point contemporary to the event. Exhibits may relate directly to an event, for example, Lord Nelson's Telescope used at Trafalgar, or indirectly in the case of a Naval Uniform from the Napoleonic Wars. As both socialogical and technological progress is closely linked to the series of events in history, such significances are important for illustrating a chronological order and for highlighting those crucial events of the past which have had a great influence on our present lifestyle.

b) Sociological Significance.

Society has evolved and developed throughout history resulting in constantly changing lifestyles. Exhibits which help to illustrate past lifestyles have socialogical significance. Such exhibits could be such that they illustrate the organization of a family or their diet; just to name two examples.

c) Technological Significance.

The development of man through history has been made possible by the evolution of technology through inventiveness and experience. For a presentation of history to be adequate, exhibits must have some technological significance, particularly with respect to technological change.

Commonly, exhibits will illustrate more than one form of significance at the same time. This is not surprising, because in reality, the various forms of significance are interrelated and dependent upon one another. It would be difficult to conceive of a historical exhibit with only one form of significance.

2.2.3.2 Display Techniques.

Many Museums, especially in the past, have been very conservative with regard to their exhibits. This conservatism takes two forms,

i) Conservative base components.

The basic displayed components are limited to smaller static artifacts which can be displayed at minimal cost, upkeep and in the smallest space available. Such narrow constraints restrict the scope of effective historical preservation as the awkward or intangible are avoided and are not preserved.

ii) Conservative display techniques.

The display techniques tend to lack imagination and any educational purpose. Typically exhibits consist of a large number of loosely connected artifcats in glass cases and cabinets. The public is expected to glean some significance from these poorly labelled, crowded exhibits. (Smith, 1972, p. 70). Frequently there is a concentration upon quantity rather than quality in such exhibits, repetitions being common.

There is presently, among many Museums, a shift away from these conservative approaches. The realization that there is a need not only to preserve history, but also to educate and entertain, has brought about these changes. Modern exhibits tend to appeal more to the senses and emotions to achieve the desired results. Effects such as an atmosphere of vibrant industry, perilous danger or magnificent beauty are now sought for. The conservative Museum approach cannot compete with this. The following illustrate some of the changes in exhibits.

a) Audio/Visual.

There has been a rapid increase in the use of audio/visual equipment in exhibits. These may be in the form of films, slides, taped commentaries and special lighting techniques.

b) Massive Exhibits.

The public generally has a basic attraction to massive exhibits. Such exhibits can be awe inspiring and immediately discernible. Often massive displays are really complex collections of small exhibits which, by necessity, are set out in a logical manner. The best examples of massive displays are preserved buildings and ships.

c) Moving Exhibits and Action.

Movement is a useful tool within a Museum. It firstly captures the interest of passersby and then can increase the length of their attention span. Movement can be used in the actual component displayed itself or as an indirect display technique. Some audio/visual exhibits fall into this category as do working models, operational artifacts and exhibits such as working craftsmen.

d) Direct Interaction.

The use of guides and the provision of education courses, seminars and library services all can add to the scope of a museum. Interaction can be designed for various levels, from the casually interested to the scholarly. Good examples of direct interaction are the traditional small boat building and sail training courses held for the public by Mystic Seaport, Maine, U.S.A., which not only entertain and educate, but also actively engage the public in preserving these skills for the future (Bray, 1979, Vol. 29, p. 108).

Innovative exhibits are not restricted to the concepts above. A very unusual example is an exhibit of an 1890's sweets shop in the Smithsonian Institute, Washington, U.S.A. which actually smells of the enticing aroma of a sweets shop (Smith, 1972, p. 71). Exhibits, if necessary, can use a number of such techniques at the same time. Steam engines displayed at the British Science Museum are both massive and in motion.

Sophisticated exhibits will cost more than the more traditional types. Hopefully, the return from the increased public interest, and improved historical preservation will more than justify the higher costs. Care has to be taken, though, to ensure that sophistication does not become extravagance as the money might be better spent elsewhere.

2.2.4 Martime Museums.

Man has had close associations with the sea for thousands of years. These associations have had a major part to play in the evolution of his civilizations and have affected the lives of people through countless generations. His affiliations with the sea have covered a wide range of activities.

The power of nations revolved around supremacy of the oceans. Navies were maintained, battles fought, ambitions realised or defeated all for its control. The sea held the key to fortunes and fame. In earlier times, exploration sought the far off reaches of the earth. Many such explorations were by sea. Successful expeditions were rewarded with new found riches leading to the colonization of distant lands and the eventual emergence of empires. Maritime trade was also of great importance. Through trade with independent countries and dependent colonies, nations became prosperous. Trade not only provided prosperity, but also a means of world wide communication of ideas and knowledge. Man has also utilized the seas for its resources. Fishing and whaling industries have provided food and other products for thousands of years. In more recent times there has been increasing interest in the sea for its resources to supplement dwindling terrestial reserves. Not only have there been researches in improving food yields from the seas but also there has been exploration and exploitation of resources such as oil reserves. The bountiful sea has even provided man with a playground for his pleasures. Boating, yachting and watersport activities are available to millions.

Man's involvement with the sea has not stopped. It is expanding in ways never before thought of. The oceans still hold many of the answers for the future and will continue to be of great significance to man for many years to come.

All the activities above have a history full of events and full of technological and socialogical development and transitions. They represent thousands of different lifestyles spread over a broad base of time. These life-styles may include those of a sailor, King, fisherman, shipbuilder or a sailor's wife, just to mention a few. At the same time, there has been an extensive tradition built on heroism, adversity, empathy and teamwork resulting in a particular mystique which is associated with things maritime.

Such a rich and varied exposé of different cultures requires the services of a specialized Museum; a Maritime Museum, to ensure its adequate preservation. Despite the implied maritime specialization, the task of such Museums is wide and varied. Maritime Museums are fortunate in that, it appears that a large proportion of the public have at least a passing attraction to the sea. Those people previously associated with it, rarely loose their interest. Those who have been remote from the sea are drawn by its promise of the exotic and that special mystique of maritime culture.

Maritime Museums do not have to confine themselves just to the past. Present day exhibits can provide fundamental knowledge about current developments in the world around them often unknown to the general public. Such information could allow a more informed comparison between the past and present and could provide a basis for an insight into future trends.

The exhibits of a Maritime Museum can take any variety of directions. A bewildering array which could cover nearly all aspects of humanity. A choice between possible exhibits has to be made, however, based upon a balance of historical value, cost and return. One popular type of maritime exhibit is the restored ship. The following sections discuss some of the concepts involved.

CHAPTER 3

SHIP PRESERVATION

3.1 BENEFITS AND RESPONSIBILITIES.

3.1.1 Benefits.

There are presently quite a large number of ships preserved around the world. A number of these are listed in Appendix C. They range in size from small craft through to ships such as the 47,500 tonne battleship, U.S.A. "North Carolina", see Plate VIII (Heine, 1977, p. 98). Their ages also vary considerably from the Kyrenia Ship of 300 BC, see Plate IX (Bass, 1972, pp. 50-52) to the Gypsy Moth IV built in 1966 (Smith, 1974, pp. 28-31). The range of ship types preserved covers sailing ships, warships, paddlers and tugs, just to mention a few. The number of vessels preserved is an indication that a large proportion of Maritime Museums consider them worthwhile exhibits.

The benefits arising from preserving a ship are many. Few objects can symbolize man's involvement with the sea as adequately as does a ship. It is for this reason that a preserved ship is commonly the central piece of a Maritime Museum's exhibits. In fact, the symbol of many such Museums is the very ship herself. Preserved ships are very versatile exhibits providing a large scope for innovative display techniques.

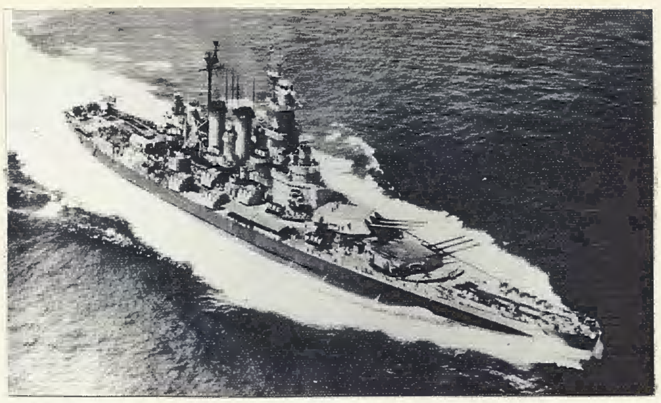


PLATE VIII. U.S.S. "NORTH CAROLINA" b.1942
SHOWN IN COMMISSION
(Smith, 1955, p.50)

PLATE IX. "KYRENIA SHIP" b. circa 300 B.C.
AS FOUND. (Bass, 1972, p.53)

Ships immediately create an impression on the public in view of their size. They are usually massive exhibits and, when exhibited in the open, can provide a distant attraction for people, acting as a landmark which focuses attention on the museum complex. Once aboard the maritime atmosphere can be immediately experienced and soon the public identifies with the exhibit. Not only is there a massive exhibit which is the ship herself, but also there are dozens of details abroad which themselves are worthwhile exhibits. These detail exhibits may relate to the technological or socialogical aspects of the ship and may be used to illustrate information such as

- the purpose of the ship
- her operation or maintenance
- the development and rationale of her design
- the way of life of her passengers and crew
- specific events in her past
- the methods and materials of her construction.

A ship can provide the basis upon which to expand the points listed above with the use of other exhibits displayed on land. In other words, the ship can provide a tangible example from which a more general overall concept can be illustrated. A particular case could be the linking of a land based exhibit on the life of seamen through the ages, with the specific example of their accommodations aboard the ship preserved.

Techniques of display utilizing movement can easily be incorporated in ship exhibits. Subtle techniques such as the gentle motion of a ship lying at her moorings, the wind in her rigging or seagulls flying among her spars all add vitality to the exhibit. More ambitious techniques are available. By maintaining, restoring and operating a ship, she can be made the focal point of the preservation of skills providing both moving displays and a means for public interaction.

A subtle benefit of ship preservation is the degree of impartiality possible within the restoration. An authentically restored ship contains, within its fabric, a tremendous range of detail. Few museum curators would be sufficiently knowledgable to be able to comprehend the full significance of much of this detail. As individual pieces, they would more than likely be rejected as being not worthy of preservation, despite a background of possibly hundreds of years development. As an integral part of a faithfully restored ship, this detail would not only be preserved, but also might have to be researched and understood as a part of the restoration, maintenance or operation of the ship. This preserves much more than just the physical component; it preserves its purpose .

3.1.2 Responsibilities.

Ship preservation, possibly more than any other type of museum activity, demands an enormous commitment from a maritime museum. The benefits of ship preservation can only be gained at a price; usually a very large one. A museum which intends to preserve a ship is committed, firstly to a large, lump-sum, initial restoration expenditure and then to ongoing future maintenance expenses for the life of the vessel, which in the case of a museum ship, will hopefully be a very long time. Just as with any other exhibit, the historical value and financial returns must justify the costs. The more that is spent on an exhibit, the greater must be its ability to give historical and monetary returns, otherwise the museum will have to meet the deficit from other sources. Ships are very expensive exhibits to restore and maintain. If a museum is to warrant the money invested in restoration and provide for future commitments of maintenance, a preserved ship must be displayed to its fullest. It can be likened to a piece of expensive capital equipment which must be utilized sufficiently to meet its costs. For full utilization, exhibits of the detail on the ship must also be utilized, a good example being the display of the tradesmen carrying out actual restoration or maintenance work on the vessel. This work would have to be paid for in any case, so that any such utilization as an exhibit will be an added bonus.

It would be a mistake to rely upon the basic attraction of a preserved ship to be the only consiously exhibited feature. If the initial interest of the public is not expanded upon it will soon fade. The directly interesting aspects of the ship have to be consciously and individually exhibited to be appreciated. It is difficult for the members of museum staffs to accept that a large proportion of visitors will not have sufficient knowledge of ships to even recognize its components, let alone understand their function. A good example of the results of poor display technique is the case of the family, who, while inspecting a sailing ship, asked where the engine was. Nowhere on the ship, nor on the shore was there sufficient information to clarify their obvious misconception. So much for the educational value of this million dollar restoration project. This type of reaction was not unique; similar comments being overheard on other occassions.

There are other responsibilities to be met concerning the technical solutions of restoration and preservation, particularly with regard to authenticity. These will be discussed fully in the following sections.

3.2 GENERAL CONCEPTS

3.2.1 Dry or Afloat.

It has been mentioned earlier in the text (Section 2.1) that the methods of preservation are determined by individual interpretations of the various concepts involved and the extent of resources available. Ships are preserved in a variety of ways depending upon the interpretations of each specific organization. There are two fundamentally different methods of ship preservation currently in use, each of which actually representing a different school of thought. These two methods are preservation dry and preservation afloat.

3.2.1.1 Dry Preservation.

Dry preservation is usually carried out on the land, either in a specially prepared dry dock or by using other arrangements such as placing the vessel under cover. It could also be carried out on a slave dock or other similar device, although no such examples are known to exist. There are many well known vessels preserved dry including the 'Victory' in Portsmouth (Bugler, 1966, pp.56-66), 'Cutty Sark' at Greenwich, see Plate X (Heine, 1977, pp.56-66) and the 'Great Britain' in Bristol, (Corlett, 1978, p.188 et seq) all of which are in the open in dry docks. The vessels 'Vasa', see Plate XI (Lungstrom, 1972, p.11) and 'Reliant', see Plate XII (McGowan, 1972, p.39) are also preserved dry, but under the cover of buildings.

There are a variety of reasons why some Maritime Museums prefer dry preservation methods.

Dr. Alan McGowan discussed, in a paper, his thoughts on the major reasons for dry preservation (McGowan, 1972, p.40).

PLATE X. (right)
CLIPPER SHIP "CUTTY SARK"
b. 1869. PESERVED IN DRY
DOCK. (Carr, n.d, back cover)

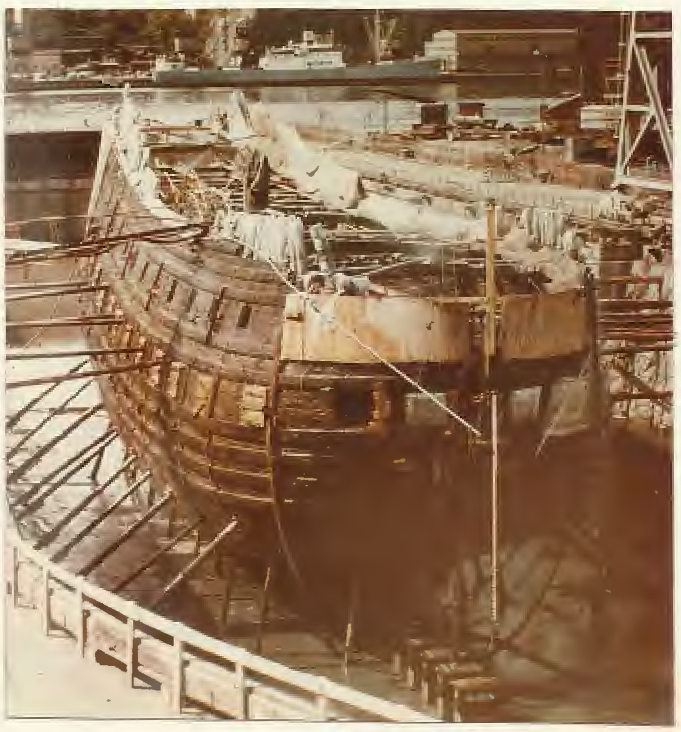


PLATE XI. (left)
"VASA" b. 1633. SHOWN AFTER
BEING RAISED FROM THE
BOTTOM OF STOCKHOLM
HARBOUR IN 1960.
(Heine, 1977, p. 123)

By preserving a ship dry, she is not subjected to the more demanding conditions of immersion. This includes the avoidance of attack by marine borers with wooden hulls and the avoidance of corrosion of iron and steel hulls. To be truly successful in the prevention of any further deterioration, vessels which are preserved dry should also be protected from the weather by being contained within a building enclosing a specially controlled atmosphere. The 'Vasa' and 'Reliant' are preserved in this manner. Vessels preserved dry out in the open may still suffer extensive deterioration from the elements as was found in the case of the 'Victory', for example (Bugler, 1966).

Preservation dry can have the following attributes:

a) Retention of the remaining original portions.

A ship preserved dry can actually preserve the remaining original fabric. This, of course, depends upon the effectiveness of the protection from the elements. The restoration methods usually used are such that they stablise and build up the remaining sections rather than replacing them.

The 350 year old timbers of the 'Vasa' are being preserved by the absorption of a preserving substance, polyethylene glycol, PEG (Lungstrom, 1972, p. 12). Similarly, the wasted iron structure of the 'Great Britain' is being built up with fibreglass (Corlett, 1978, pp. 207-208).

b) Reduced restoration and preservation costs.

For vessels preserved dry, requirements such as strength, watertightness and servicability are less severe than the requirements for a vessel preserved afloat. As the standards are lower, costs of restoration are lower. Maintenance costs are also reduced, partly because of the less severe conditions of the dry environment and partly because there is no longer a need for regular expensive dockings. Although maintenance costs are reduced, they may still be significant. For vessels exposed to the weather, maintenance will have to be regular and effective, particularly with wooden ships which do often suffer more from the weather than from any other cause. In an enclosing building vessel maintenance costs may be reduced to a minimum, but these may be partly replaced by the added costs of construction and maintenance of the building and the controlled atmosphere. Similarly, vessels preserved in the open can also have added costs from the dry berth site and facilities.

Dry preservation does not guarantee reduced rates of deterioration however. Some vessels, particularly wooden examples, have been known to deteriorate at an alarming rate once dry due mainly to insufficient thought given to stabilization. Such rapid deterioration occured with the timber ketch 'Annie Watt' after she was lifted from the water. See Plate XIII (Andrews, 1976, pp. 52-53.)

A major disadvantage of these methods, particularly when modern techniques of preservation are used, is that

PLATE XII. P.T. "RELIANT" b.1907. PRESERVED DRY IN NEPTUNE HALL, GREENWICH.(Greenhill, 1974, p. 13)

PLATE XIII. (right) KETCH "ANNIE WATT" b.1870. SHOWING HER BOWS OPENING UP AFTER BEING PLACED ON DRY LAND.(Author, 1977)

they do not significantly preserve the skills that were part of the construction, maintenance and operation of the particular vessel. It is the constant need to repair or replace on a ship that provides the site for preservation of the various skills. Similarly, in time, authentic repairs can only be made if the skills have already been preserved.

Preservation dry is more suited for certain cases:

i) Where a vessel is extremely large. There will be cases where preservation of a vessel afloat may be impractical in the long term because of the high costs associated with her size. Vessels over, say 4000 tons gross usually would fall into this category, although it is significant that most vessels of this size and over presently preserved, are afloat.

ii) Where a small proportion of the original remains. There have been a number of vessels which have survived because of a freak of nature. They are recovered in a very poor condition and usually require special stabilization and preservation techniques to survive. Examples are the Viking ships (Heine, 1972, p. 135), the 'Bremen Cog' (Heine, 1972, p. 38), the Vasa and the Kyrenia ship.

iii) As a Temporary measure. Some vessels which are to be preserved afloat sometime in the long term future, have to be temporarily preserved dry in lieu of sufficient funds. This was the case with the 'Charles W. Morgan' (Heine, 1972, p. 37) which, although originally preserved dry, is now afloat.

3.2.1.2 Preservation Afloat.

Preserving ships afloat opens up a wide range of display opportunities. They may be displayed as static or operational exhibits and those which are operational may be run on a commercial or non-commercial basis. There are many examples of ships preserved afloat. The 'Balclutha' see Plate XIV (Heine, 1977, p. 13) and the 'Charles W. Morgan' (Heine, 1977, pp. 31-37) are preserved as static exhibits. The 'Skjelskior', see Plate XV (Spies, 1965, pp. 53-63) , the 'Star of India' (Reynard, 1977, p. 13) and the 'Lady Hopetoun' are operational but are non-commercial, while the 'Waverley', see Plate XVI (McHaffe, 1977), the 'Lyttleton' (Andrews, 1976, pp. 62-65) and the 'Earnslaw' see Plate XVII (Andrews, 1976, pp. 116-117) are commercially operated vessels. Preserved ships are also used for more specialized tasks such as sail training.

The most obvious benefit of preservation afloat is the added atmosphere created when the vessel is in her natural element. All ships, when exposed to the effects of salt water and the weather will deteriorate and eventually require repair. These repairs are generally more extensive than those which would be necessary for dry preservation. For reasons of practicality, as well as the all important

PLATE XIV. SHIP "BALCLUTHA" b.1886
PRESERVED AFLOAT BUT STATIC.
SHOWN BEING TOWED AFTER
RESTORATION IN 1955.
(Heine, 1977, p.18)

PLATE XV. S.S. "SKJELSKIOR" b.1915
OPERATIONAL ON A NON-COMMERCIAL
BASIS IN DENMARK. (Postcard)

PLATE XVI. P.S. "WAVERLEY" b. 1947
COMMERCIALLY OPERATING IN
BRITAIN. (Ships Monthly, July 1979, p.4)

PLATE XVII. S.S. "EARNSLAW" b.1911
COMMERCIALLY OPERATING ON
LAKE WAKAPITU, N.Z. (Postcard)

requirements of authenticity, a ship preserved afloat must be repaired using basic 'remove and replace' methods. Those specialized methods used for dry ship preservation are usually not suited for the harsher conditions experienced by a vessel afloat.

Beyond the obvious problem of high costs of preservation afloat there is also a question arising from the long term results of repair. On every occasion repairs are undertaken, new material will be added. Over a period of time, the continuous repair will result in the vessel being a complete replica of the original. The 'Charles W. Morgan', for instance, was in 1972, 50% original and the 'Constitution' (Heine, 1972, p. 45) was only 10% original (Bray, 1972, p. 36). How does this tie in with the concept of a preserved ship?

Some museums reconcile this question by proposing that it is more important to preserve the skills of the past than it is to preserve examples resulting from these skills. (Gardner, National Fisherman, June 79, p. 78). To quote, Maynard Bray, Consultant in Shipyard Preservation, Mystic Seaport, U.S.A.,

> "Preserving old skills is just as much a part of our (maritime museums') responsibilities as preserving old ships'.
> (Bray, 1978, p. 5)

With these concepts, the long term production of an exact facsimilie of the ship through repair is the result of successful preservation of the appropriate skills.

It is possible to utilize these preserved skills as part of the museum's exhibits; producing revenue to offset the high cost of authentic restoration. By careful thought, that which would otherwise be a major burden, can be made into a major attraction. This is an example of the full utilization of exhibits as was discussed in Section 2.3.2.

One disadvantage of the concept of continual repair and replacement lies in the practicalities of the actual work. It is not always possible to repair exactly authentically. Examples of such difficulties include the use of steel because of the non-availability of iron, and the laminating of timbers because of non-availability of large, properly seasoned sections.

3.2.2 Preservation and Restoration.

Retaining an authentically restored ship for future generations is not a straightforward undertaking. This section covers some of the concepts of restoration and preservation pertaining mainly to vessels which are to be preserved afloat. Dry preservation will have differing concepts because of the slightly differing aims. That is, retaining the original as distinct from maintaining authenticity in methods and the end result.

The techniques used by museums preserving and restoring ships are much more specialized than those used for maintenance and repair in a modern commercial shipyard. The techniques differ because of differences in the aims of each. A ship repair yard aims to produce a technically satisfactory repair for a competitive price in a minimal time. A museum, on the other hand, must produce an authentic, technically satisfactory repair within the scope of its limited resources of funds, labour, expertise, etc. In many ways, the standards attained in repairs carried out for authentic ship preservation must be higher than those required for most commercial ship repairs. A commercial yard does not have to worry about maintaining authenticity, nor is it particularly worried about the long term consequences of its repairs beyond the scope of the repair specification.

Ships that last forever cannot be built. Deterioration will commence even before a ship is launched and will continue for the rest of her life. Preventative maintenance is undertaken to reduce the rate of deterioration of the ship. In time, however, the continual wear and tear on the ship while in service will result in deterioration taking its toll where the preventative measures have failed. Eventually, repairs will be necessary to restore strength and/or serviceability to the ship. Once repaired, preventative measures are again used to reduce deterioration and so the cycle continues until economic considerations deem it no longer practical. Continued regular maintenance and repair are therefore, an integral part of the ship's service life.

Some ships of the past have been renowned for their exceptional longevity. The following points list the major reasons.

i) The materials and craftsmanship which went into their construction were such that they were able to withstand the ravages of time. Many older vessels were constructed of materials such as wrought iron and teak which have excellent resistance to deterioration, even in circumstances of extreme neglect. Examples of this include the iron barque 'James Craig' (Andrews, 1976, pp. 27-30) which, after forty years as a tidal wreck, was refloated using a minimum of patching and the ship 'Edwin Fox' (Andrews, 1976, pp. 59-60) which is still intact as a hulk, having been originally built of teak in 1849.

ii) Many of the older ships were constructed with very heavy scantlings giving a large effective allowance for deterioration. For example, the 'Star of India' was built with 20mm thick iron plate bulwarks (Reynard, 1978, p. 2) and 25 mm shell plating below the turn of her bilge.

iii) Labour was cheap and easily available. The all important continuous routine of maintenance and repair was carried out by the ship's crew and in shipyards which continued to maintain a competitive, realistic pricing structure.

iv) Ships did not become technologically and economically obsolete as quickly in the past as they do today. It was worthwhile to build a ship to last and to maintain her accordingly.

Notwithstanding the above, the time eventually would come when a ship became comparitively more expensive to operate, either through higher maintenance costs or for reasons of technical obsolesence. Continued large sum expenditures on conscientious maintenance and repair would have been uneconomic. In order that the ship could operate economically for a few more years, outgoing expenses were cut by carrying out only those repairs immediately necessary and these only in a temporary manner. It is at this stage that many ships become available for preservation. Either they cannot pass the necessary surveys because of the mounting number of temporary repairs and a reluctance to spend further money, or they are put out of service by a major failure which the owner deems is uneconomical to repair. Ships that become available for preservation are, therefore, rarely in good condition and often contain a large number of defects, some of them serious (Bray, 1978, p. 8). There have been exceptions to this. The steam tug 'Forceful' (Andrews, 1976, pp. 33-34) was handed over to a museum while still in survey. On the other hand, there have been some ships acquired as wrecks, suffering from an extreme form of neglect, such as the 'Great Britain' and 'James Craig'.

Whether a ship is acquired in good condition or not, she will one day require major repairs outside the scope of normal maintenance. The following sections on restoration and preservation discuss some of the concepts involved.

3.2.2.2 Preservation.

To preserve a ship is to ensure its continued existence in perpetuity. In many ways the problems of a maritime museum with regard to preservation are similar to those of the maritime industry as a whole. Deterioration of a ship cannot be stopped entirely - it can only be minimized. As for all ships, a museum ship's continued existence will be dependant upon the extent and cost of future maintenance. In normal circumstances, when maintenance costs become too high, a ship is disposed of. This solution is against the aims of a museum, and therefore the repair methods used must reflect a concern for keeping the expenses to be sustained in the future to an acceptable level. The responsibility for the continued existance of a ship in the long term rests squarely on the shoulders of those who repair her in the short term.

Looking at this responsibility in more detail, all repairs on preserved ships should take account of the following.

i) In time, every necessary repair will have to be completed. Even those repairs which are awkward or irksome cannot be postponed indefinitely. Delays in repair will ususally just result in further deterioration of the defect.

ii) No repair can be considered permanent within the expected lifetime of a preserved ship. At some time, probably in the far distant future, the same repair will have to be redone again. Repairs must be, therefore, such that they, themselves, are repairable at a reasonable cost. (Of course anything may be considered repairable given unlimited funds, but this situation cannot be assumed).

iii) All repairs must be maintainable. Repair methods which prevent regular inspections and/or maintenance are a waste of effort because they may have to be undone (possibly at great expense) in the future to maintain the inaccessible regions beneath.

iv) The methods of preservation should be such that they do not unduly conflict with the vessel's authenticity.

For a ship to be preserved, its condition must be first stablized so that it is maintainable. Stabilization means holding the status quo, that is, preventing further serious deterioration. Stabilization includes such work as the halting of corrosion or rot and the prevention of leaking decks. In ships of relatively good condition, the stabilization process may be comparitively simple, but this is rarely the case with ships in poor condition. Such vessels may require a major undertaking just to achieve stablization. Once a vessel is stabilized, further repairs may proceed at a slower pace as the circumstances permit and without serious consequence.

Preservation of a ship automatically ties a museum to the never-ending burden of maintenance. There are many modern products and processes which carry claims of wonderful properties such as maintenance free, will last indefinitely, etc. Although use of such products and methods may at first appear tempting, past experience obviates many of the claims of these 'miracle' cures, because, if they were so successful, the whole shipping industry would have adopted them. Not only do they rarely live up to the properties claimed of them, but also there is rarely any thought given to the long term methods of their removal, repair or replacement.

A good example of the dangers of 'miracle' cures for ship preservation occured in the restoration of the barque 'Joseph Conrad' (Robinson, 1978, pp. 48-51). In 1967 the hull was lined internally with cement and sheathed externally with fibreglass. Ten years later, in 1977, serious doubts arose as to the integrity of the hull because of water leaking into it from beneath the cement liner. The hull had to be docked and major repairs undertaken. Because of the inaccessibility resulting from the internal cement liner, these subsequent major hull repairs were themselves of a type which could not be recommended, that is, doubling plates. As a result the future direction for maintenance of this ship is still uncertain. In this case, the combination of fibreglass outside and cement inside was supposed to at least hold the status quo for a reasonable cost. Unfortunately, not only did it fail, but also no thought had been given to the possible need to remove the cement liner.

To quote Maynard Bray:

> 'Saving ships is an expensive business and anyone who doesn't think so is only kidding himself'. (Bray, 1978, p. 3)

A good guide for the preservation of museum ships are the practises of the commercial shipping industry with regard to long term preservation. These practices, both past and present, have been the results of years of experience, an advantage over the uncertainty of untried practices. In general, good maritime practice requires good accessibility for construction, maintenance and repair. A museum must aim for similar attributes for its ship preservation repairs within the limitations of authenticity. Sources of information on recommended practices include Classification Society Ship Construction rules and books and papers on topics such as shipbuilding, corrosion, protective coatings, etc; both past and present.

3.2.2.3 Restoration.

Restoration consists of the returning of a component to its original form, either by refurbishing an existing component or by replacing it with a replica. Shipyards differ from museums preserving ships in that they do not have to consider authenticity. In a shipyard, as long as the repair fulfils certain necessary requirements of service, its similarity to the original has no significance. Such repairs must be carried out with the use of modern technologies if the yard is to remain competitive.

A museum, on the other hand, must consider the end result of repairs with respect to their impact on authenticity. Components must be restored as well as repaired. Museum ship restoration consists of two distinct types of repair:

i) Repairs necessary for preservation.

These repairs have to be undertaken to ensure the continued preservation, safety and operation of the vessel.

ii) Reversing alterations.

Old ships usually have undergone alterations during their service lives. Part of the task of long term restoration is to return these previously altered features back to their original form.

Both types of repair require attention to authenticity. It is more than likely that repairs necessary for preservation will be more urgent than those reversing alterations. There are two cases,however, where repairs reversing alterations may acquire a special significance. One is where past alterations have had a serious effect upon the character of the vessel. In such a case money spent in the immediate future on reversing the alteration may lead to much increased public interest and assistance. The other case would be an alteration which is in way of preservation repairs. If such a repair required removal of or allowed access to an alteration, then this may be an appropriate time to reverse such an alteration.

Again, quoting Maynard Bray.

> 'The rules for doing work on ships, or any other objects for that matter, sound straightforward enough, put back the same material in the same configuration with the same standards of workmanship and above all make whatever you do reversible. If only doing it were as easy as saying it!' (Bray, 1978, p. 9)

Maynard Bray's above statement describes the most desirable type of restoration; fully authentic restoration. The result of such methods with respect to the preservation of the ship can be accurately determined. Firstly, the repair will last at least as long as the original. Secondly, it is obviously authentic and can stand as a true exhibit, and thirdly, the repair is by its very nature as reversible as the original. In addition, such repairs allow the preservation of skills and their utilization as exhibits as well as ensuring that there is a minimum of drift in authenticity. Such methods are not the easiest, but they are nearly always the best and, as such, should provide a goal to be aimed for.

3.3 THE DILEMMA OF MUSEUMS

The choice of preservation method depends upon the specific circumstances created by each vessel and the particular museum's ability to deal with them. Whether preserved afloat or dry, it is necessary to carry out restoration and preservation in a competent and ambitious manner using the limited resources available to the best possible advantage. The last sentence in the quotation on the previous page from Maynard Bray's paper,

> '... If only doing it were as easy
> as saying it!'

is a statement of the dilemma facing museums. The long term ideal of preserving a ship completely authentically is subject to constraints which limit the resources available to the museum. These constraits are determined by the extent of funding allocated to a project, which in turn, determines the limits of materials, capital equipment, labour, skills and time. As resources are limited, it is usually not possible to reach an ideal standard of authentic preservation in the short term. Short term goals have to be set; which, because they are less demanding than the ideal, are attainable within the limits of resources. These short term goals can be regarded as the first stage of attaining the ideal. They must be such that they create the most impact and therefore are usually designed to,

i) Ensure that the vessel continues to exist (at least in the short term). This includes stabilization considerations.

ii) Attain a sufficient standard so that the ship can be utilized as an exhibit and by this means earn further funds to continue towards the ideal.

iii) Provide a basis on which further work can be carried out on a smaller scale and without fear of waste associated with good work being put over existing areas in poor condition.

The nature of short term goals must result in compromise during the restoration. In general, although compromises are necessary in the short term, they should not be of a type which would compromise the attainment of the long term ideal. Careful thought must, therefore, be given as to the consequences before compromises are allowed. Some points which can be used to guide decisions on compromises are listed below,

i) Compromises, just as all repairs, are not permanent within the life of a museum ship. All compromises should be designed and regarded as reversible. Such compromises, although necessary in the short term, can be progressively eliminated as part of an ongoing maintenance and restoration programme in the future as further funds become available.

ii) Compromises which would endanger the safety of the public and people within the museum cannot be allowed. This very definite responsibility of ship preservation includes such examples as the strength of spars and rigging, the integrity of a hull or the reliability of a boiler. This also implies that compromises in the quality of workmanship or materials are unacceptable.

iii) Compromises in work for preservation will often have more serious consequences than compromises in authenticity. The preservation commitment demands continuous expenditures on maintenance, the level of these expenditures being directly determined by the quality and extent of previous repairs.

iv) Compromises should be avoided which would require a massive undertaking to reverse or eliminate in the future. Where a major repair is being undertaken, it is worthwhile to attempt a high standard of preservation and restoration. By the same token, compromises are best placed where they are easily accessible for reversal.

v) It is better to isolate compromise if possible. Situations may arise where the priority to repair on area is very low. It may be better to carry out repairs to areas of high priority to a high standard and to defer commencement of the repairs to the areas of lower priority, rather than have a general lowering of standards over all the areas repaired.

vi) Compromises in view of the public should not be such that they detract significantly from the character of the vessel. Some compromises may have to be disguised so as to retain an authentic atmosphere. Even though such disguised compromises may appear authentic and as such, would be given very low priority for future elimination, the museum must remain sincere with itself and with the public as to their true nature and lesser historical significance.

vii) Compromises which are not necessary are defects in the ship, just as are defects caused by deterioration, damage or alterations in the past.

Careless acceptance of compromises will actually damage, or at best, reduce the significance of a vessel as a museum ship and will result in a waste of funds rather than a saving. When determining the basis upon which decisions regarding compromises are to be made, it should be remembered that short term stringencies of finance will hold little significance when attempting to justify past poor preservation and restoration techniques in the distant future. Although keeping within the limits of expenditure is of great importance in the short term, it will be the appropriateness of the policies chosen and the quality of the resulting restoration with regard to the long term aims which will be judged when viewed from the future.

Despite the limited resources, the attainment of the long term aim of fully authentic preservation must be kept in sight when determining short term goals. If this is not done, the replica, resulting from continual repair, with evolve away from its original form. To determine the short term goals, the future resources of the particular museum must be estimated. This is a difficult task especially as they will be effected by any increase in public interest resulting from the restoration process itself and its effectiveness as an exhibit. There are risks involved when preserving ships; the unknowns of resources and the full extent of repair. These risks can be reduced by determining a realistic, yet far-sighted policy which reconciles the needs and limitations of the short term with those of the long term.

CHAPTER 4

PRELIMINARIES

4.1 PRELIMINARY SURVEYS

4.1.1 Background

After acquisition in 1968, the museum kept the 'Waratah' operational until 1972; when, in view of her obviously poor condition, it was decided to lay her up. The 'Waratah' was showing signs of serious and extensive deterioration and her continued operation would have invited risk of a major failure and serious accident. Because of a lack of funds, the museum had not been able to carry out any worthwhile repairs; all the museum's repairs since her acquisition being only of a superficial nature. Subsequent to her being laid up, no useful work was carried out on her until 1975. At this time, the museum, realising that she was in danger of sinking where she lay and having access to limited funds, began considering her future.

4.1.2 Feasibility Surveys

By 1975 the 'Waratah' presented a very sorry sight. The exterior of her hull above waterlevel was encrusted with a 10mm thick layer of rust totally obscuring the wasted plating beneath. The condition of the hull below water-level was uncertain as the museum had never had the opportunity to inspect her dry. Her last previous slipping had been in 1966. All that could be seen of the hull exterior below the waterlevel was a very thick layer of marine growth. More could be seen of the interior of the hull. The bilges were fouled with grease, ash, coal and rust. Where the hull and structure were sufficiently exposed to be inspected, large areas of metalwork were discovered which were covered with a heavy layer of rust, particularly in the bunkers and bilges. See Plates XVIII, XIX, XX and XXI. On deck her appearance was no better. The bulwarks (Plate XXII) were heavily corroded, badly dented and buckled. The timber decks had weathered extensively, leaked rain-water profusely and had rotted in a number of areas. Grass and moss actually could be seen growing out of these decks.

The 'Waratah's condition appeared so horrific that there were some doubts expressed as to whether it was practical or, indeed, worthwhile to preserve her. In addition, there were fears that she might not be sufficiently strong to withstand the stresses imposed by a docking or slipping operation.

Two independent groups of surveyors were asked to inspect the 'Waratah' to give an indication of the feasibility of preserving her. One group were Department of Defence surveyors, Frank Bell and Bill Hawkins; the other Lloyd's surveyors, Frank Last and H. Gerard. The conditions for inspection of the ship were not conducive for detailed examination. Little had been done to open up the ship.

PLATE XIII. (left)
PORT WING BUNKER PRIOR TO RESTORATION WITH CEILING REMOVED SHOWING CORROSION OF HULL BENEATH. (Author, 1977)

PLATE XIX. (below)
HEAVY CORROSION IN PORT WING BUNKER SHOWING HOLES IN SHELL AND WASTED STRUCTURE PL.E7P FRS.29-30 (Author, 1977)

PLATE XX. EXTENSIVE CORROSION IN STOKEHOLD BILGE. MUCH OF THE STRUCTURE SHOWN INCLUDING KEELSON WAS TO BE REPLACED FRS. 28-32 (Author, 1977)

PLATE XXI. CORROSION IN FORWARD ACCOM. BILGE. FRS. 41-52 (Author, 1977)

The bilges were still fouled and a wooden ceiling lined most of the bunkers. A large amount of loose stores in both forward and after accommodations could not be removed at that stage and the cabin decks were still in position. Few areas of the hull had been descaled and the vessel had to be inspected whilst in the water. With such unfavourable conditions, both feasibility surveys could only be of a cursory nature.

Both surveys (See Appendix D and E) indicated that restoration appeared feasible; the report of Messrs Bell and Hawkins actually stating this.

As a result of these surveys, the museum decided to:

i) Slip the 'Waratah' as soon as possible to enable the hull exterior to be inspected and to allow the repair of any urgent hull defects.

ii) Commence dismantling of the ship, cleaning her out and generally preparing her for a more detailed inspection.

iii) Undertake to do only temporary repairs at that stage as it appeared that a major restoration commitment would be too high a strain on the museum's resources.

Initial estimates were made in late 1975 and early 1976 (Dight, 1975) covering the cost of slipping and immediate repairs.

4.1.3 Opening up for Inspection.

As was recommended by the surveyors, the 'Waratah' had to be opened up and prepared before a more detailed inspection was possible. The only effective method of surveying 'Waratah' was to inspect each component individually requiring a reasonable degree of accessibility throughout the ship. As it was hoped to carry out some hull repairs during any proposed future slipping, it was necessary to obtain a more detailed picture of the condition of the hull prior to this first slipping by ultrasonic testing of the shell. To enable ultrasonic testing to be carried out the following work was completed.

- i) Removal of all loose stores.
- ii) Removal of remaining coal and coal dust from bunkers.
- iii) Lifting of wooden ceiling in bunkers.
- iv) Removal of floor plates in stokehold and engine room.
- v) Lifting of cabin decks.
- vi) Pumping dry and cleaning of bilges.
- vii) Pumping dry of peak tanks.

4.1.4 Ultrasonic Survey of Shell.

Ultrasonic testing was a very suitable method for determining the condition of the ship's hull whilst still in the water. The aim of the ultrasonic testing was to reveal the existence and location of plates which had suffered a significantly large overall reduction of thickness through deterioration. Such plates might result in catastrophic consequences with regard to structural strength and watertight integrity if they failed.

The tests were carried out by students of the University of New South Wales as an experimental engineering report (Gardner, 1976). I had had some previous experience with ultrasonic testing whilst doing industrial training at Garden Island.

4.1.4.1 Principles.

The principles of ultrasonic testing are reasonably straight forward. An ultrasonic signal is generated and transmitted via a device known as a probe, into the material to be tested. The signal travels through the material until it comes into contact with a material interface, that is, a boundary between two differing materials. Such an interface may be an inclusion within the material, for example slag in a welded joint; or, as in the case of thickness testing, the opposite surface of the material being tested. At a material interface, a portion of the signal is reflected back through the material to a receiver contained in the probe. The ultrasonic signal is converted to an electrical signal within the probe and is then fed into a cathode ray oscilloscope (CRO). The CRO screen has an ordinate scale of time against an absissae scale of signal intensity. As the speed of sound within a given material is constant, the time taken for the signal to travel from the transmitting probe, through the material to the opposite surface and back again to be received by the probe, is directly proportional to its thickness. The time (thickness) scale on the CRO screen is calibrated by the use of a stepped test block of a similar material and with known thicknesses. (See Figure 4)

4.1.4.2 Procedure.

The ultrasonic testing machine used was a KRAUTKRAMER USK5. There are other ultrasonic testing machines available with digital output, but for this type of work the CRO output is superior because the signal amplitude and shape given by this display can be used to give an indication of the creditability of the signal.

All testing was done from the inside of the hull. Readings were taken over as much of the shell as possible. On average, two readings per frame space, per strake of plate were obtained. Where there were reasons to suspect localized corrosion, these particular regions were chosen as sites for testing; including the region of wind and waterline and sites of localized pitting on the inside. Where there were no reasons to suspect localized corrosion, readings were taken at random.

To enable readings to be taken, small areas of plate had to be thoroughly cleaned of all paint and rust on the inside surface, exposing the bare steel. This descaling was done by hand using chipping hammers and wire brushes. Once cleaned on the inside, a reading could be taken. There was no need to prepare the opposite outside surface of the hull plates because the presence of rust, marine growth or paint on this surface would have no effect on the ultrasonic reading. Prior to a reading being taken, the plate in the immediate vacinity was struck with a hammer to obtain an idea of its thickness through the sound of the ring. Readings were taken using a jelly hand cleaner as a transmitting medium between the probe and the surface of the plate. The probe was placed on the surface of the plate and moved slightly until an acceptability formed signal was displayed on the CRO screen. The thickness displayed was compared to the thickness indicated by the hammer test. If they were compatible, the reading was recorded, if not the thickness was further investigated by taking readings at other sites in the immediate vicinity.

4.1.4.3 Results and Comments.

The readings obtained were plotted on a shell expansion (See Figure 5). The maximum allowable reduction of thickness was set, after consultation with the Lloyd's surveyors, at 33% of the original thickness as shown in Figure 6. Those readings which were less than 67% of the original thickness have been marked on the above plan as have the position of holes discovered during the ultrasonic testing. Those holes found below waterlevel were plugged with softwood bungs to stop the leaks.

FIGS 4A AND 4B ULTRASONIC TESTING

FIG 4A
CALIBRATION

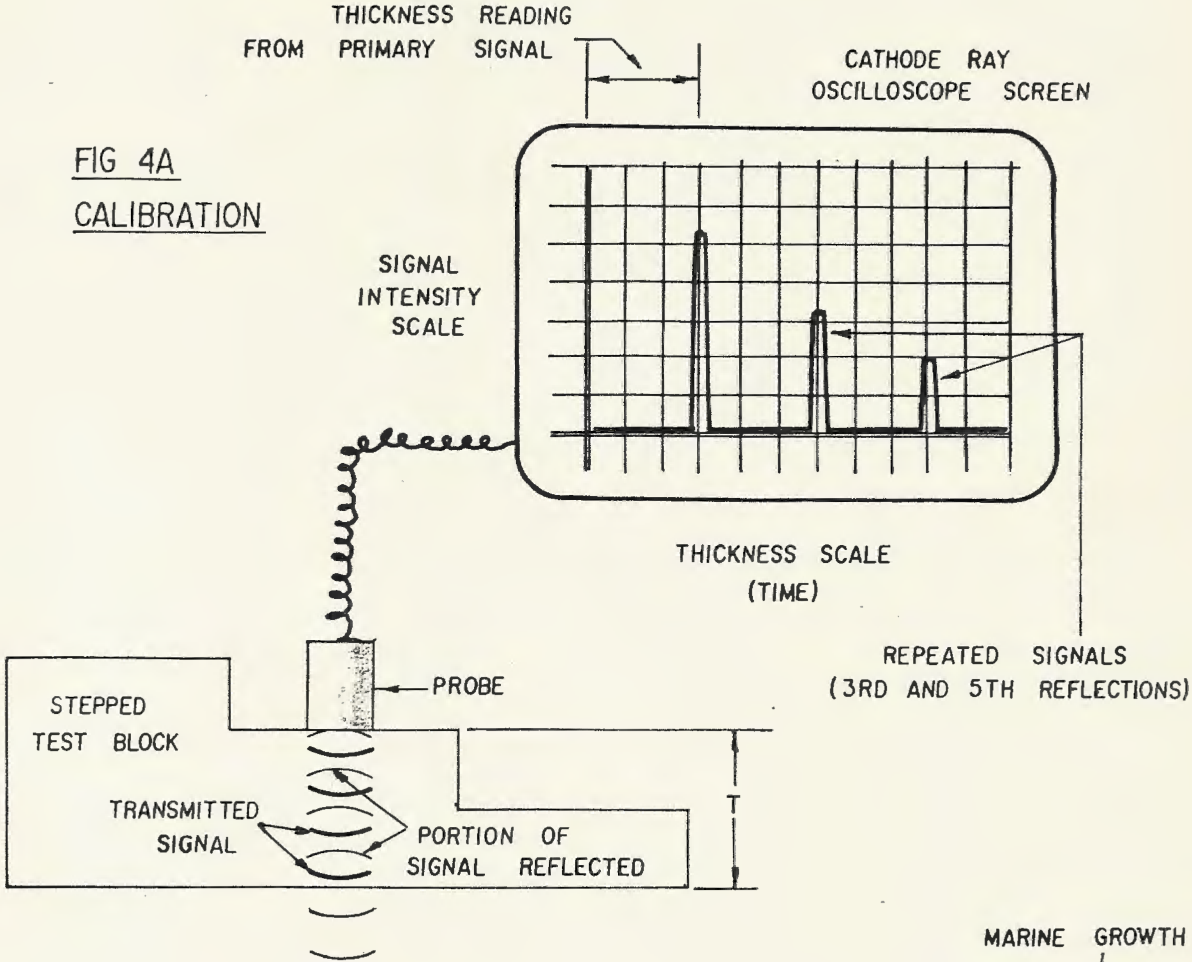


FIG 4B TESTING OF SHELL

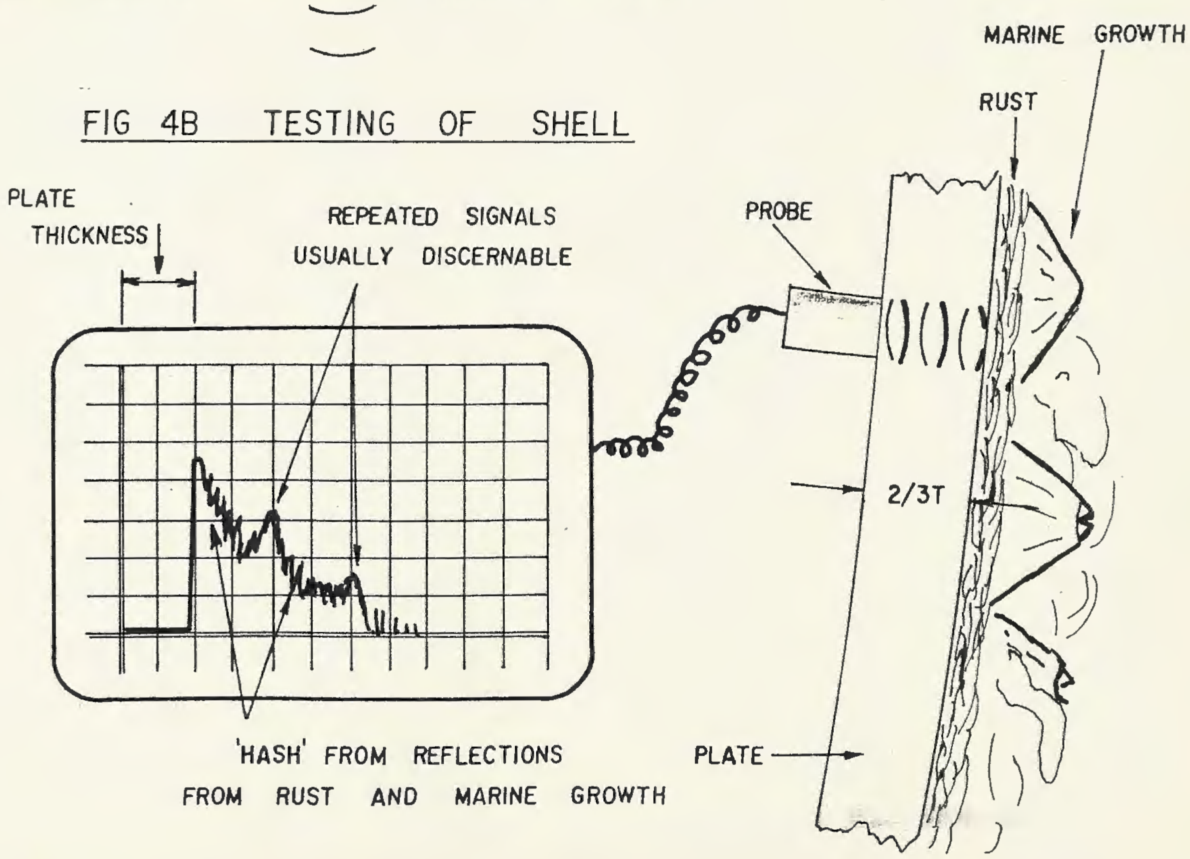


FIG 5

S.T. "WARATAH"

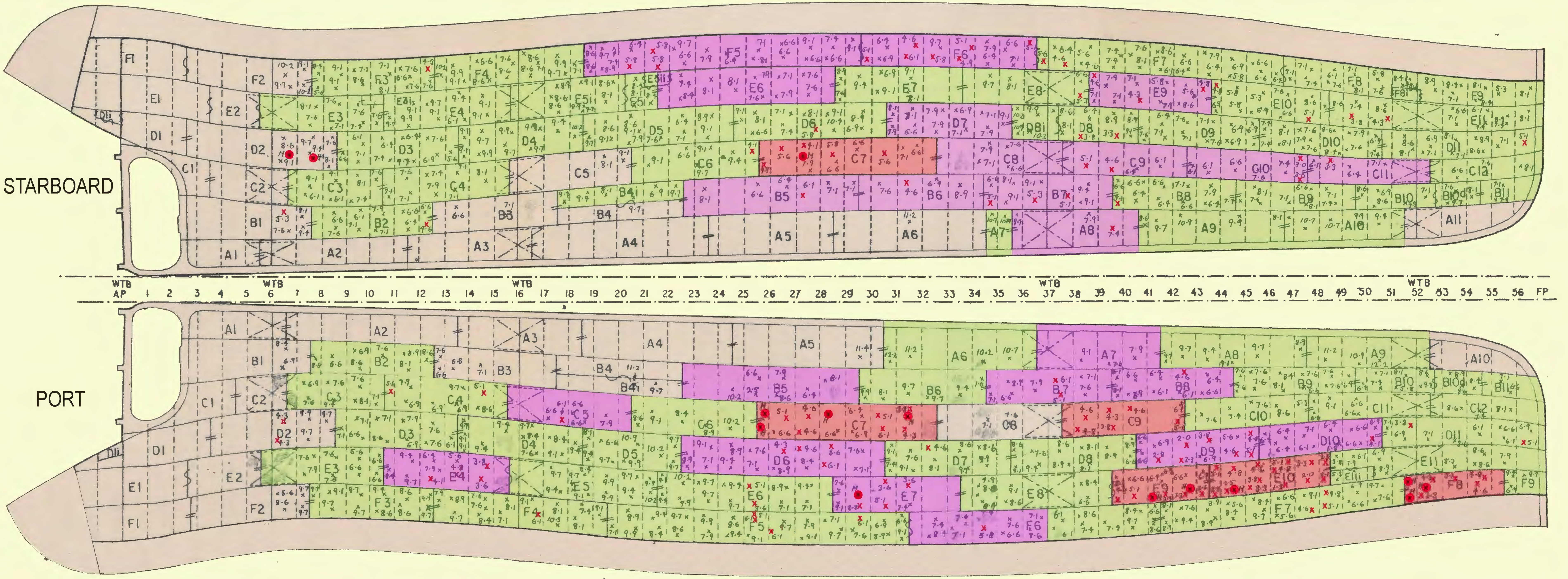
SHELL EXPANSION

SHELL ULTRASONIC THICKNESS SURVEY 1976

KEY

- × READING < 67% OF ORIGINAL
- ●H HOLE IN PLATE
- PLATE AVERAGE < 67% OF ORIGINAL
- PLATE AVERAGE 67-80% OF ORIGINAL
- PLATE AVERAGE > 80% OF ORIGINAL
- INSUFFICIENT INFORMATION

READINGS IN MILLIMETRES



FOR 11·1mm (11mm nom.) PLATE, 67% REMAINING = 7·4mm
" 9·5mm (10mm nom.) " , " " = 6·4 mm
" 7·9mm (8mm nom.) " , " " = 5·3 mm

UPPER-ORIGINAL SHELL THICKNESSES

- 11mm (·44")
- 10mm (·38")
- 8mm (·31")
- 6mm (·25")

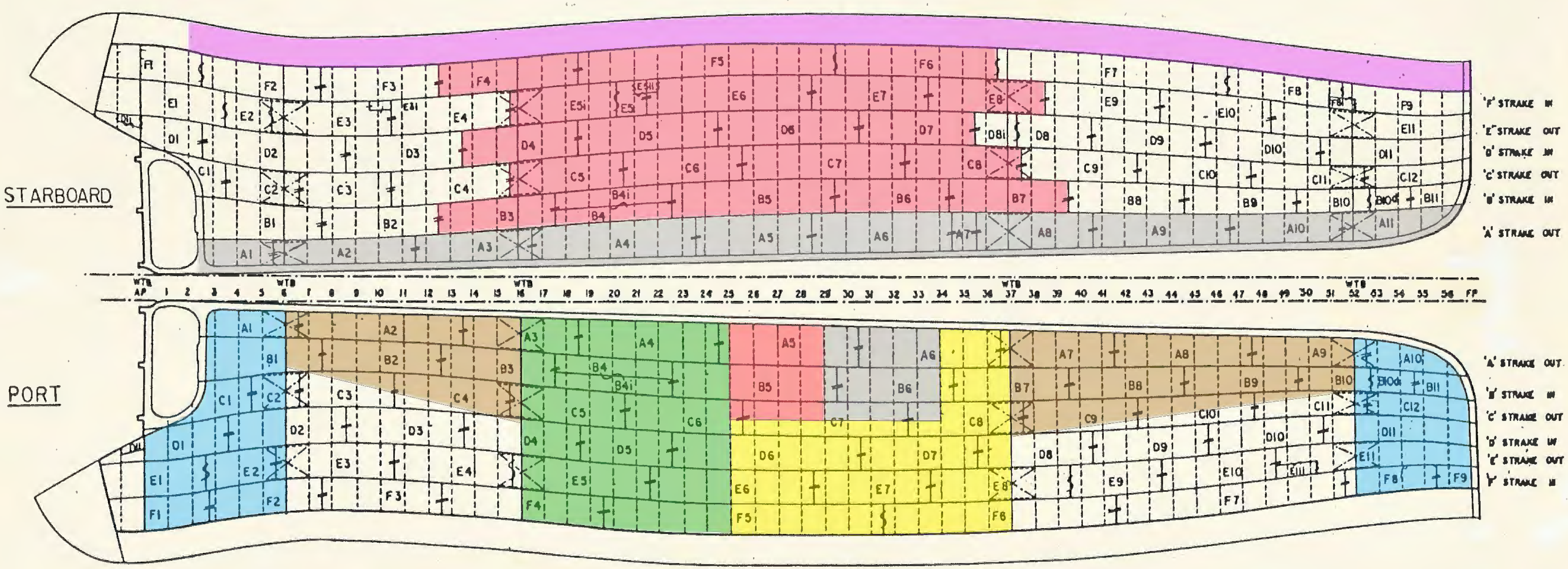
FIG 6.

S.T. "WARATAH"

SHELL EXPANSION

LOWER - INTERNAL ARRANGEMENT

- PEAK TANKS
- ACCOMMODATION
- ACCOM. BILGES
- STOKEHOLD
- BUNKERS
- BOILER SPACE
- ENGINE SPACE



Conclusions drawn from the results of the ultrasonic tests were subject to a number of limitations. Although the results may have given a good indication of the average thickness of those plates tested, there was still a possibility of undetected local wastage and holing from pitting existing in what otherwise appeared to be acceptable plates. Although such defects would be undesirable, their localized nature would reduce the significance of their failure and would not greatly increase costs if discovered on the slipway.

Readings could not be obtained for all the plates due to inaccessibility and time limitations. 'A' and 'B' strakes, see Figure 3, were covered by the concrete in the bilges. A number of test holes were chizeled through the concrete in 'B' strake to obtain some representative readings of the plating beneath. The shell plating at the level of the cabin deck in the forward accommodation was inaccessible for testing because of portions of deck remaining. Because the equipment was on loan and time was limited, the after peak tank shell plating was not tested. It was felt that the exclusion of this area from testing would not be of great significance as the plates appeared in reasonably good condition and in any case defects would not have a major effect on the vessel as a whole.

A feature of wrought iron plating is its lamellar structure. Laminations of slag run parallel to the direction of original rolling (Corlett, 1978, pp. 22-23). These laminations could possibly result in erroneous readings because of the effective material interface present. By comparing the rough indication of the plate thickness obtained by listening to its ring when struck with a hammer, to the ultrasonic reading from the same region, the probability of an erroneous reading being recorded was reduced.

4.1.5 Preliminary Slipping.

The various surveys which were undertaken provided a basis upon which work on 'Waratah' could commence. As all estimates of the probable costs still appeared to oppose the commencement of a major restoration commitment in the near future, it was decided that the restoration would have to be done in stages, the first stage designed to render the hull watertight and reasonably sound. The museum had no repair facilities of its own, so it was envisaged that the hull repairs would have to be undertaken at a commercial shipyard. A professional shipyard estimator, who was a member of the museum, prepared an estimate of the probable cost of repairs based upon the various survey reports and his own inspections. (Dight, 1976). The repairs, upon which his estimates were based,were designed to be sufficient to temporarily enable 'Waratah' to operate on the harbour. The museum decided that it would proceed with repairs under the guidelines of this estimate and set a ceiling to the maximum allowable cost of $60,000.

Several commercial shipyards were approached to undertake this work, but they were found to be reluctant to take on such a project. The reasons for this reluctance are discussed in Section 4.2.1. Vickers Cockatoo agreed to slip the 'Waratah' for a preliminary inspection. Their plan was to inspect the vessel once she was on the slip and, from their observations, determine the extent and probable cost of the repairs required. The management of Vickers Cockatoo ignored the results of the ultrasonic survey of the hull because they felt that the laminations in the iron (See Section 4.1.4.3) would have resulted in inaccurate readings.

In June 1976 the 'Waratah' was slipped on the Cockatoo Island slipway, see Plate XXIII. As the hull was lifted clear of the water, the marine growth of a decade was revealed. This growth was mainly coral; little weed having survived the shadow of the building at Blackwattle Bay under which she had been moored for three years. After ten years, there was little paint left remaining on the hull. Patches of bare rusted iron were exposed where sheets of rust had detached from the hull due to the weight of the attached marine growth. This feature, peculiar to iron hulls, was also observed on the 'Great Britain' when she was retrieved from the Falklands (Corlett, 1978, p. 6). When the remaining growth was removed from the hull, the iron plates beneath were found to have only a relatively thin layer of corrosion on the exterior surface.

Subsequent inspections by the Vickers Cockatoo staff were not encouraging. It was their opinion that the museum might have to be prepared to replace most of

PLATE XXII. SHOWING CORRODED BULWARKS AND A BUCKLED EXAMPLE OF ONE OF THE FEW ORIGINAL SPUR STAUNCHIONS WHICH REMAINED (P. Johnson, 1976)

PLATE XXIII. "WARATAH" ON COCKATOO ISLAND SLIP FOR PRELIMINARY INSPECTION. (Author, 1976)

'Waratah's' shell plating. A figure of quarter of a million dollars was mentioned for a welded repair of the shell. This figure included a contingency sum for repairs necessary to framing in way of replaced plates. No work other than that requiring the services of the slipway was included in this figure.

After these discussions, it became apparent that the museum would have to seek alternative arrangements to repair the 'Waratah'. Despite the disappointment resulting from the rather negative discussions with Vickers Cockatoo, this preliminary slipping was of great benefit. From this time, the uncertainties regarding her ability to withstand the stresses of slipping were finally dispelled. There was a large increase of interest in the 'Waratah' both within the museum and the public as a result of the increased activity. Also, while on the slip some limited short term protection was given to the hull. It was scraped and painted, zinc anodes fitted and sea cocks overhauled.

4.2 RESTORATION DRY BERTH PROPOSALS

After the preliminary slipping at Cockatoo Island, investigations were begun to find the most suitable method of carrying out the hull repairs. The proposals put forward were of two different types:

i) The use of existing ship repair facilities at an established yard.

ii) The establishment and operation of a special facility by the museum just to repair 'Waratah'.

4.2.1 Existing Ship Repair Facilities.

There were a number of proposals suggesting the use of existing ship repair facilities, both within Sydney and elsewhere. The size of 'Waratah' eliminated the use of smaller privately operated slipways which were commonly used for ferries, fishing craft and pleasure boats. Those facilities of sufficient size, in and immediately near Sydney, were all either commercially operated or government owned. Initially, the museum made enquiries at the various yards suitable, hoping to find one which would be willing to sponser the repairs even if only partially. No such sponser was found and all indications were that the museum would have to pay for most of the work. The previous discussions with Vickers Cockatoo had already provided the museum with an indication of the probable high costs and problems of carrying out repairs at such yards. The \$60,000 which the museum was prepared to allocate to the 'Waratah' was not considered sufficient to secure the hull. Being so limited in funds any job growth occuring from unforseen circumstances during the repairs would face the museum with a serious debt, particularly if these additional repairs had to be completed before she could vacate the slip. The ease at which money would be absorbed by repairs at the established yards can be appreciated when considering the following example. To carry out the shell plating repairs which were later to be done by the museum; the cost, using a 1975 estimate, would have been over $150,000 for welded replacement excluding slipping costs, blasting, painting and any work on the framing and structure. Under these circumstances any increases in the work necessary to make her watertight would have had serious consequences and, if obviously beyond the Museum's means, might have required the 'Waratah' to be dismantled where she lay on the slip.

The combination of the Museum's lack of money and the shipyard's wish to vacate the slipway as quickly as possible to meet future commitments would have allowed little consideration to be given to maintaining standards of quality or authenticity in the methods of repair.

An advantage of utilizing the services of an established yard would have been that there would be no need for the museum to make large investments in capital equipment prior to the commencement of restoration as all the existing facilities investigated were well equipped to handle the necessary repairs. As well, the use of existing facilities would have avoided the difficulties and risks of establishing and operating a repair facility using the, as yet, untried resources within the museum. Although these would have been advantages in the short term, the lack of capital equipment and expertise gained by the museum through the project, despite the high expenditures on the repairs, would have left the museum ill prepared for any future restoration and maintenance work on its vessels.

The use of facilities outside of Sydney were also considered, including shipyards at Newcastle and Singapore. The additional cost of delivering the vessel and the difficulties of remote management of the project would have more than offset any possible savings.

Without exception, the shipyards in Sydney were, at best, reluctant to even consider the project. Their major fears were the possibility of drastic job growth and whether the museum would have the resources to pay for any additional burden. Other reasons were given for their reluctance including busy future scheduling for the slips, possible industrial relations problems, dislike of major abrasive blasting operations within their yards and in the case of government yards, the wish not to set a precedent.

In view of the indicated high costs and the obvious reluctance of the various yards, further pursuit along these lines did not appear worthwhile.

4.2.2 Museum Operated Facilities.

The alternatives to utilizing the various established facilities were a number of ambitious proposals involving the Museum in the establishment and operation of its own special facilities to restore the 'Waratah'. These alternative proposals would provide a number of distinct advantages over the proposals discussed previously:

i) The Museum would be able to expect a reduction in the costs to carry out the various repairs.

ii) There would be more attention given to aspects of quality and authenticity of repairs.

iii) The associated acquisition of capital equipment and expertise necessary to undertake the repairs would prepare the Museum for the future commitments of further restoration and ongoing maintenance of its fleet of ships. Not only would this save costs in the future but also would preserve the skills and could provide a useful future exhibit.

The lower cost, higher quality and authenticity of repairs would result from a number of factors. Firstly, the Museum would have a greater flexibility in its sources of labour. A choice could be made between staff, volunteers and contractors to undertake each particular job without fear of industrial dispute. The degree of enthusiasm and dedication inherent in such a workforce would yield results of quality and authenticity which would be difficult to obtain from any other source. The second factor would be the lesser pressure from time constraints. The project could be geared more to the Museum's cash flows and there would be more time to plan appropriate solutions for problems uncovered during repairs. Greater time also would allow more detailed research to be completed on historical and technical aspects as well as possible sources of donations.

The third factor would be the improvements possible to management of the project. Decisions would be made and implemented by people who would be in a position to have a better understanding of the basic concepts of the Museum. The result would be a better control of expenditure and authenticity within the restoration as a whole.

There were two points which had to be considered for each of the proposals. The first was that a suitable site had to be found. Such a site would have to be near or on the waterfront and would have to be available for a reasonably long period at a minimal cost. Additional facilities of undercover workshop space, vehicular access and crainage would also have to be considered as they would influence the costs of establishement.

The second consideration was that the Museum would have to have faith in its ability to carry out these ambitious proposals. The resources within the Museum available for the task were as yet, untried and so there would be some risk involved. The first risk would be the high initial expenditure on capital equipment necessary to establish the site before any results would be seen on the ship herself. Once the facilities were established, the other risk would be the technical ability of the Museum to actually carry out the work required on the ship.

There were three proposals suggested. They are discussed in the following sections.

4.2.2.1 Lifting by Crane.

The Royal Australian Navy maintains a number of its support craft at Garden Island Naval Dockyard by lifting them bodily out of the water with the use of a crane. Their smaller craft are lifted with slings and/or lifting lugs attached to the hull. The larger vessels are lifted in a specially constructed cradle. The crane used for such lifts is the dockyard's 250 tonne hammerhead crane. The largest craft to be lifted by crane at Garden Island is the Diving Tender 'Seal', a vessel of similar size to that of the 'Waratah'.

The proposal of lifting the 'Waratah' onto the land using a crane was investigated. As with the 'Seal', a cradle would have to be used during the lifting operation to avoid the higher longitudinal and local stresses which would be associated with the use of slings alone. The services of a crane would have to be obtained to perform the lifting operation. The crane could be either floating, stationary, or mobile depending on availability and the particular site. Only a crane with a good reach and height of jib at the rated load would be suitable for such a task.

The major requirements for the site to take the 'Waratah' once lifted from the water would be that it was level and close to the water. Care would have to be taken in the choice of a site to ensure that there was accessibility for a number of different types of crane, otherwise the ship could be stranded if a particular crane was put out of service whilst repairs were progressing to the ship on the land. Supporting facilities such as mentioned earlier would also have to be considered.

4.2.2.2 Recommisioning Sydney Slipway.

In 1974, Sydney Slipway and Engineering Pty. Ltd, operators of what was then Sydney's largest slipway, went out of business. It had been said that the company had ceased its operations because impending repairs, which were necessary to the slipway below the tidal level,could not be justified by the expected future income. The site had subsequently been sold and the slipway cradles and winch were partially dismantled. A proposal was investigated to recommission this slipway to a sufficient standard to take the 'Waratah'.

The slipway had originally been used for vessels many times the displacement of 'Waratah'. It was felt, therefore, that; depending upon the type of defects present below the tidal level, the Museum might not have to undertake the repairs. Recommisioning of the slip would have entailed the construction of a new cradle. The new cradle could have been substantially simpler and lighter than the original. Any debris or silt which had collected on the rails would have to be removed and the slipway winch repaired or substitute found. Adjoining the slipway site were the original workshop buildings and a number of antiquated cranes. If the slipway were recommissioned these would have proved invaluable.

Initial enquiries unfortunately indicated that the site could not be made available for this purpose; the new owner intending to place dolphins directly in way of the slipway entrance.

4.2.2.3 Recommissioning Blackwattle Bay Dock.

In the early 1950's the Electricity Commission of N.S.W. constructed an ash loading facility at Blackwattle Bay. Ash, brought by truck from the coal-fired Pyrmont power station, was to be loaded into hopper barges via hoppers within the facility. These barges were then towed out to sea where the ash was dumped. As part of the original construction of the ash loading facility, two dry docks were incorporated into the design for maintenance of the hopper barges. Pumps, a pump room, a dock gate and cranage were supplied to service the docks.

By the 1960's the ash loading facility had fallen into disuse. Much of the dock equipment had been removed and scrapped. The Museum had had associations with the site since 1973 when a lighter, which was part of the Museum's mooring arrangements at an adjacent site, sank one night forcing the Museum to find alternative moorings for its ships. The Museum moved into the disused ash loading facility where, through the generosity of the Electricity Commission, it had been allowed to remain.

It was proposed that the Museum should recommission one of the two docks to take the 'Waratah'. Such recommissioning would require:

i) Permission from the Electricity Commission to use the site.

ii) Acquisition of a dock gate.

iii) Acquisition of pumping equipment.

iv) Removal of accumulated silt and debris from the bottom of the dock.

v) Acquisition of keel blocks and shores.

The site at Blackwattle Bay had a number of favourable features. Work in the dock could largely be done under the cover of a building. Both cranage and workshop space were available and the Museum would not even have to move its operations.

There would be problems, however, using the dock including the difficulty of removing the mud from the dock and the low clearance beneath the building which would require the removal of 'Waratah's' top hamper above boat deck level.

4.2.3 Elimination and Further Investigation

Two of those proposals considered appeared the most practical; they being lifting 'Waratah' out of the water by crane and recommissioning the Blackwattle Bay dry dock. Investigations had indicated that the cost of repairing the 'Waratah' in an existing commercial or government shipyard would have been prohibitively expensive and the results would have, more than likely, been unsatisfactory (not to mention the difficulties of finding a yard which was prepared to do the work). Because of the unavailability of the site, the proposal to recommission the Sydney Slipway could not progress further. Future activities were therefore concentrated on researching the two most practical proposals.

4.2.3.1 Lifing by Crane.

The 'Seal' which was mentioned previously in Section 4.2.2.1 had very similar dimensions to those of the 'Waratah' as can be seen in the following comparisons (Andrews, 1973, p. 48).

	SEAL	WARATAH
DISPLACEMENT (tonnes)	120 (Standard)	100 (1976)
LENGTH BP (metres)	30.5m	30.5 m
BEAM (metres)	6.7m	6.2 m

Because of the similarity of dimensions, the cradle used to lift the 'Seal' was used as a basis upon which to develop the design of a cradle for 'Waratah'. The cradle used to lift the Seal is shown in Figure 7. As can be seen, this cradle was in contact with the keel of the vessel at two points along its length during the lifting operation. Once on the shore, additional supports were positioned along the keel to distribute the loads.

In view of her deteriorated condition, this design would have to be altered to support the 'Waratah' more effectively during the actual lifting operation. A preliminary arrangement for a cradle to lift the 'Waratah' is shown in Figure 7. The following list the major proposed alterations from the original basis design.

i) Extension of the overall length of the cradle from 15 metres to 24.5 metres to reduce the hogging moments caused by the overhang of the bow and stern.

ii) Provision of intermediate transverses along the length of the cradle to support the keel more evenly.

iii) Provision of a third longitudinal beneath the keel of the ship to reduce the distortion of the intermediate transverses and to ensure that they take a fair proportion of the load.

Details such as the position of lifting points and the major transverses would be similar to the basis design.

FIGS 7
LIFTING CRADLE

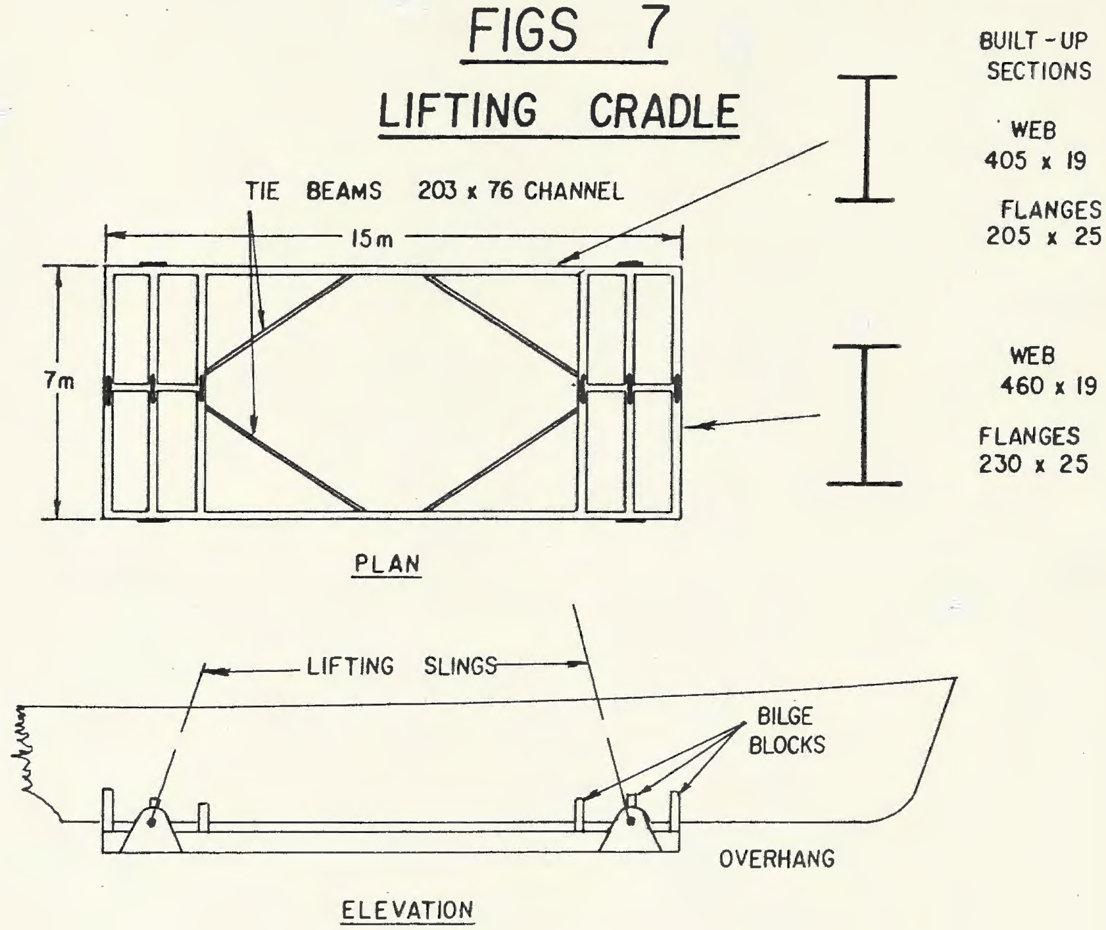


FIG 7A

LIFTING CRADLE
GARDEN ISLAND

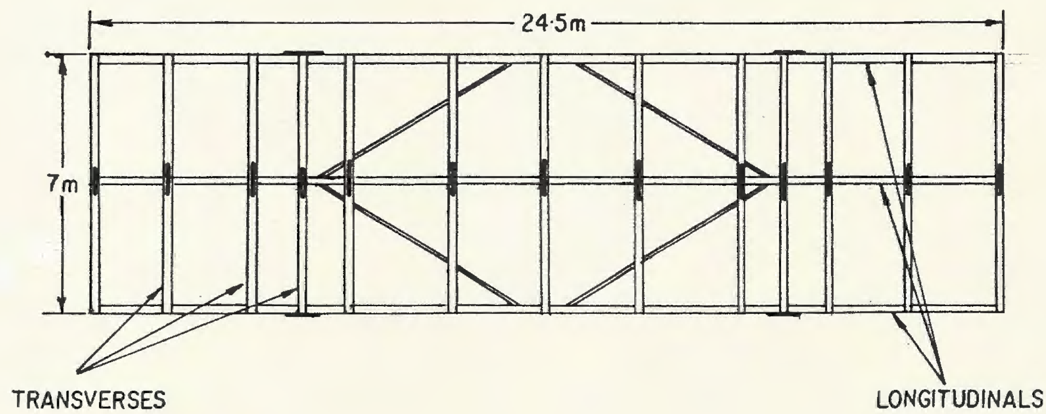


FIG 7B

PROPOSED LIFTING CRADLE

The cradle at Garden Island had a nett weight of 12.4 tonnes. By increasing the steel weight in the proportion of the lengths and then adding an additional weight to account for the intermediate transverses, an estimate of the steelweight for the proposed design was obtained. This came to 21.5 tonnes. Based on an approximate 1977 steel price of $300 per tonne, the steel material cost of the proposed cradle would have been $6,500. Additional costs would have to be added for fabrication, crushing caps, hire of cranage and slings. It should be noted that the fabrication costs would have been less than those of the dockgate proposal, to be discussed later, due to the absence of long watertight welds.

A number of suitable sites were investigated for this proposal, but none appeared to be available.

4.2.3.2 The Dry Dock.

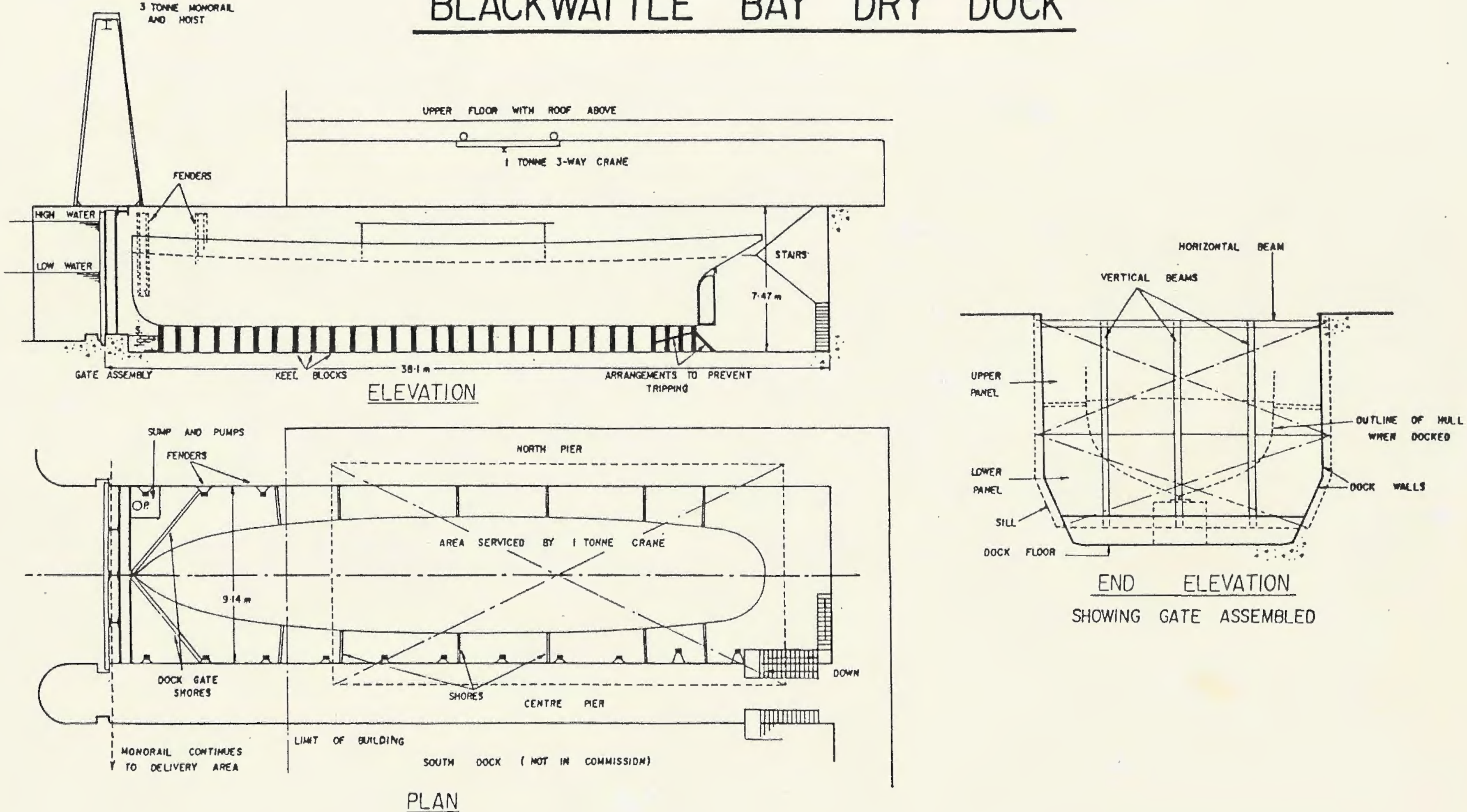
Both of the dry docks at Blackwattle Bay had the following dimensions.

LENGTH	38.1 m
WIDTH	9.14 m
DEPTH OVER SILL (low water)	3.15 m

The docks were constructed of re-inforced concrete with walls 3 m thick and a dock floor of 1.4 m thick. The layout of the dock can be seen in Figure 8.

FIG 8

BLACKWATTLE BAY DRY DOCK



The construction plans, which were obtained from the Electricity Commission, revealed the original arrangements of the dock gate. This gate was of composite construction made up from a number of individual components which were assembled in situ. A primary framework of heavy rolled steel joists sat in specially cast pockets in the dock walls and floor. This framework in turn, supported four separate timber panels which lay against a cement sill; also cast into the dock walls and floor, to form a watertight seal. The various components were assembled and dismantled in position with the use of an overhead monorail and hoist.

By 1977 there was little of the dock equipment remaining. The timber panels had been scrapped and the vertical stiffeners in the primary framework were missing. Also, the pumping machinery had been removed.

All that remained was the main horizontal stiffener of the primary framework and the monorail/hoist facility which was in a state of disrepair. The condition of the dock floor itself, the sill and a number of the supporting pockets was unknown.

4.2.4 The Final Decision.

Initially it was believed that the lifting of 'Waratah' onto the land using a crane would be the more feasible proposal. There were fewer technical unknowns to be overcome, particularly when considering the uncertainty surrounding the problems of initially positioning the dock gate to obtain a watertight seal and then removing the mud within the dock. The main problem to be faced with lifting by crane was the difficulty of obtaining an available site. As initial investigations to find such a site had proved fruitless, the Museum began to look at the dock proposal more seriously. The Electricity Commission was approached for permission to recommission the dock, which they gave. The Museum, therefore, concentrated its efforts on this proposal.

CHAPTER 5

THE DRY DOCKING OF 'WARATAH'.

5.1 RECOMMISSIONING THE DRY DOCK.

5.1.1 The Dock Gate.

5.1.1.1 Preliminary Investigations.

The major item of expenditure expected during the recommissioning of the dry dock was the construction of a new dock gate. A number of points had to be considered in the design of this gate.

i) Strength.

The dock gate had to be sufficiently strong to resist both the static head and possible impact and dynamic loads. The lives of people and success of the project would depend upon the gate not failing in service.

ii) Cost.

The cost of the dock gate had to be kept to minimum because of the limited funds available. Not only did the gate represent a substantial lump-sum investment which had to be paid before restoration could begin; it also carried some risk because of the numerous problems which had to be solved ahead. In addition, it was envisaged that the gate would be written off once the 'Waratah' was undocked.

iii) Weight.

Weight had to be kept to a minimum for two reasons. The first was to enable economical handling; if possible, by the monorail and hoist at the Blackwattle Bay site. The second reason was to keep the material cost and therefore total cost to a minimum.

iv) Assembly.

The design of the sill severely limited the options available with regard to the methods of installation and removal of the gate. The dock gate would have to either be lifted into position whole or assembled in situ. Other arrangements such as hinged gates or floating caissons could not be used given the existing shape of the sill.

v) Watertightness.

The conditions during the positioning of the gate might not be conducive to obtaining a good seal. The sill might have been found to be difficult to clear completely or might have been in poor condition. The easier the gate was to assemble the more likely that a watertight seal would result. Other factors such as the length of joints between the assembled components, which had to be rendered watertight, also had to be considered.

5.1.1.2 Dock Gate Proposals.

The following proposals were considered for the replacement dock gate:

i) The Original Design.

The original design was described in Section 4.2.3.2. Certain features of this gate would have been expensive to build in the 1970's, that is, the timber panels. Also, the number of joints below water level was considered undesirable.

ii) Reinforced Concrete.

A gate made from either one single panel or a number of panels of reinforced concrete was considered. Indications were that both configurations would have been costly to build and very heavy.

iii) Timber.

A proposal was considered to construct the gate from heavy section timbers assembled in situ. This proposal relied on a cheap source of suitable timber, for example, second hand structural timber. No such source was found. A significant problem would have been the rendering of so many joints below waterline watertight.

iv) Both single panel and multiple component steel gates were proposed. The single panel gate, although easier to position would have been expensive and heavy. The multiple component gate would be lighter and cheaper, but more difficult to assemble and render watertight.

Of the various proposals considered, an all steel multiple component gate was chosen. Investigations had revealed that none of the materials considered could be obtained at a significantly lower price. The all steel multiple component gate was found to best fulfil the points raised in Section 5.1.1.1. Cost and weight could be kept to a minimum as could the length of watertight joints. The loads would be well within the reasonable range of the material and it could withstand a degree of rough treatment in assembly and during service.

5.1.1.3 Design of the Gate.

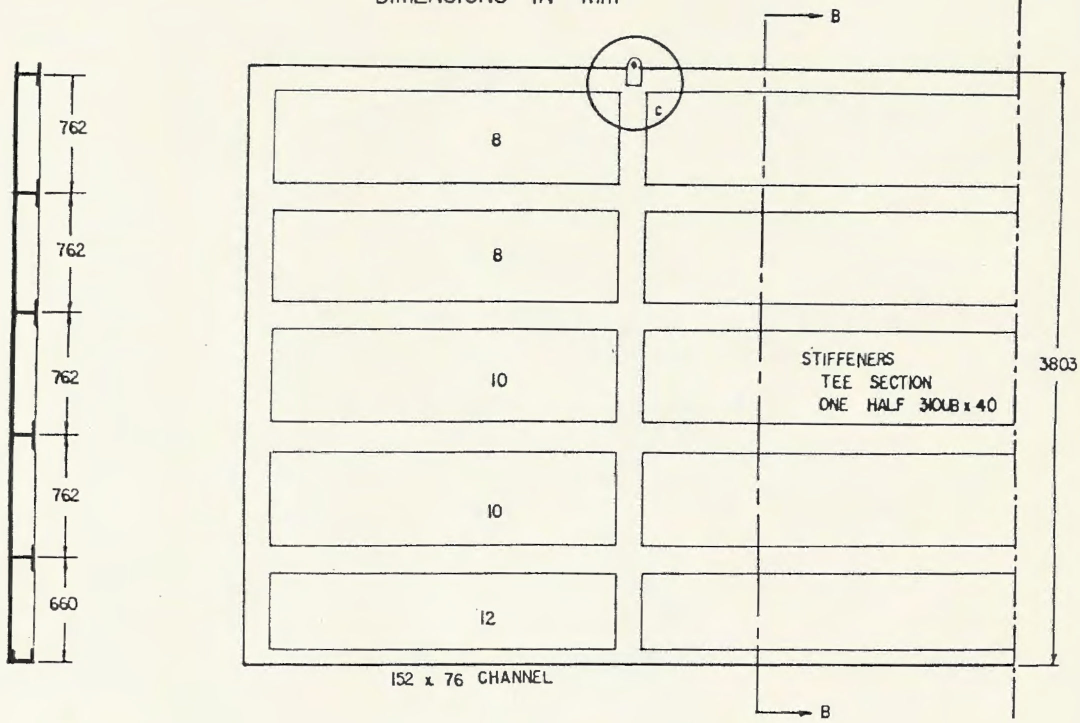
Dimensions and shape of the sill were determined from the original construction plans (Electricity Commission of N.S.W. 1949-53). As there might have been unmarked amendments to these plans prior to the dock's construction, measurements were taken to check the agreement between the plans in our possession and the dock as built. The shape of the sill was determined using a long pipe as a probe. As the plans agreed with the dock, as built, the new dock gate was designed to fit the sill shown in the original construction drawings.

The proposed new gate was of very similar arrangement to the original composite gate. As in the original, a primary structure of steel beams supported panels which kept out the water. Instead of timber panels, stiffened steel panels would be substituted. See Figures 8, 9 and 10.

FIG 9

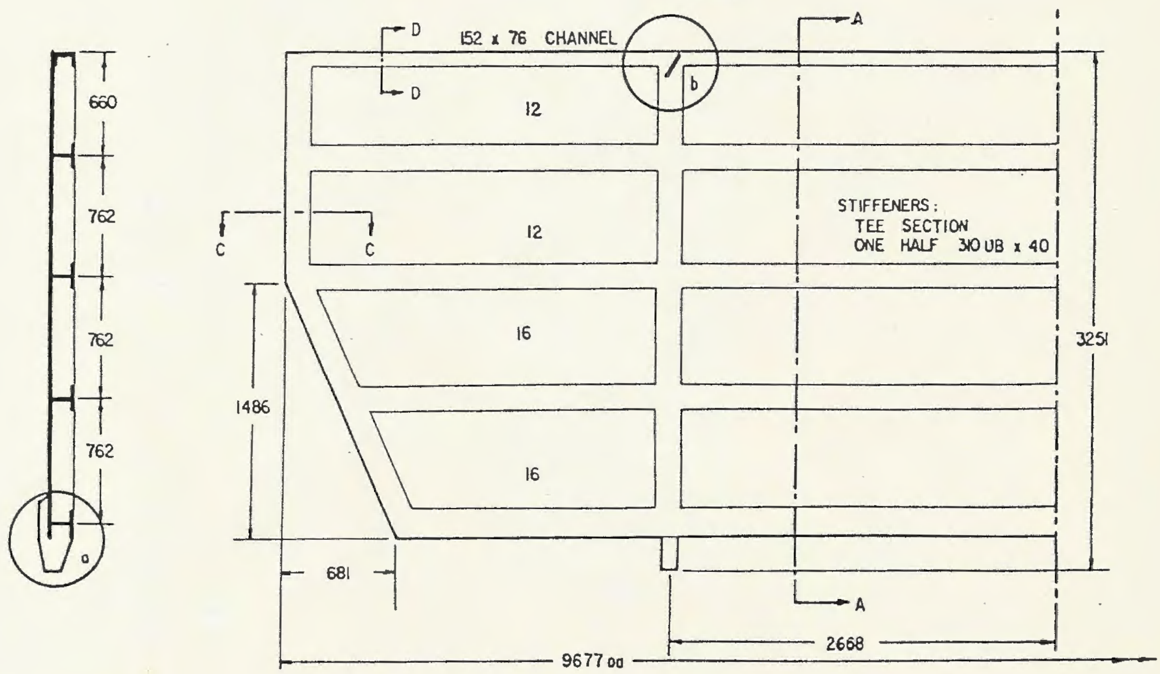
DOCK GATE DESIGN 1977

DIMENSIONS IN mm



SECTION BB

HALF ELEVATION OF UPPER PANEL

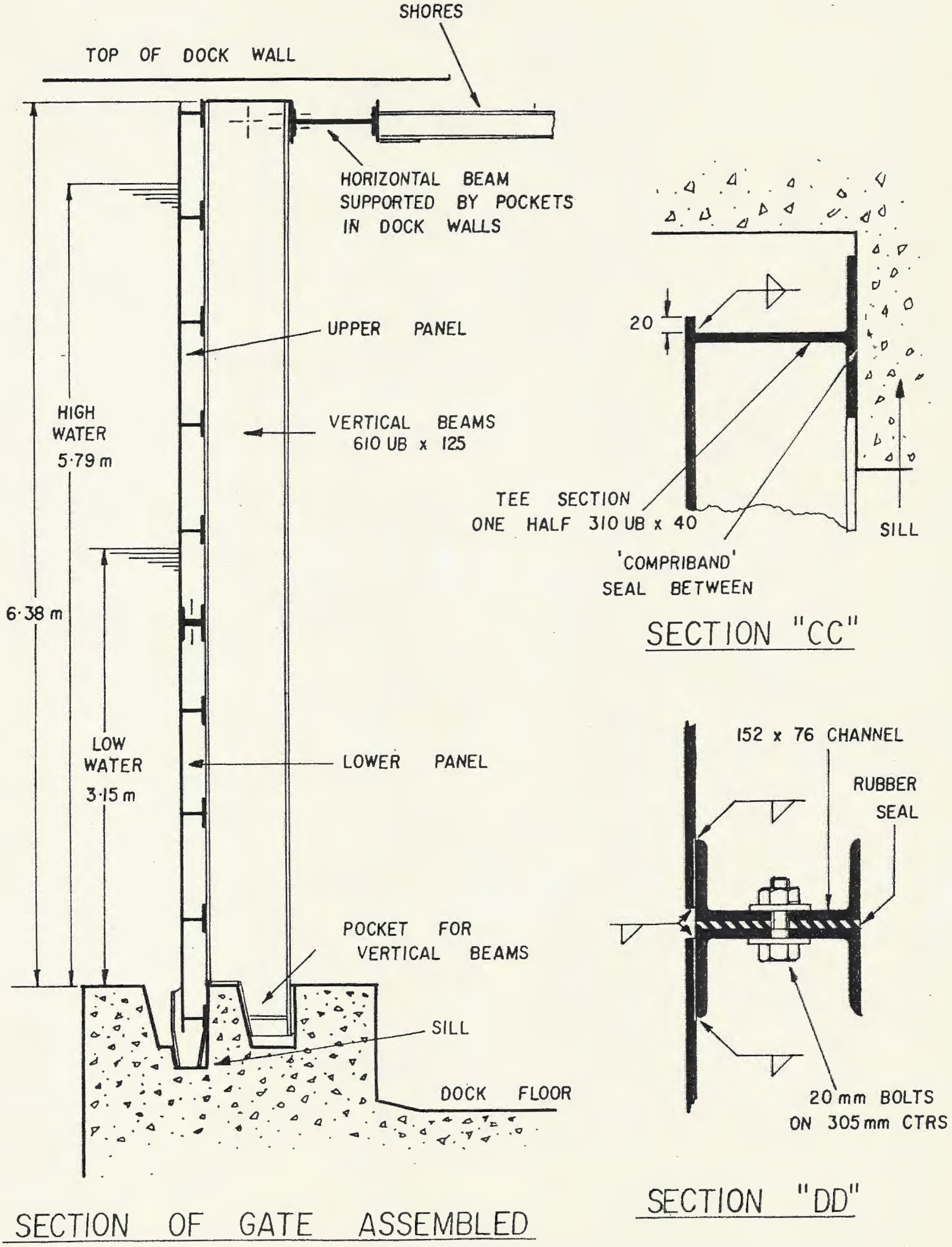


SECTION AA

HALF ELEVATION OF LOWER PANEL

FIG 10

DOCK GATE DETAIL



The structure of the dock gate was analysed assuming a static head of 6.4m of sea water. This head was well above the maximum head at high tide of 5.79m to compensate for the effects of the wash from passing vessels. Other loads that had to be considered were loads from vessels laying alongside the gate or actually striking it. The following is a general summary of the design, the detailed calculations appearing in Appendix F.

PRIMARY ANALYSIS

The primary structure of the new dock gate was arranged in the same way as in the original, making use of the pockets in both the dock floor and walls. The horizontal beam (See Figures 8 and 10) which lay along the upper edge of the gate, was the major structural component. Because its collapse would have been catastrophic, it had to be designed with a high load factor, particularly as it would have to take the brunt of any of the impact loads mentioned above. The original horizontal beam had remained at Blackwattle Bay. As it appeared to be in good condition, it was decided to incorporate it as part of the new gate.

When the old horizontal beam was analysed for the stressed condition, it was found to have a stress factor of only 2.0. Considering the vital role of this member, the stress factor was too low. This problem was overcome by bracing the horizontal beam by the use of two shores. These shores ran between the centre of the beam and the dock walls (See Figure 8). The critical load as calculated for these shores would have increased the load factor substantially, but it was felt that the mountings holding the shores on the dock walls would have failed at a load below the critical load. Even so, the effective load factor was increased considerably.

The stress factor for the vertical beams of 610UB x 125 kg/m section was calculated as 2.1. This value was considered adequate for their service.

SECONDARY ANALYSIS.

At the secondary level, the panel stiffening in association with its plating was analysed for bending due to the hydrostatic load at the bottom of the gate between two points of support; the worst case being taken. For the purposes of this analysis, the effective width of plating acting in association with each stiffener was assumed to be 40 times its thickness (20t on each side). A number of stiffener sections were investigated, the final choice being one half a 310UB x 40, that is, a 155 mm x 155 mm tee section. The stress factor of 1.95 for this loading was considered sufficient. Figure 9 shows the stiffened panels.

TERTIARY ANALYSIS

The thickness of plating was chosen, through calculation, to give a load factor of 2 for buckling. The resulting plate thicknesses, once adjusted to preferrred sizes, varied from 8 mm at the top to 16 mm at the bottom.

Although some corrosion allowance may have been implied in the load factors, no specific thickness additions were made. The addition of a corrosion allowance would have resulted in an increase in the weight and cost of the gate and was unnecessary because the gate was only intended to have a service life of a few years.

Where watertightness was required, welding was continuous on both sides. Elsewhere it was intermittant. It was hoped that the intermittant welds would allow water to drain from the panel stiffeners but this was prevented by clogging of the gaps by rust and mud. A more positive drainage system would have been more successful.

The final design developed as a result of discussions with a number of people. After the preliminary design was analysed, it was checked by two independent engineers, who suggested certain alterations, mainly to the panel stiffening. Also, further alterations to facilitate assembly and fabrication were suggested by the foreman of the contracted company constructing the gate. These included the addition of intercostal vertical stiffening on the panels to prevent distortion, the use of plates of preferred widths on the panels and the addition of locating pins to assist the positioning of the upper panel over the lower during the gate assembly.

The total weight of steel in the gate (excluding the horizontal beam) was about 11 tonnes. Each component was designed to weigh less than 5 tonnes, as this was thought to be the capacity of the hoist and monorail at the Blackwattle Bay site. Unfortunately, the actual capacity of the crane was less; for, although it was shown to be 5 tonnes on one plan; an amended plan was later received which stated it to be 3 tonnes. This was checked with the manufacturer of the hoist and confirmed. By this time the gate was nearing completion. Any alteration to reduce the weight of each component would have been expensive. To overcome this problem, an analysis of the various components of the monorail and its pylons was made. This analysis revealed that a 5 tonne load could be lifted in safety. The power hoist, however, could not be used as it did not have sufficient reserves of torque in its power unit and also it did not appear greatly over designed. In addition a motorized hoist would have resulted in additional dynamic loading. In its place, a 5 tonne chain block on a beam traveller was substituted.

5.1.1.4 Construction.

Once the gate design had been completed, tenders were called for its construction. The Museum had decided not to undertake the gate's construction itself because of a number of reasons. Firstly, the Museum had not at that time acquired sufficient equipment nor expertise to build the gate efficiently and to the high standards of quality necessary. Established fabrication shops were in a much better position to undertake such a task. Secondly, there were many other jobs which had to be done to prepare the 'Waratah' and the dock site for the impending docking.

Five tenders were received for the construction of the gate. Four of these were between $10,000 and $11,000, the fifth being $15,000. It was decided to accept a tender of $10,800 submitted by Patterson Welded Machinery. This tender was chosen because

i) The firm was well established and had a reputation which was known to be good.

ii) The firm could be depended upon to deliver the gate within a set period.

iii) The Museum could have confidence in Patterson's ability to estimate accurately the figure submitted in their tender.

iv) The firm had shown more than just a financial interest in the project.

Patterson's constructed the gate without any major problems, the cost being within the tendered price.

5.1.2 Preparing the Dock.

5.1.2.1 Survey of the Mud.

Over the years during which the ash loading facility had been in operation and then subsequently abandoned, the dock had partially filled with mud and debris. A survey was made of the mud depth in the dock by volunteer divers. A long pipe, similar to that used to investigate the sill, was pushed ino the mud until it struck the dock floor. A diver marked the level of the mud on the pipe, which was then withdrawn and the depth measured and recorded. The mud depths were taken at a number of positions in the dock, the results being shown in Figure 11 and Appendix G. There appeared to be about 2 m of mud in the bottom of the dock, this varying from deeper along the dock walls to shallower along the centreline. The mud continued at this level over the top of the sill and out into Blackwattle Bay.

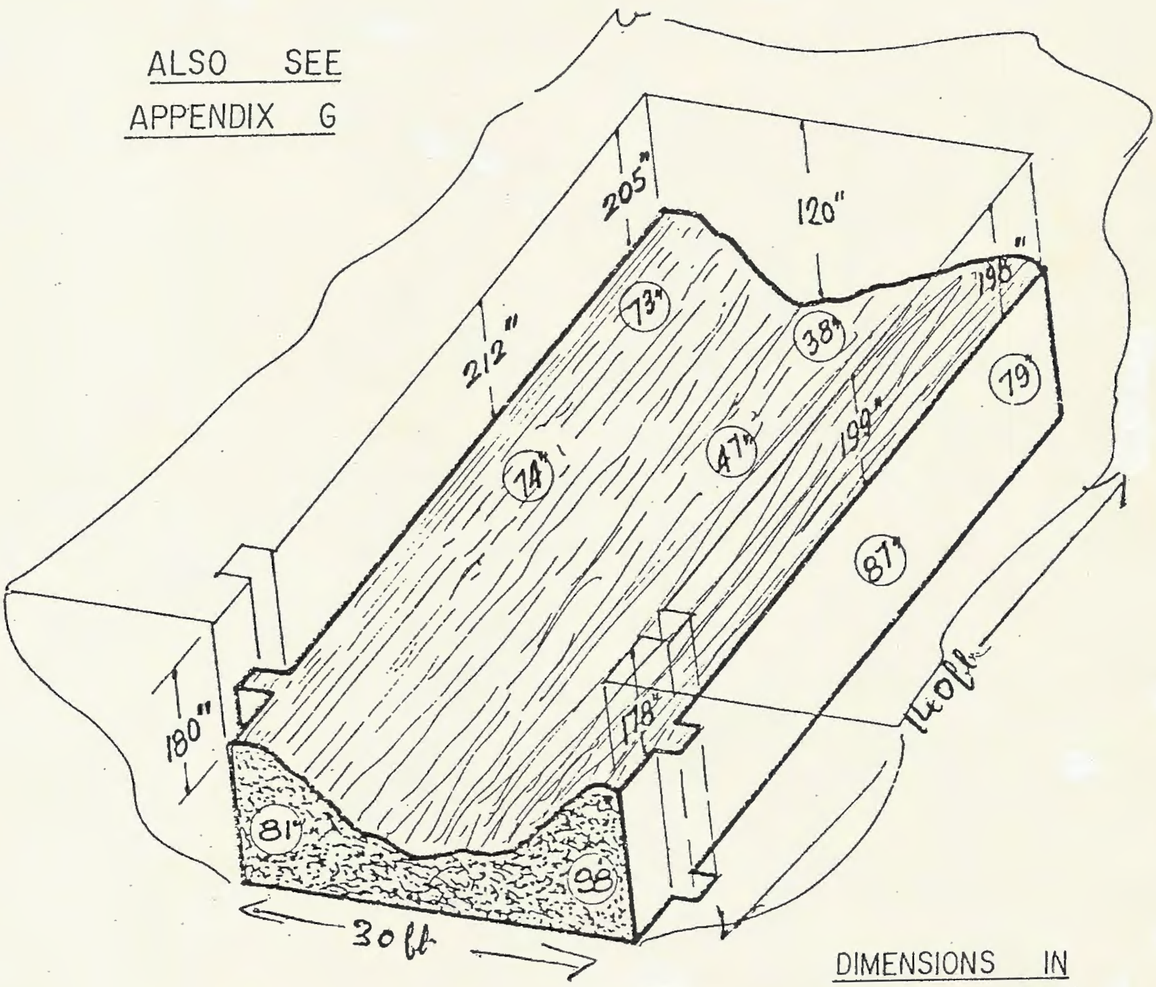
5.1.2.2 Clearing the Sill.

Before the dock gate could be assembled into position, the sill had to be cleared of its 1.3 m layer of mud. The first proposal put forward was to dredge, not only the sill, but the dock as a whole. Most of the dredges which might have been available were far too large to operate in the dock. The only small dredge discovered which would have been suitable was not to be available for a number of years. One alternative proposal which was

FIG II

SURVEY OF MUD BLACKWATTLE BAY DOCK 1977

ALSO SEE APPENDIX G



DIMENSIONS IN IMPERIAL UNITS

NOTE: CIRCLES INDICATES DEPTH OF MUD.

considered was to make a small grab dredge by placing a mobile crane on top of a flat top lighter. Such a dredge could not be used, however, because its jib would have interfered with the monorail and the building while it was working in the dock. Also, the grab could have damaged the sill. Another proposal which was considered was the construction of a small suction dredge. Initial investigations indicated that the acquisition, operation and maintenance costs would have been prohibitive and so this proposal was abandoned. When considered in retrospect, however, this proposal might have warranted further attention in view of the methods which were later used to clear the dock.

A number of attempts were made by divers to clear the sill using an air lift. This device made use of an air induced suction within a pipe. The method was found to be only partially successful. The work was slow in the difficult conditions in the dock. As soon as the mud was disturbed visability in the water reduced to nil. As the work was so slow and the divers were only available on an occasional basis, an alternative method had to be found.

One alternative method which was tried was to scour the area of the sill clear of mud, using the propeller race of a small tug secured immediately above it. Despite repeated attempts, no significant effect was discernible.

The method eventually adopted to clear the sill made use of a jet of compressed air. An air lance was made from a 25mmϕ length of pipe which was connected to an air supply. This lance was pushed into the mud with the air rushing out of its end. The air bubbles and associated turbulences displaced the mud, putting it into suspension in the water. A portion of this suspension would drift away from the vacinity of the sill where the mud would drop out of suspension. Although the process was slow, it was simple and could be carried out over long periods either manned or unmanned. The air lancing process was continued for about two weeks until the main bulk of the mud over the sill had been removed. The remaining sediment consisted mainly of coarse grit and solid objects such as bricks and tyres. The volunteer divers then cleared the sill and pockets of as much of the larger objects as was possible. The sill was then ready to accept the gate.

5.1.2.3. Assembly of the Gate.

The first components to be assembled into position were those comprising the primary framework. This was begun by lifting the main horizontal beam into its position across the dock. Each end was fitted into a pocket in the dock wall. The vertical beams were then put into position. Even after the preparation of the sill, some sediment remained in the sill and pockets. The presence of this sediment did not allow the vertical beams to drop into position. Each beam had to be positioned using a 'pile driving' action progressively forcing the beam into the silt. To asist this operation the air lance was used to undermine the beams within the pockets, enabling them to sink further.

With the primary frame in position, attention was directed to the positioning of the panels. A similar problem to that encountered when positioning the vertical beams had to be faced to position the lower panel. The same methods were used to sink this panel into the sediment. This work was carried out prior to the fitting of a gasket around the perimeter of the lower panel. Once the panel was sufficiently deep in the sediment, it was removed and the gasket fitted. This gasket was made from a material known as 'Compriband' which is used extensively in the building industry for expansion joints. The lower panel was then carefully lowered back into position. A similar gasket was fitted on the upper panel before it was positioned on top of the lower panel. As originally designed, a rubber gasket was placed between these panels, which would then be fastened together with bolts. (See Figure 10) This arrangement was used when the dock was emptied for the first time. It did not perform up to expectations, allowing water to leak past. When the dock was emptied for the second time, a 'Compriband' seal was substituted but it too was not completely satisfactory. The rubber gasket might have been more successful had runs of weld been placed along the mating surfaces of the joint so that they would bit into the gasket as the bolt fasteners were tightened.

5.1.2.4 Pumping Dry.

Once the dock gate was assembled in position, the dock could be pumped dry. A two stage axial flow pump with a capacity of $8.2m^3$/min was obtained on long term loan from WARMAN INTERNATIONAL PTY. LTD. This pump, driven by a 15 KW, 3-phase 415V electric motor, was designed mainly for mine drainage and irrigation purposes. Even though it was not specifically designed for extended operation in salt water, the pump performed extremely well even when pumping mud and copperslag slurries. Over the two years of its operation, the pump only failed once and then the fault was electrical.

The pump was lowered into position and pumping was commenced. It was believed that, as the differences in head between the water within and outside the dock increased due to the pumping, the effectiveness of the seal at the gate would increase from the resultant head difference acting on the gate. To achieve the initial difference in head, the pump had to be able to overcome the initial leakage past the gate. Pumping was commenced at the beginning of an incoming tide to assist the initiation of this difference in head.

The first attempt to pump the dock failed because the leakage past the gate was too much for the pump. To improve the seal, the gate was wedged hard against the sill. When pumping was again commenced; gravel, rope, woodchips and plastic were dumped directly in front of the gate so as to be drawn into the leaks and thereby stem the flow. As the pump began to gain on the leakage, the difference between the heads increased and the leakage decreased. Eventually the joint between the panels was exposed at which time it was bolted together further reducing the leakage.

The dock was pumped dry in about six hours. On the first occasion when the dock was emptied, the leakage past the gate was less than on the second occasion when the 'Waratah' was actually docked. This was because the gate had fitted closer and the gasket was less damaged from the assembly on the first occasion. The leakage was later substantially reduced on the second occasion by caulking around the sill with rope and wooden wedges. On both occasions, mud from inside the dock was dumped on the waterside of the gate to further reduce the leakage. See Plate XXIV.

5.1.2.5 Mud Removal.

The pumping revealed over two metres of mud in the bottom of the dock (Plate XXV). After the previous proposals for dredging of the mud had been abandoned, it was felt that it was not worth considering other proposals until the situation could be ascertained with the dock pumped dry. A preliminary attempt was made to remove the mud by hand. Twenty volunteers worked a full weekend using shovels and buckets, but with little effect. The conditions were very difficult for this type of approach as the mud was so liguid that a man would sink up to his chest in it. It became obvious that such techniques would not be practical, at least in the earlier stages of the mud removal.

A representative from SYKES PUMPS was consulted on the problem. His suggestion was to remove as much of

PLATE XXIV. (left)
SHOWING MUD BEING DUMPED IN FRONT OF THE DOCK GATE TO SEAL LEAKS. DOCK PUMP IN FOREGROUND (Author, 1977)

PLATE XXV. (below)
DOCK AFTER BEING PUMPED DRY SHOWING THE MUD 2m DEEP COVERING THE DOCK FLOOR (Author, 1977)

the mud as possible using a sludge pump. SYKES PUMPS generously lent the museum a submersible 3-phase, 15KW sludge pump to undertake this task. To enable the mud to be pumped, it was first made into a slurry by playing the stream of a fire hose onto it. Once it was a slurry, it was pumped into a hopper barge to be taken out to sea and dumped. Initially, the fire hose was manned from the top of the dock walls, but as the amount of heavy material exposed increased, it became necessary to man the fire hose from within the dock itself. To enable the slurry to be shepherded toward the pump from the extremities of the dock, pathways through the remaining debris had to be cleared. In time, the conditions on the dock floor had improved to the extent that work was begun removing this debris from the dock. A large variety of objects were found in the bottom of the dock including timber, scrap steel, bricks, tyres, rocks and a number of articles from the dock's original operation such as pipes and the lower block and hook from the hoist servicing the gates. Even the remains of a large tool kit were found buried in the mud. A large amount of timber was also found in the bottom of the dock. It would appear that this timber had floated in, become waterlogged and sunk.

As the level of the mud subsided, there appeared to be a change in its consistency. The upper 120 cm had been mainly a black ooze which, when mixed as a slurry, had pumped well. With time, however, the pumping method became less successful until it had little effect. About a metre of mud and debris remained. The upper 15 cm was made up of coarse particles such as shell grit and small stones. Beneath this was a layer of ash, probably overspill from past ash loading operations. This layer of ash had the consistency of moist clay and like the coarser particles above, could not be removed by pumping. Both these layers had to be removed by hand using shovels and, where necessary, picks. The spoil was shovelled into wheel barrows, which were then lifted out of the dock to be emptied. This work, although labour intensive, was practical mainly because the labour was voluntary. Approximately 300 tonnes of mud was removed by this method. The mud removal only took about four weeks.

5.2 DRY DOCKING THE 'WARATAH'

5.2.1 Docking Arrangements.

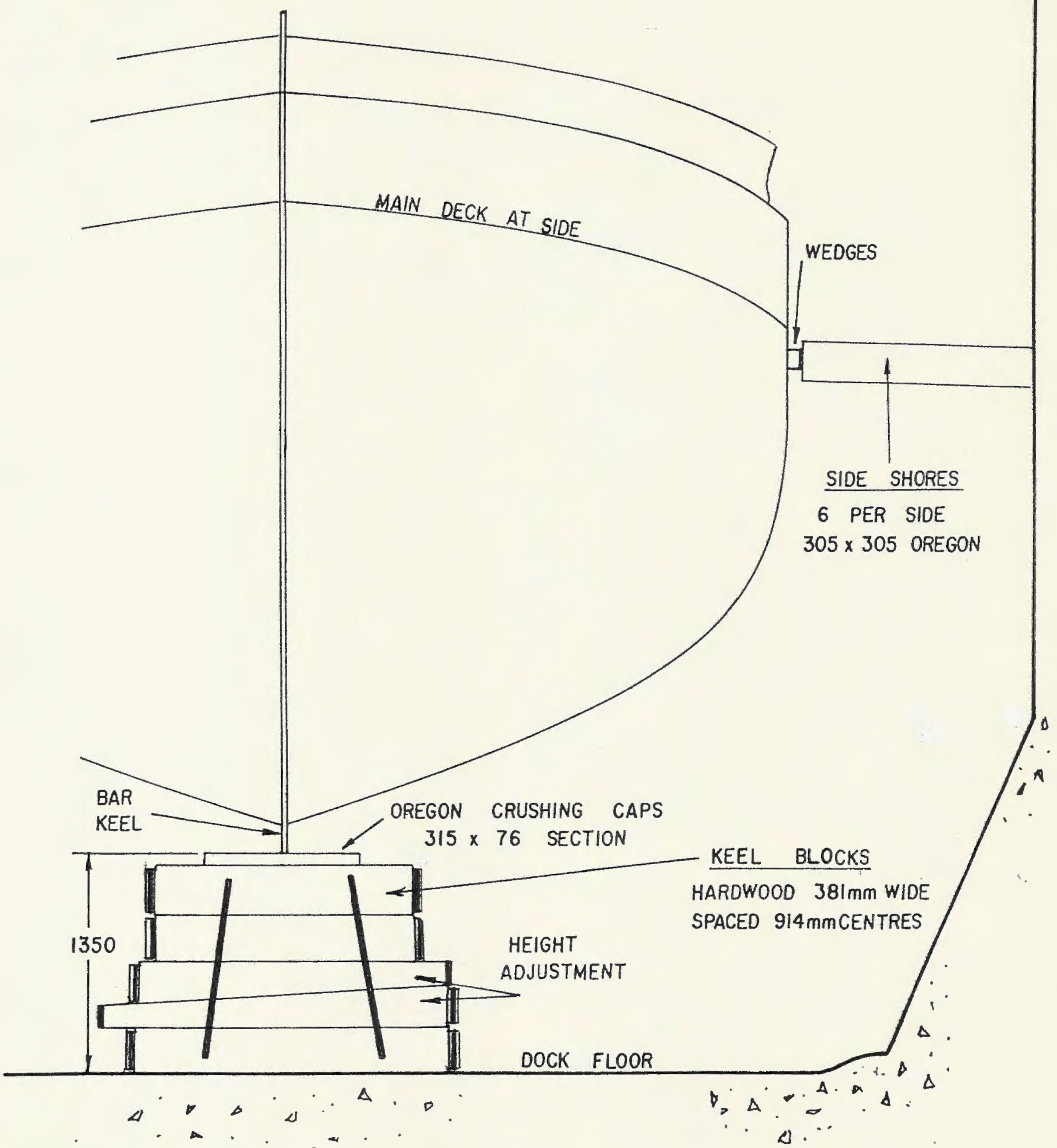
5.2.1.1 Configuration.

The 'Waratah' was docked using a combination of keel blocks and side shores as shown in Figure 12. This configuration was preferred over the alternative configuration of keel and bilge blocks for the following reasons:

i) A configuration using side shores was more suitable for fine lined ships with a large deadrise as in

FIG 12
S.T. "WARATAH"

DOCKING ARRANGEMENTS
1977



DIMENSIONS IN mm

the case with 'Waratah'(See Figure 2) (Benkovsky, N. D., p. 108).

ii) Bilge blocks required a more accurate positioning of the blocks during setting up and greater care with positioning the ship during docking.

iii) Space on the dock floor was limited. The shore configuration required much less dock floor area than the bilge block configuration.

iv) A large amount of plating and framing had to be repaired, at and around the turn of the bilge, directly in way of where any proposed bilge blocks would have to lay.

5.2.1.2 Keel Blocks.

The number of keel blocks which would be necessary to support the ship was determined by the crushing forces exerted by the keel bearing against the wooden crushing cups on the top of the keel blocks. (See Figure 12). With a shore docking configuration, the entire weight of the ship is taken by the keel blocks. The total width of 'Waratah's' bar keel, including garboard plates was only 51 mm, providing a comparatively small bearing area in contact with the crushing cups. The following points had to be considered when determining the size of the crushing cups and number of keel blocks.

i) The maximum recommended crushing pressure was 4300 KN/m^2 and should be preferably less (Rawson & Tupper, 1976, p. 286). This figure was for pressures exerted over a flat surface.

ii) The 'Waratah' would remain docked for an unusually lengthy period. There was a possibility of a cutting action occuring with the bar keel on the crushing caps with passing of time.

iii) During the docking, a significant proportion of the 'Waratah's' shell and structute might be removed at any one time. Adequate and even support of the ship, when in circumstances of a weakened condition due to repairs, would be paramount.

iv) One or more of the keel blocks may have to be removed during the docking to allow access to the keel and garboard strakes for inspection or repair.

The calculations for the keel blocks are given in Appendix H. The keel blocks, which were arranged at 915 mm centres, were capped with 305 mm wide by 76 mm thick oregon crushing caps. When compared to commercial operations, the load on the keel blocks was light, but it must be remembered that the circumstances were quite different. The keel blocks aft were positioned with an even closer spacing to withstand the higher forces taken in this region during docking. The aftermost blocks were also tied together and bracketed to the dock floor to withstand tripping forces (See Figure 8). More will be said on this subject in Section 5.2.2.2. All the keel blocks were attached to the dock floor and the top face of the crushing caps were set up as level as possible by adjusting the keel block wedges and fitting packing where necessary.

5.2.1.3 Shores.

Sufficient shores were used to allow one or two to be removed from each side without jeopardizing the vessel. A reference was found (USN) giving a criterion for the design of side shores. This criterion required the side shores to be sufficiently strong to withstand accelerations of the vessel (due to an earthquake) of .2g. Calculations based upon this criterion are given in Appendix H.

In actuality, the timber shores used were of much greater strength then that which was required, because this timber was obtained gratis. Where possible, the shores were positioned in way of areas of greater strength on the 'Waratah' such as bulkheads. See Figure 8.

5.2.2 Docking Calculations.

5.2.2.1 Stability.

Before the 'Waratah' could be docked, an investigation of her stability during the docking operation had to be undertaken.

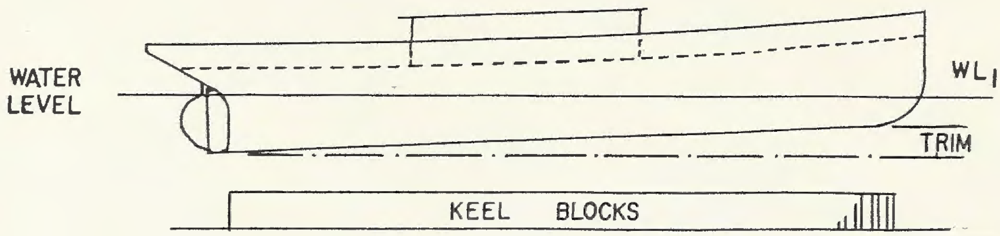
Stability during docking is especially of interest for vessels with a large rake of keel such as the 'Waratah'. Such vessels experience a reduction of their metacentric height (GM) during the period between when the keel first makes contact with the keel blocks at a point aft and when the whole keel comes into contact with the keel blocks. This is shown in Figure 13. After this period, the vessel is held upright by shores or bilge blocks as the remaining water is removed. The most critical period (that of lowest GM) occurs just before the keel touches the keel blocks fore and aft.

To enable an analysis of the 'Waratah's' stability during this most critical period, the position of the centre of gravity of the ship and hence her value of GM, had to be obtained. These values were determined by carrying out an inclining experiment on the 'Waratah' (Yates, 1977). The inclining experiment was carried out with the ship in a similar condition to that in which she would be docked. The value of GM obtained by this inclining experiment was 1.63 m. More detail on this experiment is given in Appendix I.

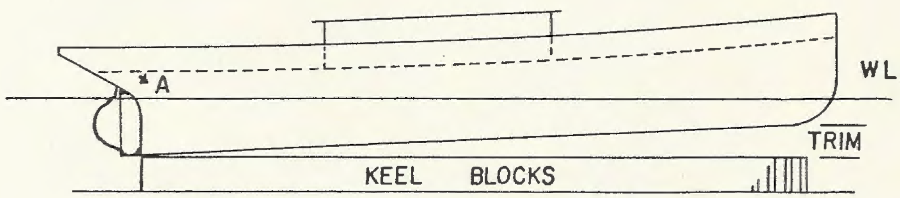
Calculations were then made to determine the minimum stability during docking using the method shown in Barnaby, 1967, p. 93. These calculations also appear in Appendix I. The value of GM obtained was 1.37 m which was more than sufficient to ensure stability during docking.

FIG 13

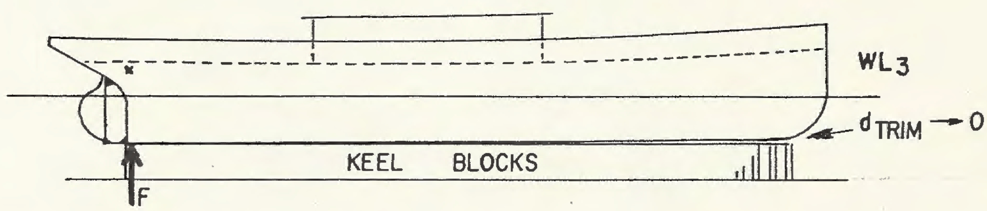
DOCKING PROCEDURE



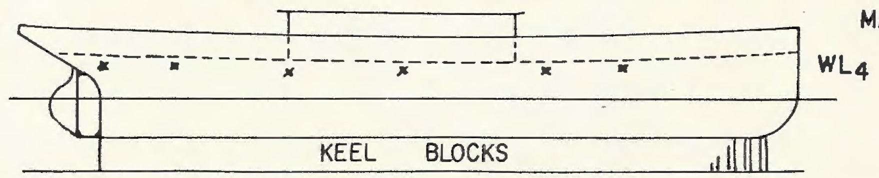
VESSEL WITH TRIM BY THE STERN. WATER BEING PUMPED FROM DOCK VESSEL SETTLES DOWN TO KEEL BLOCKS



AT WATERLEVEL WL_2 KEEL TOUCHES BLOCKS AFT. SHORES FITTED AT 'A'



WATERLEVEL CONTINUES TO DROP. UPTHRUST 'F' INCREASES UNTIL THE WATERLEVEL REACHES WL_3 WHEN TRIM BECOMES ZERO AND THE KEEL COMES INTO CONTACT WITH THE BLOCKS ALONG ITS LENGTH. THIS IS THE CRITICAL PERIOD WHEN GM IS MINIMUM AND AFT CRUSHING FORCE MAXIMUM



AT WL_3 THE REST OF THE SHORES ARE FITTED AND THE DOCK PUMPED DRY.

5.2.2.2 Aft End Crushing Force.

At the same time that GM is at a minimum during the docking operation, the crushing force on the aftermost blocks is at a maximum. This force begins acting when the keel just touches the keel blocks aft. It steadily increases as the water level recedes until it reaches a maximum just before the keel touches the blocks along its length. This crushing force is really an upthrust imparted to the keel steadily reducing the trim (See Figure 13). The crushing force, if allowed to become to high, would damage the crushing caps and keel blocks in this region.

The crushing force was calculated for the 'Waratah', see Appendix I. The value obtained of 6.9 tonnes was not considered excessive particularly as it would act only for a short period.

5.2.3 The Docking Operation.

Before the dock was flooded, a variety of reference marks relevant to the keel blocks were drawn on the dock walls so that the ship could be accurately positioned once the dock had been flooded. Inaccurate positioning of the ship over the blocks could have resulted in the ship falling off the keel blocks or damaging her stern frame. Once the various preparations had been completed within the dock, it was flooded as shown in Plate XXVI. The gate was then removed, the 'Waratah' brought into the dock and the gate reassembled.

PLATE XXVI. (left)
FLOODING THE DRY DOCK SHOWING KEEL BLOCKS READY TO TAKE THE SHIP. (Author, 1977)

PLATE XXVII. (below)
DEFECTIVE PLATING PL. B5P WHITE CIRCLES INDICATE RUST HOLES. SMALL CROSSES, DRILL TESTS WITH THICKNESS READING (inches) MARKED ALONGSIDE. (Author, 1977)

The actual docking operation was superintended by Mr. W. Anderson and Mr. J. Stewart, both of whom were associated with the Captain Cook Graving Dock at Garden Island Naval Dockyard. Before pumping was commenced, a slight heel present in the vessel was removed by shifting of weights. The ship was positioned over the blocks by adjusting her mooring lines and lining up the reference marks. When the pumping was commenced, the various measures described in Section 5.1.2.4 were put into action to reduce the leakage around the gate. The dock was pumped until the keel came into contact with the keel blocks aft. At this moment the pump was stopped and two shores wedged into position, one each side in line with the aftermost block. These shores were positioned so as to be available to assist in keeping the vessel upright during the rest of the critical docking period, if necessary. Pumping of the dock was again commenced and the ship progressively lost her trim until the keel came into contact with the keep blocks along its whole length. The pump was again stopped and the remaining shores wedged into position. A total of six shores were fitted along each side. Once securely held by the shores, the remaining water was removed leaving the vessel dry.

5.2.4 The Dock During Use.

When the dock was originally built no provision was made for a sump to drain away any leakage and rainwater. After the 'Waratah' had been docked, problems were encountered with this water laying over the whole dock floor and making working conditions unpleasant. This problem was overcome by the construction of three sumps; a large one built above the dock floor from brick to take the leakage past the gate and two smaller ones excavated in the dock floor to drain it. The large sump held two pumps; a 76 mm submersible 415V electric pump connected to a float switch which handled normal leakage and the large dock pump which was available as a standby. Another small submersible pump serviced the two small sumps as necessary.

The conditions within the dock were very harsh on the various pumps. The combination of intermittant use, aerated salt water, and erosion from particles of copper slag, resulted in a number of failures with the small pumps.

5.2.5 The Undocking.

This section is included as part of the chapter on Docking to maintain continuity in the treatment of the topic. Chronologically, it is out of place as it occurred a year and a half after the docking and after all the work on the hull below waterline had been completed.

As with the docking, a number of the 'Waratah's' characteristics had to be investigated before she could be undocked. Values had to be determined for the following characteristics.

i) Stability when floating freely

ii) Stability as the bow lifts

iii) Trim when floating freely

iv) Aft end crushing force

5.2.5.1 Weights and Centres Estimation

Since the docking in 1977, there had been a large number of alterations to the vessel. Just as with the docking calculations, the displacement of the ship and the position of the centre of gravity had to be determined for the undocking calculations. Unlike the docking, however, the ship could not be inclined to ascertain these particulars. Instead they had to be estimated analytically.

The movement of weights off and on the ship over the 1½ years the ship had been in the dock had not been recorded. In a normal shipyard, a shipwright might be employed to record these movements, but the museum did not have such resources available at its disposal.

As the date of the undocking drew near, a list was made of the various components aboard, together with their estimated individual weights, longitudinal, vertical and where necessary transverse centres of gravity. These estimates were determined by a variety of methods. Where there was some doubt regarding an estimate, it was made with a bias toward the worst case; for example, weights with a high centre of gravity or positioned well aft were biased on the heavy side. It was felt that it was wiser to investigate the worst case rather than to attempt an elegant solution of great accuracy because any error could have had serious consequences.

A breakdown of the weights and centres estimates appear in Appendix J. The sum of the estimates gave a displacement of 97.84 tonnes, VCG of 2.58 m and LCG 13.31 m forward of the aft perpendicular for the vessel in an unballasted condition at the stage of completion at the time of undocking.

5.2.5.2 Undocking Calculations.

Using the above particulars of displacement VCG and LCG, an analysis of the 'Waratah' was made while floating freely and during the undocking operation. The calculations appear in Appendix J. The following values were obtained:

GM floating freely	=	1.23 m
GM as bow lifts	=	.3 m
TRIM floating freely	=	2.14m (by the stern)
Aft end crushing force	=	23.96 tonnes

The GM floating freely of 1.23 m would have been acceptable, but the other three values were more contentious. The value of GM as the bow lifts was rather low considering the inaccuracies inherent in the weight estimates. The large trim by the stern could have possibly resulted in the tripping of the keel blocks aft or the slipping of the ship off the blocks during the undocking. Finally, the aft end crushing force of 24 tonnes was excessive.

To achieve more acceptible values, the condition of the ship had to be altered. The most effective solution was to reduce the trim to a minimum. This would reduce the following

i) The loss of GM in the grounded condition
ii) The aft end crushing force
iii) The tripping forces due to excessive trim
iv) The dependence upon the accuracy of the weights and undocking analysis.

A reduction in trim was obtained by placing 18.7 tonnes of ballast forward. Seven and one half tonnes of water and 1.2 tonnes of chain and steel scrap were placed in the forward peak tank. Nine tonnes of ballast in the form of test weights were placed in the bilges immediately abaft of the collison bulkhead. It was not only desirable to place the ballast as far forward in the ships as possible, but also to place it low down in the ship so as to avoid increasing the value of the VCG. The ballasting was calculated to leave the ship with a small trim by the stern when floating freely. This was to make the undocking process more predictable and progressive and to allow the two aftermost shores to remain as long as possible so that they could assist in maintaining the vessel upright if necessary.

An analysis of the 'Waratah' in the ballasted condition gave the following values.

GM floating freely	=	1.23 m
GM as the bow lifts	=	.93 m
TRIM floating freely	=	.72 m (by the stern)
Aft end crushing force	=	9.0 tonnes.

The appropriate calculations are given in Appendix J. The values given above were all considered to be acceptable for the safe undocking of the ship.

A slight list to port was indicated by the weight estimates. This was compensated for by placing a total of 600 kg along the starboard rail.

5.2.5.3 The Undocking Operation.

Once all ballasting and hull preparation had been completed on the ship and all scaffolding and equipment removed from the dock, flooding could begin. The dock was flooded through a 300 mm gate valve which had been attached to the dock gate just above low tide level. Calculations were made to determine the water level at which the bow would lift so that a final check could be made of the watertightness of the hull before committing the ship to undocking. These calculations gave a waterlevel 2.1 m above the keel blocks. When the waterlevel reached 1.9 m the flooding valve was closed and the hull inspected for leaks. Although a number of minor weeps were discovered no major leaks could be found. The flooding was therefore continued. When the water reached the 1.98 m waterline, the bow lifted. The final drafts when floating freely were 2.08 m aft and 1.83 m forward. The displacement was 91 tonnes (PWD, 1902, lines) and trim only .25m.

The large discrepency which was present between the calculated and actual conditions was the result of the weight estimates having a bias toward the worst case.

CHAPTER 6

'WARATAH' HULL RESTORATION CONCEPTS.

6.1 DETAILED INSPECTION OF THE HULL.

6.1.1 Preparation.

After the ultrasonic survey of 1976, stripping of the hull in preparation for inspection and repair were continued. All the fittings on the 'Waratah' were progressively removed so as to expose the bare hull and structure. A list of the major tasks undertaken to prepare the ship over and above the work described in Section 4.1.3, includes the following:

i) Removal of timber decks
ii) Removal of all piping
iii) Removal of auxilary machinery
iv) Descaling of the exterior of the hull above waterline
v) Descaling of selected 'safer' areas of the hull interior below waterline
vi) Stripping of engine and boiler
vii) Removal of sponson
viii) Removal of mast, wheelhouse, funnel and mooring posts
ix) Lifting of cement in waterways
x) Lifting of cement in a large portion of the bilges.

The time and labour that was necessary to complete this work was substantial, requiring, together with the docking preparations, well over a year.

As this work progressed, numerous defects on the vessel were exposed. A picture of the extent of deterioration evolved, and with it, a better appreciation of the work to come. Some regions, however, were in too poor a condition to disturb whilst the ship was afloat. One such region, the port side wing bunker, is shown in Plate XXIII.

After the 'Waratah' was docked, work continued to prepare her for a detailed survey. The small quantity of marine growth present on the hull was removed and contractors employed to abrasive blast the exterior of the hull. Once the hull exterior had been blasted, a number of the hull components were marked on the outside plating to assist identification during subsequent surveys and repairs. Each hull plate was identified by a coded designation, beginning with a letter (A, B, C ...) denoting the particular strake of plating, followed by a number (1, 2, 3...) denoting the position of that plate along its particular strake. The frames were also designated by a number beginning with 0 at the after perpendicular and progressing forward. Every fourth frame number was marked on the hull over the position of the particular frame. The shell expansion shown in Figure 14 illustrates this identification system. The position of bulkheads, boiler stools and other components were also marked on the exterior of the hull. Although this work took quite some time, it was later found to be worthwhile saving much confusion and preventing mistakes.

6.1.2 Shell Survey.

Once all the various preparations had been completed, detailed inspection of the hull was begun, starting with an inspection of the shell. Each plate was first hammer tested to obtain an indication of its 'soundness'. Where a plate sounded thin, where it appeared to be heavily wasted or where the previous ultrasonic surveys had indicated a low thickness reading, the plate was further investigated. Small test holes were drilled through the plate and a crude gauge used to measure its thickness. Naturally, before such readings were taken, any scale present in the vacinity of the holes was removed. Drill testing was continued in the plate until sufficient readings had been taken to determine whether the plate was acceptable, locally wasted or generally wasted. As with the ultrasonic testing, the minimum remaining thickness acceptable was taken as 67% of the original. An observation which arose from this survey was that the previous ultrasonic survey had been remarkably accurate, even where readings had been recorded as isolated cases.

Other features of the shell which were inspected included rivet heads, both interior and exterior, butt straps, stem and keel bars, stern frame and plate edges. A shell plate tested and marked for replacement is shown in Plate XXVII.

6.1.3 Hull Structure Survey.

Unfortunately, blasting of the interior of the hull was not included as part of the preparations for survey. A number of areas were still encrusted with rust and were extremely difficult to inspect adequately. Even after they had been substantially descaled with pneumatic tools and needle guns, many defects were later found to have been overlooked in the initial inspections. Often these defects were only discovered after the internal structure had been blasted or it had been in way of major adjacent repairs and had been partially dismantled. Surveying therefore continued as the repairs were progressing, every opportunity being taken to inspect components as they became exposed.

6.1.4 Deck Structure Survey.

Once the timber deck and cement in the waterways had been lifted, inspection of the deck structure was not difficult. Where necessary, components were descaled with pneumatic tools before inspection. In general, where corrosion had begun, it was serious, usually penetrating the member.

6.2 DEVELOPMENT OF THE AIMS OF THE 'WARATAH' RESTORATION PROJECT.

6.2.1 Determining Factors.

As a result of the preliminary surveys and slipping (Sections 4.1.2 and 4.1.5) having indicated that the costs of a major restoration project would be prohibitively high, the Museum had reduced the scope of its immediate aims for the 'Waratah' to just temporarily securing her hull and, if possible, enabling her to have some limited operational capability on the harbour. Subsequent to these surveys, the situation changed. Factors arising from the difficulty of finding a dry restoration berth, the expanded knowledge of the 'Waratah's' condition and the apparent strength of the Museum's resources altered the short term emphasis from a temporary repair of the hull to a full commitment to repair the vessel. The reasons for this change are listed below:

i) Many defects of a major nature were discovered in the ship's primary structure. No worthwhile restoration work could be done to the ship, either while dry or in the water, unless these major defects were rectified. Any attempt to carry out repairs over a bad base would have been a waste of time and money.

ii) It became obvious that if repairs progressed on a small scale, job growth would become a significant factor. For example, in many areas where there was defective plating the framing also had to be rebuilt before the plating repairs could be completed.

iii) The 'Waratah' was deteriorating rapidly. Without a full commitment to check this deterioration, the practicality of her restoration in the future would diminish as the costs would escalate. The 'Waratah' was way beyond the scope of preventative maintenance. Only if the ship were repaired to a reasonable standard, could maintenance procedures prove effective.

iv) The recommissioning of the Blackwattle Bay dry dock had provided the Museum with a tremendous opportunity to undertake a major repair of the vessel at a minimum cost. Circumstances as favourable as these might not have arisen again.

v) Although watertightness and structural considerations required the dry dock only to repair the hull; the Museum had to also commit itself to outfit and machinery repairs as well. A necessary part of repairing the hull was the obtaining of sufficient access for inspection and repair. Most of the outfit and machinery had to be removed, some portions being damaged or destroyed in the process. This outfit and machinery could not be left dismantled because:

- Some of the outfit and machinery were essential to the ship for a variety of purposes such as weathertightness, mooring and pumping of bilges.

- The continuity of the restoration would be disturbed. This could have resulted in the loss of some aspects of the knowledge of how the vessel was to be re-assembled. In addition, those components which were not fitted could have easily been lost or misplaced.

- Concentration upon the hull alone would have not resulted in the vessel being an effective Museum exhibit. If the ship were substantially incomplete or if the restoration work had been halted, the ship could not be displayed to give some short term return.

6.2.2 Revised Aims of the Project.

As a result of the changing factors discussed in the previous section, the short term aims became more ambitious and broad. These aims were,

i) To prevent the 'Waratah' sinking or having to be scrapped.

ii) To prepare and repair the 'Waratah' to a condition where the use of preventative maintenance measures would be effective. This would require the corrosion in the 'Waratah' to be substantially checked.

iii) To complete sufficient of the restoration for the 'Waratah' to be an interesting and safe exhibit for the public, thereby capable of realising some return.

iv) To carry out the repairs so that the result would appear as authentic as possible.

v) To repair 'Waratah' to a condition that would enable her to be again operational. It was intended to achieve at least a limited coastal capability.

vi) To preserve those skills relevant to the construction and operation of a ship of her era.

vii) To obtain a high standard in those repairs completed during the project. It was not known whether the Museum would ever attempt to obtain a commercial harbour passenger carrying ticket for 'Waratah' but at least those repairs undertaken should be capable of passing the necessary surveys.

The various aims were not at that time particularly well defined, but they were the first application of some of the thoughts in Chapter 3.

6.3 CRITERIA DETERMINING THE EXTENT OF HULL REPAIR.

The 'Waratah's' hull had suffered markedly from the effects of deterioration over the years. A large percentage of the hull showed some effect from this deterioration with varying degrees of seriousness. Before repairs could commence, decisions had to be made to determine the extent of repair which would be necessary. Each case had to be considered on its merits, judgement being used to decide whether a particular defect warranted corrective action. The most sure method would have been to replace all sections which showed any signs of deterioration. This solution was not practical within the scope of a major restoration commitment carried out over a short time period. (Although it will tend to happen in the very long term, see Section 3.2.3.1). Decisions had to be made which fulfilled the aims discussed in the previous section and yet were within the Museum's resources.

Some of the points which were considered when deciding whether a component was to be replaced or retained were as follows:

i) The magnitude of stresses imposed on a particular component and the consequences of its failure had to be considered. Failure of certain members, such as boiler stools and sections contributing largely to the vessel's longitudinal section modulus, would result in catastrophic consequences. In these cases, less deterioration was tolerated than would be in non structural components.

ii) Corrosion in the extreme fibres of a structural member was considered less acceptable than corrosion close to its neutral axis. For example, the corrosion of the flange of a reverse angle was considered more significant than the equivalent corrosion in the main angle.

iii) A component exhibiting corrosion in a region which had generally been weakened through deterioration; for example, in adjacent framing, was more likely to need replacement than if that same component existed as an isolated corroded case in an otherwise unaffected region.

iv) Most of the repairs in the past had substituted steel for the original iron. These replaced components were actually stronger than they were when originally built because of the superior strength properties of the steel. The ultimate tensile stress of steel is 30% greater than that of wrought iron (Tod, 1909, p. 302) and the yield stess 80% higher (Stromeyer, 1914, p. 158). Not only could the percentage reduction in thickness for the older steel components be higher, but also a substantial percentage of new steel could make up for some of the loss in strength due to corrosion in adjacent members.

v) Those components in areas suffering harsh conditions of service or which are inaccessible for maintenance are prone to further deterioration. The retaining of an already corroded component in such an area would be unwise.

vi) The 'Waratah' was to be preserved using sophisticated corrosion control systems. As it was expected that these systems would substantially reduce corrosion in the future, a large proportion of the corrosion allowances inherent in the original scantlings could be missing without dire consequences.

After discussions with Lloyd's surveyors (See Section 4.1.4.3) the minimum thickness of plating was fixed at 67%. This percentage was modified to some extent by the points raised in i) to v) above, and was used as a basis for determining the extent of plate replacement. No such simple relationship to the original could be used for the various other structural and built-up sections, however. The distribution of the corrosion on the member (see point ii) above) determined the reduction of section modulus and strength.

A basis for some of these decisions was obtained by comparison to those scantlings recommended in contemporary ship construction rules (Japanese Government, 1903) for iron and steel ships. Comparison revealed that 'Waratah's' scantlings were often in excess of the iron scantlings. The contemporary steel scantlings served to provide a comparison with the replaced steel components on the vessel. These comparisons of the individual components had to be made within the context of the particular total structure.

6.4 REPAIR METHOD PHILOSOPHIES.

6.4.1 Alternative Methods of Repair.

In section 3.3 the dilemma facing Maritime Museums when restoring ships was discussed. Limited resources in the short term must be used to fulfil the long term aims as well as possible. As a result, various compromises had to be made in the methods of repair. The following describe a number of these methods of repair used during the restoration of the 'Waratah'. Each method described represents a different degree of compromise.

6.4.1.1 Authentic Repair Within the Museum.

The most satisfactory method of repair was authentic repair carried out within the Museum's own organization. Such methods provided the Museum with the best opportunity to fulfil its various aims. These repairs were undertaken using the appropriate materials, skills and tools to produce an authentic result. By carrying out the work using the site, volunteers, staff and equipment available within the Museum itself, the necessary standards of quality and authenticity were more easily maintained, costs in some cases were substantially reduced and the various skills preserved within the Museum environment.

Unfortunately, although these methods were the most desirable, they were not always the most practical solution for the following two reasons:

i) Situations arose were such methods were not economically feasible, such as some specialized one-off jobs and small job lots where the cost of the necessary equipment or materials would have been prohibitively high. One example was the difficulty of justifying the expense of purchasing plate rolls for the relatively small quantity of plates to be rolled during the 'Waratah's' restoration.

ii) Although the Museum's aims included the preservation of skills, these could not be learned overnight. Those tasks which were extensive or which had to be repeated a number of times gave ample opportunity for the necessary skills to be learned and practices. There were a number of tasks which were of a one-off or small job lot nature which did not permit sufficient opportunities for the various skills to be gained.

6.4.1.2 Authentic Repair by Contractors.

In those instances where the previous methods were found impractical, other alternative methods had to be considered. Methods using outside contractors to achieve authentic results were considered and used on a number of tasks. These contractors were utilized both on and off the Museum site depending upon the nature of the work. Most of the work which was contracted off site was of a type which required the services of specialised facilities which were beyond the Museum to acquire. Obvious cases of work done by contractors off site included the casting of components, heavy machining, mass production of various fasteners and very heavy boilermaking processes such as hammer forging. Not only were the resources unavailable to do these tasks but also the skills necessary. Contracted work on the site usually brought in skilled labour which was unavailable at that time within the Museum itself. Work requiring the skills of a blacksmith and shipwright was contracted out until the Museum's volunteers and staff had gained sufficient of these skills through assisting the contractors, to take over the work.

The main drawback of employing contractors to carry out such repairs was the relatively high cost, particularly as the work was often of a specialized nature, in small job lots and generally demanding a high standard of workmanship. In some cases, other problems were encountered through a difficulty in seeing the basic aims of the project and the presence of preconceived ideas.

6.4.1.3 Disguised Use of Modern Techniques.

A number of cases arose where the cost of an authentic repair by either of the preceding two types of methods was prohibitively expensive. The next alternative considered was the use of modern techniques and materials to obtain a repair which, when finished, appeared authentic. A number of repairs on the 'Waratah' had to be carried out in this manner including the substitution of steel for the original iron in all replacements (except castings) and the arc welding of the bulwark staunchions and subsequent finishing by grinding to yield a result similar to the original forged or fire welded staunchions. In this manner the authentic atmosphere of the vessel was retained, but unfortunately none of the authentic skills were preserved. In addition, as the repair was done using completely different methods, the significance of the original form was ususally not fully appreciated.

An interesting observation which was made during the 'Waratah' restoration project was that the effort that went into making an unauthentic repair appear authentic was often greater than would have gone into making the original. It is for this reason that the management of such restoration projects must possess an awareness of both modern and traditional methods, together with their applicability to each particular task free of any preconceived ideas. It is quite possible that, for extensive jobs, the use of authentic traditional methods will be more economical than attempting to disguise modern techniques.

6.4.1.4 Obvious Use of Modern Techniques.

There were a number of cases on the 'Waratah' where repairs were made by using 'obvious', although not necessarily blatantly obvious, techniques. These methods were used for two purposes:

i) Where it was felt that considerations of cost or servicability gave no reasonable alternative. Such methods were used to weld inserts into plating, join new sections of framing to existing sections and to join the various sections of the keelson in the vacinity of the boiler. A good example where the application of such methods was invaluable were the inserts welded into plates B1 port and starboard where an authentic repair would have required a very major dismantling of the stern in way of the stern tube, at fantastic cost and effort.

ii) For modifications to previous alterations regarded as 'temporary' in nature. Unfortunately, although a number of alterations of a unauthentic nature were present on the 'Waratah', not all these could be reversed in the immediate future, given the limited resources available. Those that remained were altered and modified using modern techniques without much regard given to an authentic result, although, naturally, care had to be taken not to significantly alter the character of the vessel. As these alterations must be replaced in the future, fastidious attention to any minor modifications was not justified.

6.4.2 The Balance Between the Various Methods.

Decisions had to be made to determine which type of method, discussed in Section 6.4.1 above, was the most suitable for each particular repair task. A balance had to be struck between the limits of the resources presently available on one hand and the fulfilment of the various long term aims on the other. The determining factor was not simply a matter of 'which method is the cheapest?', but rather 'which method is the most effective?'

The four alternatives in Section 6.4.1 have been arranged in reducing ability to fulfil the Museum's aims given access to unlimited resources. As resources were limited, the most desirable methods were not always the most practical and so, at times, one of the alternative methods had to be used, but only after careful consideration of the consequences. Judgement had to be used to determine whether each particular repair necessitated the use of compromise.

It was sometimes a problem that this judgement was based upon preconceived ideas rather than the merits of the particular case. Although past experience could be an invaluable part of a decision, it had to be suitably modified to be useful within the context of what was, a rather unique concept. The application of preconceived ideas without proper consideration of the actual project tended to result in errors which were to be regretted later.

As was stressed in Chapter 3, all work done on the ship had to be such that it was reversible within the bounds of reality, otherwise long term preservation would be seriously hindered. Regardless of which repair concept was chosen, this had to be kept in mind. In fact it was this concept which allows the use of compromise for, as long as the work was done so that it was reversible, all compromises could be regarded as only short term features which could be replaced in the future as funds became available. In practice, replacement might not occur until deterioration had made the compromised components unservicable.

6.4.3 Authenticity when Reversing Alterations.

A list of the major alterations which had been carried out in the past on the 'Waratah' is given in Appendix K. Achieving authenticity, when reversing alterations, was found not to be a simple task. When in the past alterations were made, the original components were discarded and the original form lost. The altered components were usually of little use as a guide for authentic replacement. The appropriate form of an authentic replacement had to be determined through research. The primary sources used for such research were contemporary photographs and original plans of the ship and any remnants of the original component or its fastenings remaining on the vessel itself. Unfortunately, it was not always possible to obtain sufficient information from these primary sources on which to base the reconstruction of a component. In these cases an educated guess had to be made by referring to a number of secondary sources of information such as contemporary books on ships and shipbuilding, books on the historical development of ships and comparison with similar ships either directly (if a similar ship exists) or through plans and photographs. Descriptions and comments from retired seamen and shipbuilders were also of great assistance. Even if the resulting reconstruction was not exactly authentic with regard to the 'Waratah', as she was built, it could at least be considered typical of ships of her era.

6.5 MODUS OPERANDI.

The repair work carried out on the 'Waratah' fell into three main categories:

- Hull
- Machinery
- Outfit

The work on the hull held precedence over work in the other two categories, particularly in the earlier stages of the restoration project, for the following reasons.

i) The essential nature of the hull often meant that work on the outfit and machinery could not be commenced until the repairs to the hull had been substantially completed.

ii) The facilities provided by the dry dock were indispensible for the repairs of the hull; but were of much lesser significance for machinery and outfit repairs. As the Museum's tenure on the dock site was uncertain, it was imperative that the full utilization of the dock facility be ensured by concentrating upon the hull in the earlier stages.

Although repair of the hull did have the precedence, a limited amount of work was also carried out concurrently on both the outfit and machinery. Most of this work was carried out off the ship herself and included such tasks as shaping the mast and overhauling some of the auxilary machinery. The opportunity was also taken at this stage to have many of the necessary patterns, castings and other specialised jobs made by various contractors off the site. The commencement of this work at an early stage, even though on a small scale, had a number of advantages. Firstly it provided a wider scope for the application of volunteer labour. Not all the Museum's volunteers were capable of or indeed interested in the heavy boilermaking work necessary for the repair of the hull. The early commencement of work in these areas gave more lead time for ordering of the materials and tools necessary because it was often the case that the requirements were only known once the particular job was begun. Finally, work done on machinery and outfit could produce tangible and obvious results in a minimum of time, this maintaining morale during periods which would otherwise be rather monotonous.

6.6 SIGNIFICANCE OF THE HULL RESTORATION.

The essential part of a ship is her hull, upon which all machinery and outfit are just additions. Many Museum organisations have exhibited a reluctance; almost a fear, against embarking on major hull repairs as part of a restoration project. This has particularly been the case with restorations of metal hulled vessels over about 30 m in length. The major reasons that have been given concentrate upon the fear of possible high costs. The following list some of these reasons:

i) It is often rather difficult to obtain the use of a suitable dry restoration berth over a long period and at minimal cost. Not only are the long term costs of such facilities usually very high, but there is often an additional requirement to employ the men working at these facilities further increasing the costs. (See Section 4.2.1).

ii) Major restoration of the hull usually requires extensive dismantling and removal of outfit and machinery beforehand. This is not a very rewarding task as the ship may actually appear worse than before such work was begun. As was mentioned in Section 6.2.1 the removal of outfit and machinery immediately requires a commitment to replace them.

iii) The hull of a vessel is usually the most complete part of a ship prior to the commencement of restoration.

Because the hull can be examined physically, the extensive nature of the work required is far more obvious than the rather insiduous cumulative nature of work on the scores of components of outfit and machinery, which may or may not exist at the time of evaluation.

iv) There is an apparent lack of confidence within Museums to be able to carry out the various traditional repairs required on the hull particularly those of a heavier nature.

Few, if any, of the larger metal hulled Museum ships have undergone major hull restorations. A number of those iron and steel hulled ships which have been preserved afloat have been fortunate in that they have not yet required hull repairs of a major nature. Both the Steam Tug 'Forceful' and the ship 'Star of India' are examples of such vessels. Those ships which were acquired with hulls in poor condition either have been displayed dry as in the case of SS 'Great Britain' and the Paddle tug 'Reliant' or have been subjected to less than authentic hull repairs such as that on the Barque 'Polly Woodside', see Plate XXVIII (Darrough, 1978, p. 95). It is possible that some of those historic ships which operate on a commerical or semi-commercial basis have been exclusively repaired by authentic methods in the past, but as we move out of the '70's it is to be suspected that these vessels are now repaired by electric welding.

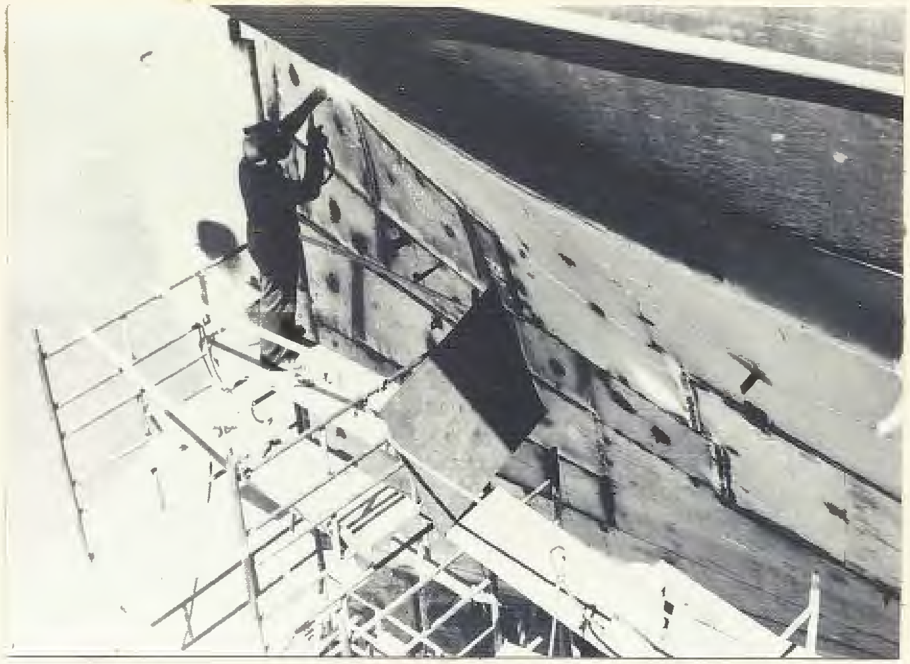


PLATE XXVIII. DOUBLING PLATES WERE WELDED OVER LARGE SECTIONS OF THE BARQUE "POLLY WOODSIDE'S" HULL. THIS METHOD IS UNAUTHENTIC AND DIFFICULT TO REVERSE (L. Doeg, 1974)

PLATE XXIX. REPAIRS SHOWING NO THOUGHT FOR FUTURE MAINTENANCE. REINFORCED CONCRETE LINING IN BARQUE "JAMES CRAIG". EXTERIOR OF HULL WAS ALSO OVERPLATED. (Author, 1979)

As the hull is such a fundamental part of a ship as a whole, it is imperative that its repair is carried out so as to ensure long term preservation. A mediocre repair of the hull, followed by an extravagent restoration of a vessel's outfit and machinery is a very short sighted approach and will lead to enormous diffculties in the future resulting in the wastage of the limited resources. It is because of the reluctance of many organisations to become fully committed to an extensive hull restoration, that they often have fallen vulnerable to the various 'miracle' methods and materials offered by high pressure salesmen. A number of ships have suffered as a result of such 'miracle' remedies including the barques 'James Craig' and 'Joseph Conrad', the main problem with both of these vessels being that neither had provision for reversibility for the future maintenance and repair. See Plate XXIX.

The hull of a preserved ship is as an important a responsibility of a Museum as is the rigging or engines, decks or panelled saloons. Perhaps in many ways it is more important, because it is the hull, more than any other component of a ship, that will determine the future maintenance costs. The expenses of a first class hull restoration are likely to be high, but are not disproportionate when taken in the context of the cost of the whole restoration, being approximately 1/3 to 1/5 of the total cost. Savings through improper methods on the repair of the hull would have comparitively little effect on the short term costs of restoration and yet could easily lead to much higher costs being incurred in the future.

If a vessel is to be truly representative of her era, those repairs undertaken on her hull must be as authentic as possible. It would be true to say that traditional repairs would be much more costly than modern repairs in a normal commercial situation, but, as was mentioned in Section 3.2.2, the circumstances surrounding a restoration are quite different. The combination of the extra expenses incurred to make an unauthentic repair appear authentic (See Section 6.4.1.3) and the greater scope for interest which traditional repairs engender, both to the public and the volunteers, makes authentic restoration of the hull a more attractive proposition.

A number of Museums who have used modern techniques extensively to restore their vessels give technical reasons to justify their lack of authenticity. A favourite excuse worth discussing further uses the following argument.

'Riveting could not be used on the ship because the vibrations caused by the riveting operation would loosen large areas of the old rivets which would fall out or, at best, leak.'

This statement was found to be in direct contrast with the experience gained while repairing the 'Waratah' where:

i) After over 15,000 rivets had been hammered home on the 'Waratah', no old rivets were discovered with leakage from this cause.

ii) The vibrations caused by the removal of the old rivets with blows from a sledge hammer were much more severe than those vibrations caused during the subsequent riveting. Only three rivets over the whole hull were found to have been seriously disturbed by this work.

iii) Those rivets which were disturbed by these processes were defective anyway and should have been replaced regardless of the adjacent repair work.

These three observations put the above excuse for unauthentic repair into question. As the 'Waratah's' plating was thinner than that of the ships for which this argument was used, the effects of a given nett reduction in thickness would have most probably been greater on the soundness of the rivets on the 'Waratah'. Despite this, extensive loosening of rivets was not encountered.

Whether the repair is to be welded or riveted the deteriorated portions have to be removed, unless the unsavoury repair of doubling is used. To remove these portions, the rivets have to be knocked out, this being the period of greatest vibration during a riveted repair.

These vibrations must be experienced whichever repair method is to be used.

Finally, it is widely known that welding often results in high contraction stresses. If there is a repair which could seriously effect the tightness of rivets it is welding, and it is for this reason that special procedures are recommended for the welded repair of a riveted structure (D'Archangelo, 1969, p. 286), see Section 7.2.5. From the foregoing experiences on the 'Waratah' it would appear the use of such arguments cannot be justified and that it is more than likely that an excuse for a second rate repair, or the product of a number of preconceived ideas. It is worthwhile to note that this argument was actually quoted by a number of professionals including at least one ship surveyor.

When all is said and done, the authentic and proper restoration of a hull (and the ship as a whole) depends upon the particular Museum's commitment to the eventual fulfilment of its aims and its ability to provide the necessary resources both in the short term and long term. Although compromises will have to be made in most restorations, they should not be permitted to compromise the Museum's aims.

CHAPTER 7

HULL RESTORATION (STEELWORK).

7.1 INTRODUCTION.

Once the 'Waratah' had been docked and the detailed inspections were well in hand; work was commenced on restoring the hull. Figures 14, 15, and 16 illustrate the extent of repairs to the shell plating, internal hull structure and deck structure respectively. This chapter is not intended to be a detailed record of all the work carried out during the restoration of the hull. Its purpose is to illustrate some of the more significant parts ot the restoration; partly to give an indication of the scale of the work involved and how it was approached and partly to provide a number of practical examples for the concepts discussed in Chapters 3, 4 and 6.

In describing the work carried out on the 'Waratah', work on outfit and machinery have been excluded. This has been mainly for the purpose of brevity within the thesis and does not indicate that this work was any lesser in scale nor significance within the restoration. The restoration work on the hull has been chosen for illustration mainly because of the points raised in Section 6.6.

KEY

REPLACED PLATING

DOUBLE RIVETED BUTTSTRAP

WELDED BUTT JOINT

S.T. "WARATAH"

SHELL EXPANSION

FIG 14

SHELL REPLACEMENT

1977-79

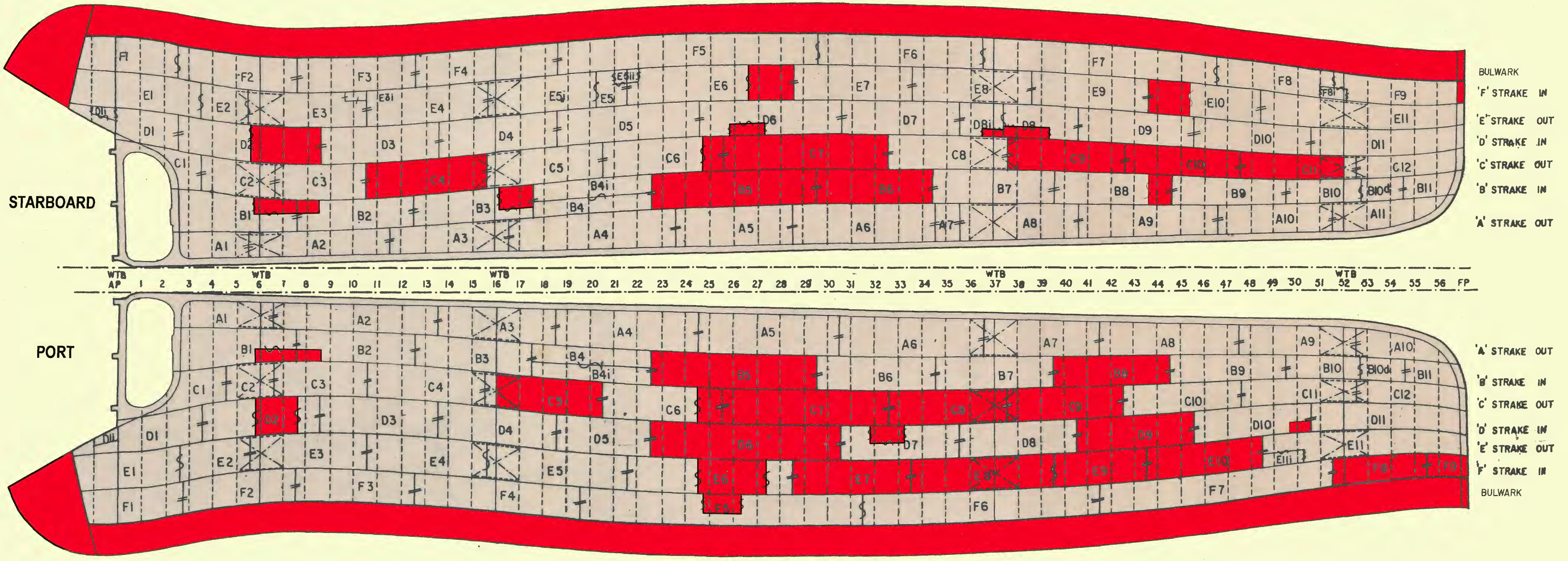


FIG 15

S.T. "WARATAH"

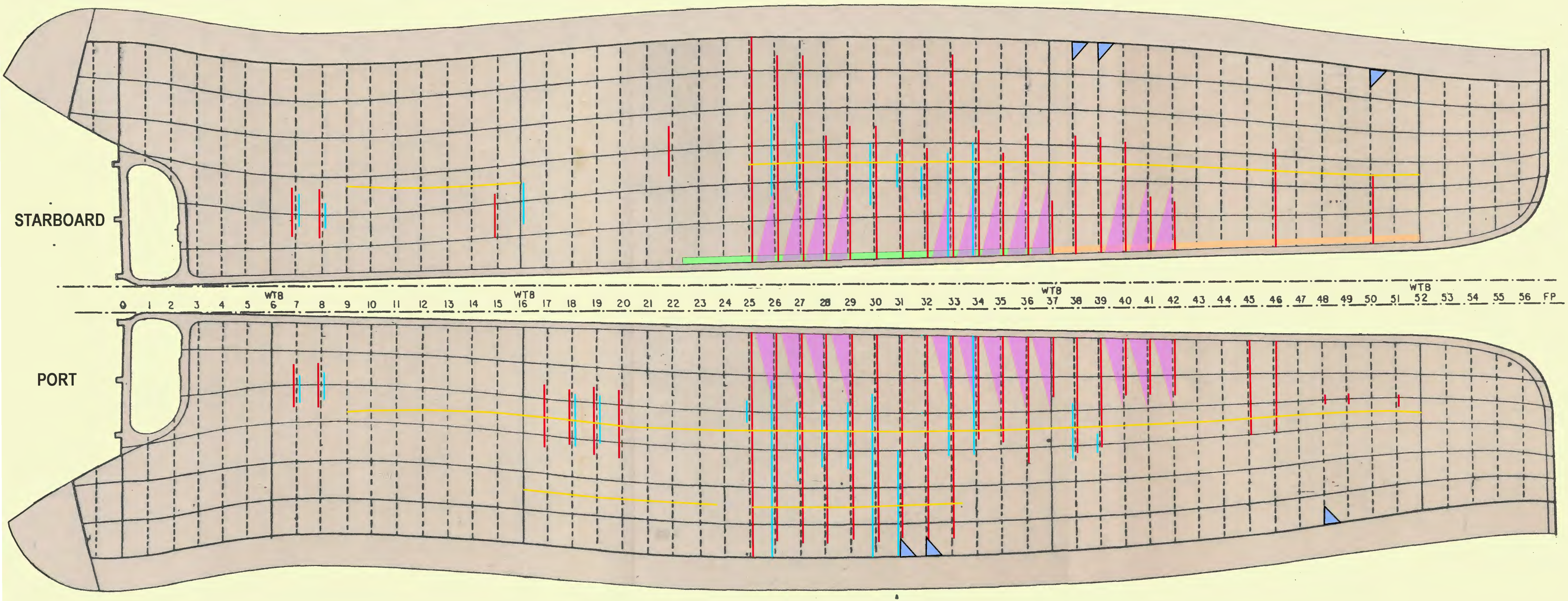
INTERNAL STRUCTURE EXPANSION

STRUCTURAL REPAIRS

1977-79

KEY

- REPLACED STRINGER
- REPLACED MAIN FRAME ANGLE
- REPLACED KEELSON
- REPLACED REVERSE ANGLE
- REBUILT KEELSON
- REPLACED HALF FLOOR
- REPLACED BEAM KNEE



S.T. "WARATAH"

MAIN DECK STRUCTURAL PLAN

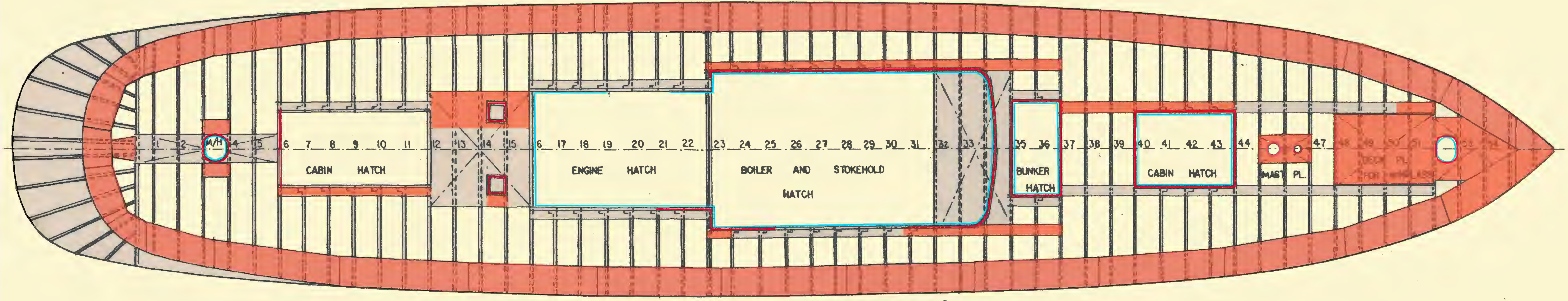
FIG 16

STRUCTURAL REPAIRS

1977-79

KEY

- REPLACED PLATING (STRINGER PLATES, TIES, ETC)
- REPLACED ANGLES (SHEER, WATERWAY, BOUNDARY)
- REPLACED COAMING



7.2 SHELL PLATING.

The first major repairs undertaken on the hull were to the shell plating. Figure 14 shows the extent of the shell plating replacement. Approximately 20% of it was replaced. The following sections describe the replacement of these plates in some detail to show the basic skills used in most of the hull repairs.

7.2.1 Methods of Plate Repair.

Three types of shell plate repairs were carried out on the 'Waratah's' hull. The decision as to which method was used depended upon the extent of corrosion and factors of strength and cost. The three types of repair were:

i) Complete replacement of an individual plate was carried out when the plate exhibited extensive corrosion over a large portion of its area.

ii) Insert plates were welded into existing plates where the corrosion was more local in nature. The deteriorated portion of the plate was cut away and a new section fitted and welded to the cut edges of the remaining portion of the plate. The plate insert was then riveted to the adjoining hull structure in the same way as the original portion it replaced.

iii) Pad welding was used to fill localized pits in otherwise acceptable plates.

7.2.2 Removal of Defective Plating.

The first step when replacing a plate was the removal of the existing defective plate. The rivets, which attached the plate to the adjacent framing and plating were removed by burning off their heads with an oxy-acetelyne torch and then knocking out the remaining portion of each rivet with a drift and a sledge hammer. The rivets were usually cut on the inside of the hull because the heads on this side, being pan heads, were proud of the plates (See Figure 17). In addition, many of the rivets on the exterior of the hull would have necessitated the burning operation to be overhead; a very unpleasant task. A large size cutting tip was used in the gas torch when cutting rivet heads and high oxygen and acetelyne pressures were used. The rivet heads had to be heated and cut as quickly as possible, to reduce the transfer of heat into the adjacent plating and so to lessen the chance of 'nicking' the plate during the cutting operation. Burning the rivets was usually done by just cutting away the pan head flush with the plating. In a few cases, where the rivets had been found difficult to remove, it was necessary to burn out the core of the rivet shank as well as burning away the rivet head. The job of burning out rivets quickly and efficiently required a high degree of skill which came only after much practice. It was for this reason that skilled

FIG 17

REMOVING RIVETS, ETC

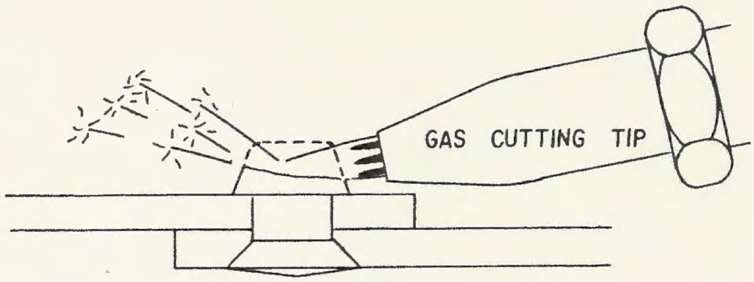


FIG 17 A

CUTTING AWAY RIVET HEAD WITH OXY-ACETYLENE

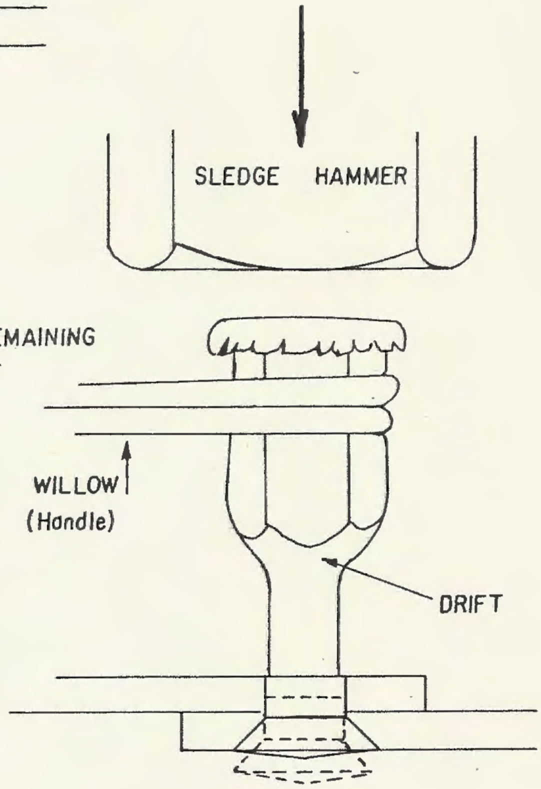
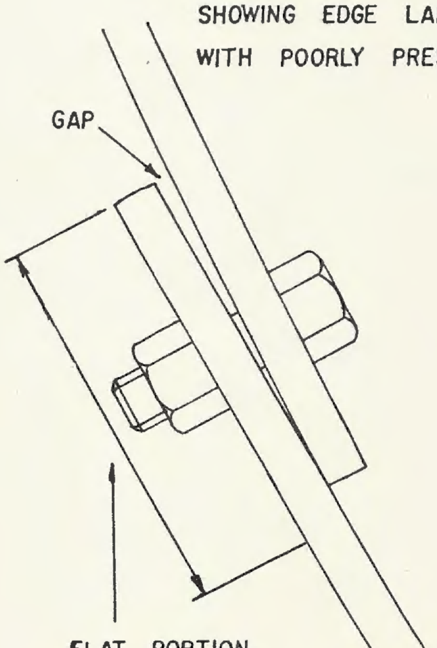


FIG 17 B

PUNCHING OUT REMAINING PORTION OF RIVET

FIG 17 C

SHOWING EDGE LAP FORMED WITH POORLY PRESET PLATES



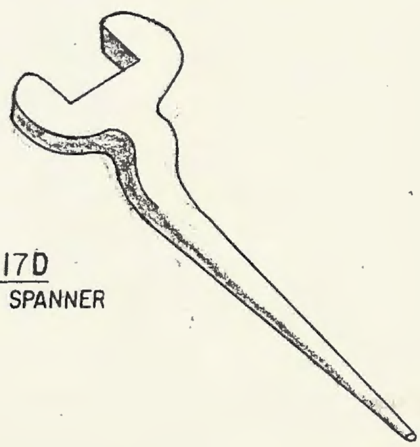


FIG 17D

PODGER SPANNER

rivet burners in commercial shipyards of the past were highly prized (Halliday, 1942, p. 10). Any welds, which held the plate to be removed to the surrounding structure, were also cut away as were the boundries of defective areas to be replaced by inserts.

The remaining portion of the rivets was removed by two men, one holding a drift on a long willow over the rivet, the other wielding a 4.5 - 6.0 kg sledge hammer. (Figure 17b). Each rivet required a number of heavy blows from the sledge hammer before it was removed. In some of the more confined areas, specially shaped drifts had to be used and at times the rivets had to be removed by one man alone.

The 'Waratah's' shell plating was constructed using an 'in' and 'out' system of strakes (See Figure 3). Every second strake overlapped the strakes on either side of it so as to provide a seam for riveting a watertight joint. Where the transverse framing passed over the outside strakes, special liners were used to fill the intervening space caused by the overlap. The position of a particular plate on the hull; that is, whether the plate lay in an inside strake or an outside strake, largely determined its ease of removal. Those plates laying in outside strakes were ready to be detached once the rivets and any welds had been removed. On the other hand, those plates in the inside strakes were more difficult to remove because, even though they were unriveted, they were still held in position by the overlapping seams of the adjacent outside strakes. To enable these inside plates to be removed, portions of the adjacent outside strakes had to have their rivets removed so as to allow sufficient freedom of movement of the inside plates. Fortunately, many of the plates which were removed from inside strakes during the 'Waratah' hull restoration were adjacent to outside strakes which, themselves, had to be replaced. (See Figure 14).

Once all the rivets, welds, etc, had been removed, the plates were finally detached from the hull with the use of sledge hammers, steel wedges, cro—bars and a chain block.

The number of plates that were removed concurrently was kept to a minimum so as not to weaken the vessel unduly. Also, the platework at any one time was distributed on both the port and starboard sides to avoid any undesirable distortions resulting from an imbalance. Where it was felt necessary, bilge shores were positioned in way of areas weakened during the repairs to help support the structure. (See Plate XXX)

7.2.3 Preparation of the New Plate.

7.2.3.1 Presetting of Curvature.

Most of the plates in 'Waratah's' shell had some degree of curvature (See Figure 2). Fortunately, although

PLATE XXX. LARGE SECTIONS OF SHELL PLATING REMOVED. PL. C6P WAS PARTIALLY UNRIVETED TO ALLOW REMOVAL OF PL. B6P (INSIDE STR.) NOTE BILGE SHORES. (Author, 1978)

PLATE XXXI. FITTING PL. D8P (INSIDE STAKE) BENEATH THE LAPS OF ADJACENT OUTSIDE STRAKES. (Author, 1978) a few of the plates which were replaced required some pre-setting; the greater proportion of plates replaced were offered up to the ship's frames without presetting; the required curvature being obtained by the use of bolts.

Most of the plates which were preset were given a curvature around one axis only; any small amount of double curvature present being pulled into shape by the use of bolts once in position. The presetting of these plates was done mainly by outside contractors using plate rolls. A few plates were set using a hydraulic press. Although this machine was later to be found very useful for setting double curvature, it did not provide as good a plate finish as that obtained with the plate rolls; definite lines of deformation being discernible. A few of the shell plates required a degree of double curvature to be preset. In the earlier stages this was mainly done by beating the plates with sledge hammers, as at that time, the Museum did not have access to the hydraulic press.

A lesson that was learnt while presetting these plates was that it was advisable to work plates that are a few centimetres oversize so as to allow sufficient bite for the setting machinery. By doing this the plate is deformed right to the extremities of the finished sized plate. Some plates were preset after being cut to the finished size. The result was that the last few centimetres were not set which made these plates very difficult to bolt up tightly along the lapped seams (See Figure 17c).

7.2.3.2 Drilling of Rivet Holes.

If the plate had been preset oversize or had required no presetting, it was then cut to finished size. The original plate was clamped over the new plate and the outline marked. The plate was then oxy -cut to size and the edges ground smooth. To mark the various rivet holes, the original plate was again clamped over the new plate and the holes centre punched. In some cases, where the curvature on the hull was tight; templates were taken off the hull and the holes marked from the templates.

When drilling holes for rivets above about 8 mm diameter, the drill used was about 1.5 mm greater in diameter than the actual rivet. The clearance fit was provided to allow for any slight misalignment of the holes within a joint after it had been set up and to allow for the slight expansion of the rivet shank once it had been heated. For the 16 mm rivets which were used over the majority of the hull repairs (See Figure 3), the rivet holes were drilled to 17.5 mm diameter. Pilot holes were first passed through the plate to facilitate the drilling and to relieve the forces on the drilling machinery. The 17.5 mm holes were then drilled, using a drill press around the periphery of the plate and a portable drill on a magnetic base for those holes beyond the reach of the drill press.

Once the rivet holes had been drilled, they were then countersunk using a 90° countersinking bit. Both the drill press and the portable drill on the magnetic base were also used to countersink the holes. Care had to be exercised when countersinking the plates as it was easy to become confused and countersink the wrong side of the holes. In addition, not all the holes on each plate required countersinking, those on the inside of the joints being left plain.

After the holes had been drilled and countersunk, all burrs on the faying surfaces (those surfaces that come into contact in a riveted joint) were removed by grinding to ensure that they would lay close together. Close fitting of faying surfaces was a prerequisite for obtaining a watertight joint (See Section 7.2.7).

7.2.4 Setting up.

7.2.4.1 Preparation of the Hull.

Removal of defective plating revealed the hull structure beneath. The opportunity was taken to closely inspect the structure for deterioration and to descale those members which would have otherwise been inaccessible. Where inspection revealed structure which was defective, its position was noted to be dealt with after the new hull plate had been fitted. The faying surfaces of the adjacent plates, frames and butt straps were descaled with needleguns and given a thick coating of red lead primer. Similarly, the faying surfaces of the new plates were also given a coat of red lead primer after any burrs had been ground away. Where the removed plate had been a part of an outside strake, the old frame liners were assembled and inspected for corrosion. Those that had been badly corroded or had been lost were replaced with new liners. The liners which were to be used, were descaled and coated with red-lead. The butt straps adjoining new plates were also inspected for deterioration and replaced where necessary.

7.2.4.2 Positioning and Bolting.

The plates were lifted into position on the hull using chain blocks or, where it was possible, the air hoist on the overhead, three-way crane (See Figure 8). To assist this operation, lifting lugs were welded to the inside of the plate; these to be later removed once the plate was securely in position. Positioning of the plates in the outside strakes presented no problems, but positioning those plates which lay in the inside strakes was much more difficult. These inside plates had to be manipulated under the seams of the adjoining outside strakes as shown in Plate XXXI . A podger spanner (17d) was used to line up the rivet holes once the plate was roughly in position. A number of bolts were fitted through the rivet holes until the plates was safely attached to the hull in the desired position. Where the plates had to be pulled into the curvature of the hull, a number of extra long bolts were used to reach across the intervening gap. Nuts were fitted and progressively tightened to bring the plate into the desired shape.

Before the plate was too securely bolted into position, strips of saturated felt were placed between the faying surfaces to assist watertightness of the joints (See Section 7.2.7). The butt straps and where necessary, the liners were also fitted at this stage. Once the saturated felt was in position, the faying surfaces of the various joints were tightly drawn together by tightening numerous bolts. Sufficient bolts were used to achieve a very close fit; the frequency varying from one bolt for each five rivet holes in the best fitting areas to a bolt for every rivet hole in areas such as seams along the incorrectly rolled plates (See Section 7.2.3.1). Usually, one bolt for every two or three rivet holes was sufficient. It was desirable to use as few bolts as possible to set up a plate, consistent with the joint being properly close, because the removal of bolts caused delays during the subsequent reamering and riveting operations. A tool which was found to be great value during setting up was a pneumatic wrench which was used to tighten and loosen the thousands of fasteners used.

7.2.4.3 Reamering.

Before the plates were riveted, all the rivet holes were reamered with a 17.5 mm taper reamer. By reamering the rivet holes, the easy entry of the rivets in the subsequent riveting operation was assured as any shoulders caused by misalignment of the holes were removed. Those holes which were free of the securing bolts were the first to be reamered. The securing bolts were then transferred to reamered holes allowing the remaining holes to be also reamered. Care had to be taken to ensure that the filings from the reamering and dirt from other sources did not find its way between the faying surfaces. Compressed air was used to clear the seams of dirt and filings before they were finally tightened. Most of the reamering was done using the taper reamer in a large electric drill. Two men were required to ream using this drill, one to handle the drill itself, the other to resist its torque by holding it at the end of a long extension handle.

7.2.5 Welding.

Any welding which was necessary on the new plating had to be completed before riveting to avoid straining of the rivets through weld contraction. (D'Archangelo, 1969, p. 286). The majority of welding which had to be carried out on the shell was around plate inserts. The edges of the plates were prepared with a single vee to ensure adequate penetration of the weld. A gap of between 1.5 mm and 3 mm was left between the two edges of welded butt joints. Welding was usually commenced along the inside of the seam because this allowed the work to be done downhand. The exterior of the butt was then gauged out using either a grinder or an oxy-acetelyne torch so as to remove the slag from the back of the first weld. The weld was then completed by welding from the outside.

It was often observed that after welding had been completed, rivet holes in the vacinity had to be re-reamered because of the resulting constraction.

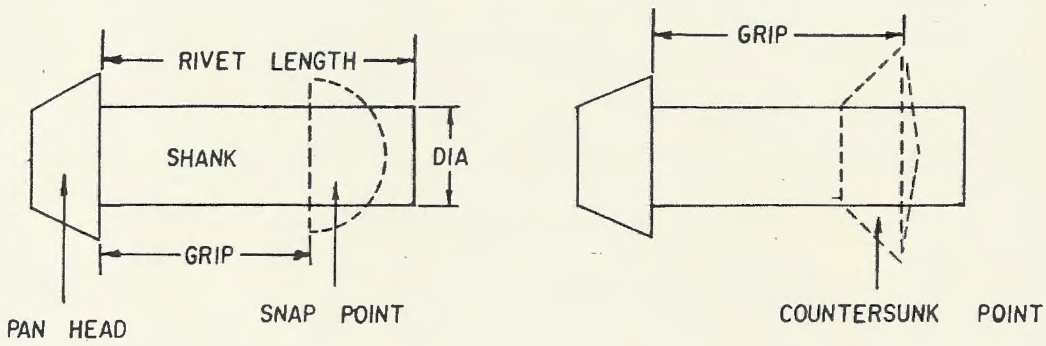
7.2.6 Riveting.

Riveting is the joining together of members using fasteners which are worked once they have been put into position.

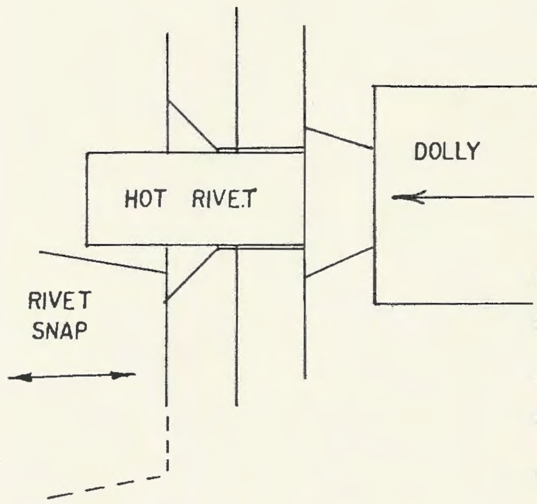
The rivets used on the 'Waratah' had to be specially made for her restoration by outside contractors. The rivets were made in a number of different diameters and lengths to suit the various applications around the vessel (See Figure 3). The thicker the section of the components to be joined, the larger the diameter of rivets which were necessary to give the joint adequate strength. Tables have been produced relating the recommended rivet diameter to the thickness of the members to be joined (Lloyds, 1898, Table S8). The rivet lengths were determined by the total thickness of the joint (known as the grip) (See Figure 18) and the shape of the rivet point (the formed head). A table, relating the lengths of rivets required for various grips, points and rivet diameters, was consulted for the purposes of ordering the initial batches of rivets

FIG 18

RIVETING

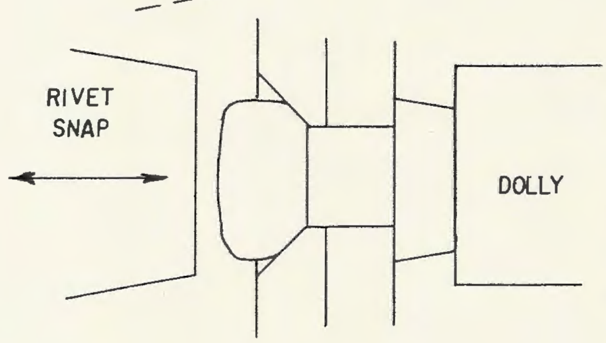


RIVETING PROCEDURE



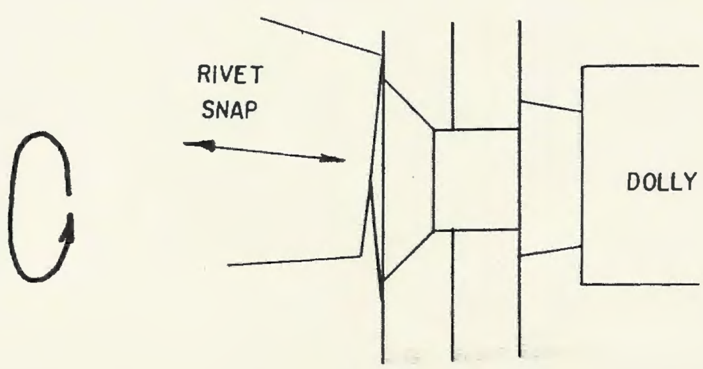
STEP I

HOT RIVET PLACED INTO HOLE AFTER WHICH ITS HEAD IS STRUCK WITH THE DOLLY TO DRIVE IT HOME. A FEW BLOWS ARE ALSO DELIVERED BY THE RIVET GUN TO THE ADJACENT PLATE



STEP II

RIVET GUN IS USED IN LINE WITH THE AXIS OF THE RIVET, UPSETTING ITS SHANK AND FILLING THE RIVET HOLE.



STEP III

POINT OF RIVET IS WORKED TO FILL THE COUNTERSINK BY ROTATING THE HANDLE OF THE RIVET GUN ABOUT THE AXIS OF THE RIVET.

(BHP, 1952, p.231). These tabular lengths were later found to be about 5 mm short of the actual rivet length required in the range of rivets used for the shell plating. These short rivets were not wasted, however, as they were used for other applications on the ship. In time, the correct length of a rivet for a particular job could be gauged by the eye of the riveter on site.

7.2.6.1 Heating the Rivets.

All the rivets 8 mm diameter and above had to be heated prior to being driven, usually in a forge. A number of different types of forges were used to heat rivets over the period of the restoration. The first forge which was used was fired on coke. The draft was forced by the injection of compressed air beneath the coke fire. (See Figure 19a). This type of forge would have been very similar to those in use when the 'Waratah' was built. Although about 2000 rivets were driven into the shell plates using this forge, it was found to possess the following disadvantages:

i) The efficient use of the forge was a very skilled task which only a few people were able to master. Not only were there a number of rivets at various stages of heat in the forge, but the fire had to be tended at the same time. Rivets were easily lost in the fire and, if they were allowed to overheat, they burned severely. As a result, the quality and speed of the 'rivet cooking' varied greatly depending upon the skills of the rivet cook.

FIG 19

RIVETING TOOLS

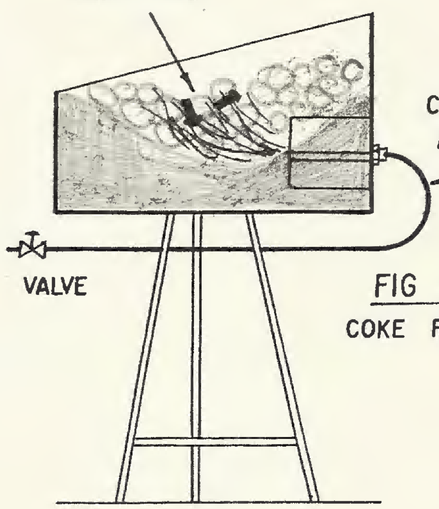


FIG 19 A
COKE RIVET FORGE

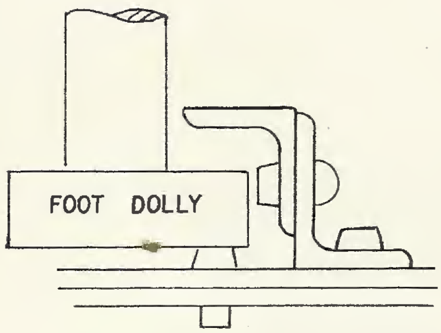


FIG 19 B
FOOT DOLLY AS USED TO HOLD RIVETS BENEATH A REVERSE ANGLE

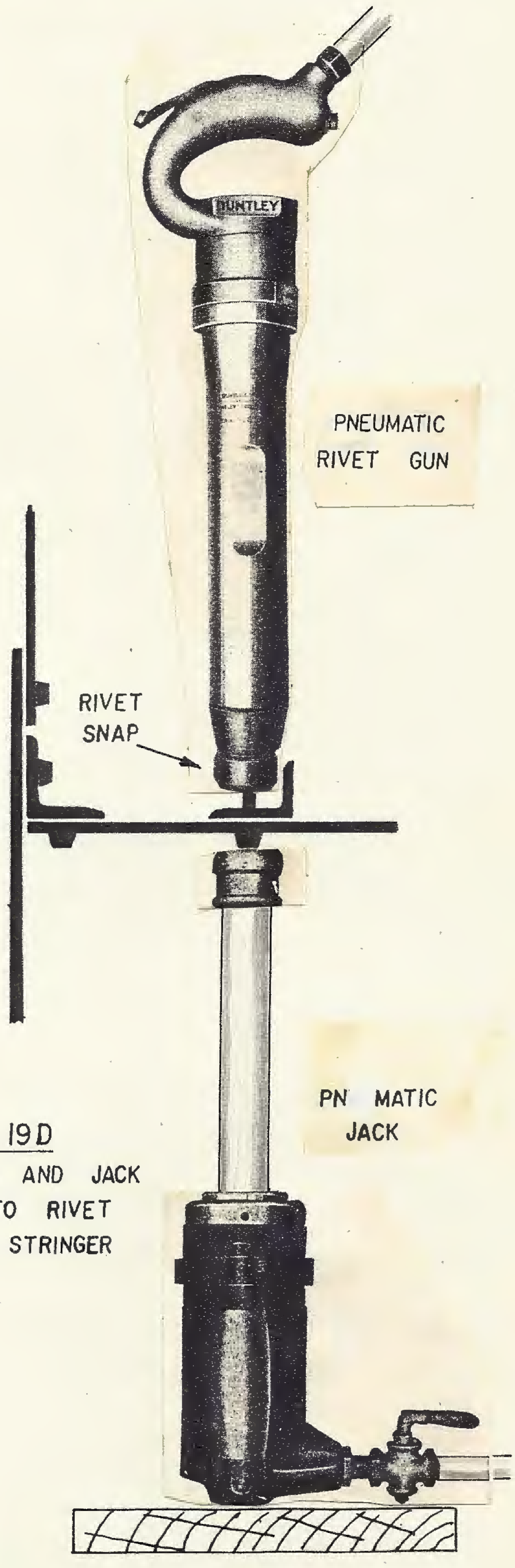


FIG 19 D
RIVET GUN AND JACK AS USED TO RIVET THE DECK STRINGER

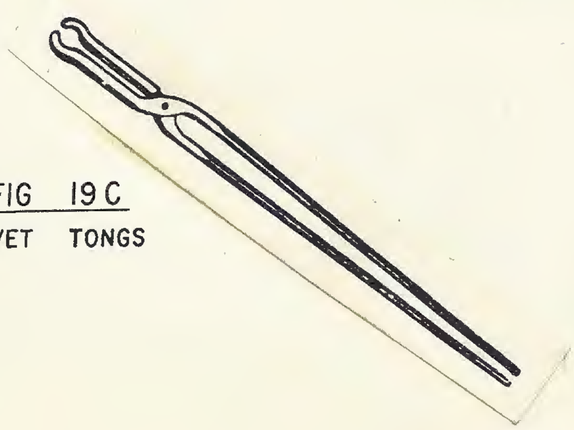


FIG 19 C
RIVET TONGS

ii) The use of the coke forge was very dirty. Rivets coming out of the coke fire were often covered with red hot slag. Not only did this slag make it more difficult to place the rivet into the rivet hole, but also it was quite hazardous to the riveter being capable of causing serious burns. The coke forge was also messy because the area in its vacinity soon became fouled with its ashes.

iii) The lighting up and preparation of the coke forge was found to be a time consuming job.

Unfortunately, although the use of the coke forge was authentic, its continued used under the circumstances was not considered practical. The maximum day's riveting with the coke forge had been only 200 rivets, with the average being only half this figure. As there were over 15,000 more rivets to be driven in the 'Waratah' with only one riveting team operating at any one time (these same people doing most of the other boilermaking work as well), an alternative for the coke forge had to be found. In looking for an alternative, the aim of preserving the skills had not been abandoned completely, because the various skills required to use the coke forge had, at least, been practised.

Numerous experimental forges were tried using a number of alternative fuels including diesolene, oxy-acetelyne and straight propane. The fuel that was found the most successful was oxy-propane. A forge was constructed with a hearth of bricks, supported on a steel stand. The flame was delivered by a large, commercially available, oxy-propane heating torch supplied with gas from an appropriate gas mixer. The heating torch was held in position on the forge stand with the use of a clamp. (See Plate XXXII). Rivets which had been heated in this forge reached the riveter considerably hotter and more frequently than rivets which had been heated in the coke forge. The result was that the riveter was able to ensure a better formed rivet point and the rate of riveting increased dramatically. As the control of the flame was instantaneous, up to a dozen rivets were heated at the same time and there were fewer rivets which were burnt.

The major disadvantage with the oxy-propane forge was the higher fuel cost. The cost of fuel for the coke forge had been almost negligible but the cost of fuel for the oxy-propane forge was about 20 to 25 cents per rivet. The added fuel costs were somewhat offset, however, by the higher riveting rates attained, particularly as at least one member of the riveting team was usually one of the paid Museum staff. It was to ensure the efficient use of fuel that all the rivet holes were reamered prior to riveting because delays caused by difficulties placing the rivets in the rivet holes were costly with regard to fuel. Using the oxy-propane forge, the record day's riveting increased to 400 rivets, while the average increased to about 200 rivets per day. The average for a day's

PLATE XXXII. (left)
HEATING RIVETS USING THE OXY-PROPANE FORGE. NOTE HOT RIVET IN TONGS. (Author, 1978)

PLATE XXXIII. (below)
HOLDING UP RIVETS IN PORT WING BUNKER. NOTE NEW SECTIONS OF FRAMING. NEW STRINGERS AND PORTIONS OF REVERSE ANGLES HAD NOT YET BEEN FITTED. (Author, 1978)

riveting would have been higher, except that there were rarely over 200 rivet holes set up for riveting at any one time. The day's riveting was usually completed within only a few hours, the rest of the day being available for other work. An indication of the potential of this type of forge can be gained from the fact that in one particular area, over 130 rivets were driven in one hour.

The rivets were heated to a yellow heat (about 1100^{o} c) at which stage they exhibited a glazed, shiny appearance. The rivet, once hot , was then removed from the forge with tongs (See Figure 19c) and passed to be placed into a rivet hole.

7.2.6.2 Holding Up.

Once the hot rivet was placed into the rivet hole from the inside, a heavy dolly was then struck against the rivet head to drive it home. It was then rested hard against the rivet head for the duration of the actual riveting operation to brace the rivet against the blows of the riveter and to hold it in position. (See Plate XXXIII). Dollies of a variety of forms were used for various purposes around the ship. The dolly which was used for most general purposes was made from a 15-20 kg cylinder of steel with a handle welded on its end. For other more specialized work, other types of dollies were used such as the foot dolly which was used to hold up rivets underneath reverse angles and stringers (See Figure 19b). Other methods for holding up rivets will be discussed in later sections.

7.2.6.3 Forming the Rivet Point.

The rivets were knocked up using a pneumatic rivet gun. This tool delivered a continual succession of percussive blows via a snap to shape the rivet point. (See Figure 19 d). The shape of the end of the snap determined the final shape of the rivet point. All the rivets in the shell plating were finished with a countersunk point (See Figure 18a) using a flat ended snap. The use of the rivet gun was not an anachronism in the era when the 'Waratah' was originally built for they were in use at the turn of the century (Babcock, 1898, pp. 28-42) and most of the rivets in original structures on the 'Waratah' appeared to have been done by machine.

As soon as the hot rivet was placed into the rivet hole, the riveter began his work. The first blows of the rivet gun were to the plate immediately alongside the rivet with the dolly backing up the rivet (See Figure 18, step 1). This helped to ensure that it was fully home in the rivet hole before it was knocked up. Once the rivet was home; the riveter began to upset the shank of the rivet by hammering the end of the shank directly along its axis. (See Figure 18, step 2). As the shank swelled it filled the rivet hole and partially filled the countersink. The rivet gun was then manipulated by rotating its handle in a circular motion to fashion the rivet point (Figure 18, step 3). A successful rivet was tight in the hole, filled the countersink completely and was just proud of the plate surface, protruding in the shape of a shallow cone.

The rivets contracted upon cooling, drawing the surfaces of the joint together. Skillfull use of the rivet gun, together with this contracting action was capable of drawing joints together which initially had gaps between the faying surfaces of up to 1 mm.

When riveting was done in way of the securing bolts, rivets were first driven into the rivet holes immediately adjacent to each bolt. The bolt was then removed and a rivet driven in its place. By this means, the plates were kept in close contact despite the need to remove the securing bolts.

7.2.6.4 Teamwork.

Usually, four men worked together as a riveting team consisting of a rivet cook, rivet passer, holder-up and riveter. Where the work was more open, sometimes only three men were necessary. Efficient riveting required the persons involved to display a high degree of teamwork as once the rivet was taken out of the forge, the whole riveting process could only take seconds. The quicker it was done, the hotter the rivet remained during the riveting process and the better the result. The need for teamwork was especially apparent when the riveter was separated from the rest of the riveting team by being on the outside of the hull, particularly when there was noise from other work on the site.

7.2.6.5 Rivet Testing.

All the new rivets were inspected and tested for tightness. Rivets which, upon inspection, did not fill the countersink completely were removed and replaced. Tightness of the rivets within their rivet holes was tested by tapping the rivet point with a small hammer while, at the same time, feeling for any relative movement between the rivet and the adjacent plating. Rivets which were found to be loose were either removed and replaced or were tightened up cold using the rivet gun and dolly. Care had to be exercised when tightening up rivets in this manner because it was possible to loosen those rivets immediately adjacent.

7.2.7 Watertightness.

7.2.7.1 Methods.

Watertightness of riveted hulls was achieved by a combination of the following methods:

i) Close fitting of faying surfaces when preparing for riveting by ensuring that there are no foreign particles between the faying surfaces and by tightly bolting the joints.

ii) Close spacing of rivets.

iii) Good quality of riveting ensuring tight rivets with well formed heads.

iv) Use of saturated felt stopwaters between the faying surfaces.

v) Caulking of plate edges and butts.

vi) Rust forming between the joints.

vii) Red lead/white lead stopwaters.

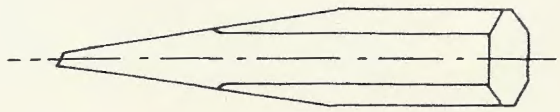
A number of these methods have been discussed as part of the preceding sections.

7.2.7.2 Caulking.

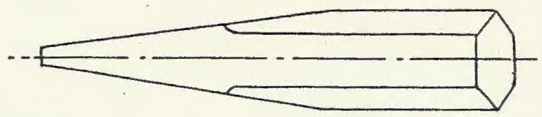
Once the riveting on the shell plates had been completed, they were caulked. Caulking of the plates was achieved by burring one plate edge onto another to form a watertight seal using either hand or pneumatic caulking tools (See Figure 20). The caulking of edge laps (the plate seams on the shell) employed a different method to that used when caulking the butt joints. The edges of lapped joints were thickened by staving with a chizel point, so forming a shoulder to caulk the joint. (See Figure 20c).

FIG 20

CAULKING, TOOLS AND PROCEDURES



STRAIGHT SPLITTER (TOOL "A")



ROUGH TOOL (TOOL "B")

FIG 20A HAND CAULKING TOOLS

PNEUMATIC CAULKING CHIZEL

FIG 20B

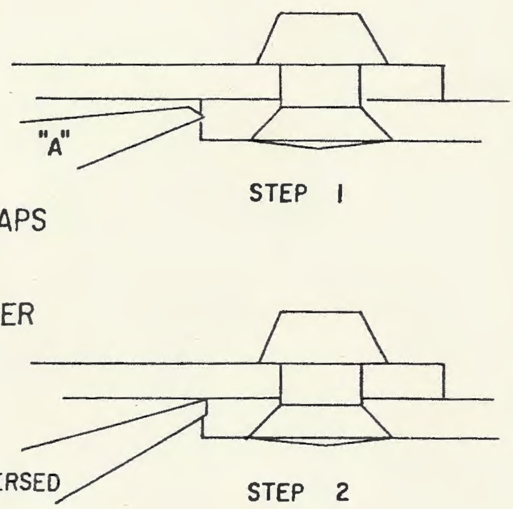


FIG 20C CAULKING EDGE LAPS BY STAVING AND FORMING A SHOULDER

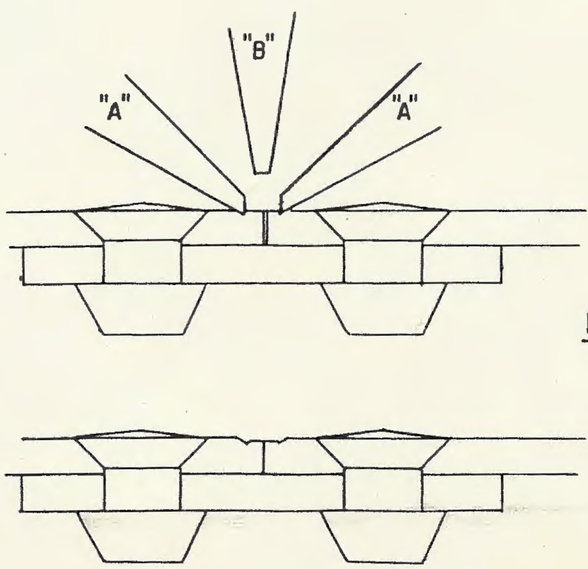


FIG 20D CAULKING BUTT JOINTS BY ELONGATING AND THINNING

Caulking of a butt joint was achieved by elongating its edges by thinning until they met (See Figure 20d). Where the gap between the two plates of a butt joint was too large, it was first packed with strips of steel and then caulked. To assist the attainment of a watertight joint, a putty of red lead and white lead was forced into the joint with the caulking chizel so as to act as a stopwater.

Generally, caulking of the edge laps did not prove to be difficult. The butt joints, on the other hand, were hand were found to be much harder to caulk, partly because there was no lapping plate to guide the caulking chizel and partly because many of the butts had gaps which were slightly too large. A point that should be remembered, however, was that the new steel plates were much more difficult to caulk than were the softer original iron plates. Caulking was only necessary on the outside of the edge laps.

7.2.8 Water Testing.

Before the hull was floated, it was subjected to water testing. A powerful jet of water from a 76 mm fire hose was directed at close range over the whole area of the exterior of the hull. Leaks were spotted by an observer on the inside of the hull. The first water test revealed nine leaks, most of which were past butt joints. Many of those butt joints which had leaked had been especially difficult to caulk because of a shortage of appropriate scaffolding. The leaking joints were subsequently recaulked and the hull subjected to a second water test. Remarkably, although most of the joints which has previously leaked now appeared tight, a number of new leaks were discovered, including a loose rivet. The rivet was replaced and the leaking joints recaulked. The third water test on the hull revealed no further leaks, permitting the hull to be floated.

Later, while the 'Waratah' was being undocked, the hull was given a final inspection for watertightness just prior to her lifting off the keel blocks (See Section, 5.2.5.2), quite a few minor weeps were discovered, despite the result of the final water test. As it was believed that these weeps would eventually be sealed by rusting within the joints, it was decided to complete the undocking. (Campbell-Holmes, 1941, p. 318). In time, the weeps did cease; most of them having stopped within the first fortnight after the undocking.

7.3 TRANSVERSE STRUCTURE.

The extensive repairs which were carried out on the transverse structure during the 'Waratah' restoration are shown in Figure 15. The members included in the transverse structure for the purposes of this section are the main frame angles, reverse angles, plate floors stringer and keelson angle lugs and heel pieces, see Figure 3. The transverse structure of the deck is not included, nor are the transverse bulkheads.

7.3.1 Frame Angles.

Approximately 8% of the main frame angles and 29% of the reverse angles were replaced. The methods of repair used were similar for both main and reverse angles.

7.3.1.1 Removal.

The repairs to the frames were not commenced until after new plating in the immediate vacinity had been fitted. Concurrent replacement of shell and frames was avoided because it was feared that a serious loss of strength could have resulted and the shape of the vessel in that area could have been lost.

Rejected floors and sections of angle were removed by cutting away and removing the rivets attaching them to adjoining angles, floors, shell plates, stringers, keelson, etc. Where only a portion was defective, it was cropped at the extremities of the section to be removed.

7.3.1.2 Shaping.

The fine lines of the 'Waratah's' hull (See figure 2) were such that most of the angles of the transverse structure had been set with curvature. As a result, most of those sections of frame angle replaced during the 'Waratah' restoration required the new sections to be preset with curvature prior to fitting.

The frame angles were set by working them hot. The angles were heated in a coke forge to a bright red heat. (See Plate XXXIV). This forge, which worked on a similar principle to the coke rivet forge mentioned earlier, was capable of heating about one metre of angle at a time. Once the angle was sufficiently hot, it was worked by repeatedly striking it with a sledge hammer over a crude bending jig, (See Plate XXXV), until it had either attained the desired shape in the region of the heating or until it had lost too much heat to continue the working. The angle was heated and worked a number of times to give it the correct shape. At intervals during the working of the angle, its shape was checked against that of the old removed section of frame. Once the angle had been given the correct curvature, the shape of its flanges were further refined using a tool known as a 'flatter'. (See Figure 21a)

The main angles of transversely framed, riveted ships were progressively bevelled in the forward and aft extremities of the ship so that they would come into close contact with the shell plating and yet have their webs perpendicular to the centreline of the ship (See Figure 21b). Fortunately, nearly all of the main angles replaced during the 'Waratah' restoration were in the midships region and therefore did not require bevelling. The only exceptions were the small sections in frames 7 and 8 which were bevelled in situ.

PLATE XXXIV. (left)
HEATING FRAME ANGLE IN COKE FORGE. (Author, 1978)

PLATE XXXV. (below)
HOT WORKING ANGLE FRAMES TO SET CURVATURE. (Author, 1978)

FIG 21

FRAME REPAIR DETAILS

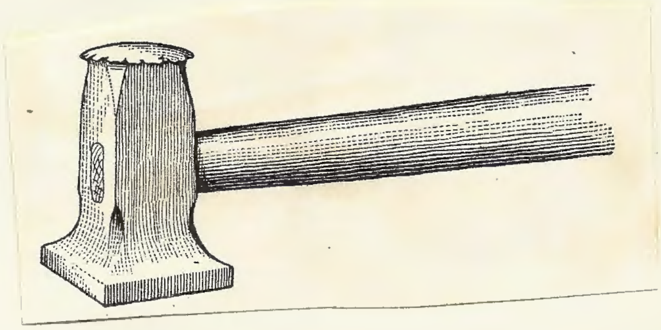


FIG 21A
FLATTER-USED WITH SLEDGE HAMMER FOR WORKING FLAT SURFACES

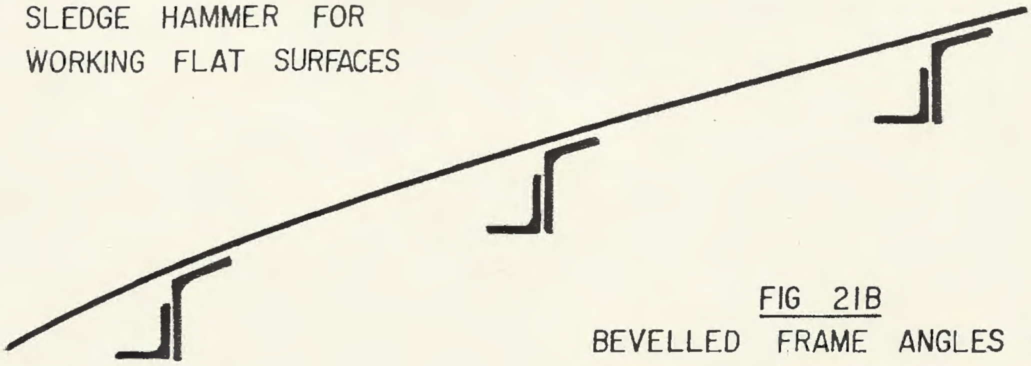


FIG 21B
BEVELLED FRAME ANGLES AT FORWARD AND AFTER ENDS OF A SHIP.

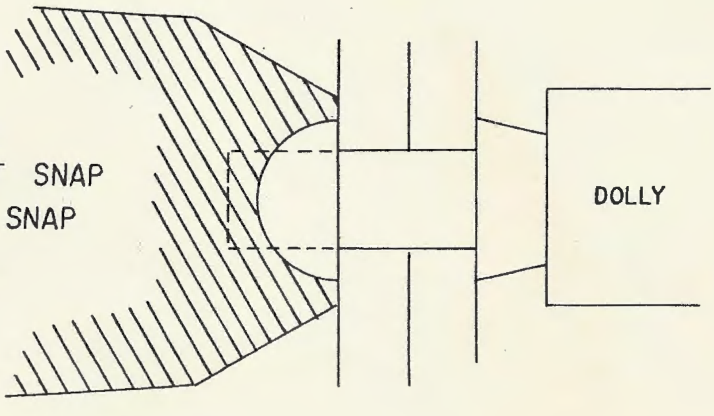


FIG 21C
INDENTED RIVET SNAP USED TO FORM SNAP (ROUND) POINTS.

The methods used to set the frame angles during the restoration were much less sophisticated than those used to set them originally when the vessel was built (Campbell-Holms, 1942, p. 486 et seq.). Unfortunately, the equipment which was necessary to shape the frames in an exactly authentic manner was not available to the Museum at that time. The main disadvantage of the methods which were actually used was that the length of angle which could be worked was limited by its weight. A number of the longer sections of angle which were replaced had to be set in two shorter lengths and then subsequently welded together.

One interesting advantage of the two angle composite structure of the transverse framing was that each angle could be worked using much lower forces than those which would have been required for a single section of similar strength.

7.3.2 Plate Floors.

Approximately 20% of the floors in the 'Waratah' were replaced during the restoration as shown in Figure 15. Once the defective floor plates had been removed, replacements were made using the old floor plates as templates in a similar manner to that used to make the new shell plates. In addition, new stringer and keelson angle lugs, heel pieces, centreline floor buttstraps and other items were made where necessary, to replace deteriorated components.

7.3.3 Drilling and Setting Up.

The rivets holes were marked from those of the adjoining structure remaining in the ship and then drilled with a 17.5 mm diameter drill bit on the drill press. No countersinking was necessary for the holes in the transverse structure as the points of the rivets were not countersunk.

The various components were bolted in position and the ends of the new lengths welded to the cropped ends of the remaining sections. The rivet holes were then reamered with a taper reamer fitted to a pneumatically driven drill with a right angle drive. The electric drill fitted with a reamer could not be used for this work because of the proximity of the adjacent structure. For some of the more awkward rivet holes a specially modified reamering bit was used, driven by the pneumatic wrench.

7.3.4 Riveting.

All the rivets in the transverse framing, other than those passing through the shell plating, were finished with a 'snap' (or rounded) point. (See Figure 21c). This point was formed by using a special indented snap in the rivet gun.

The rivets in most of the transverse structure were held in position during riveting by a pneumatic jack (See Figure 17e). This device consisted of a piston in a cylinder operated by compressed air which was controlled manually through a value. When in position the air was admitted to the cylinder which, through the movement of a piston, held the rivet by bracing against an adjacent frame.

A short rivet gun was obtained to do this work because the usual model could not fit between the frames to knock up the rivets. The riveting of the transverse structure was much slower than riveting the shell plating because the work was found to be more awkward and complex.

7.4 DECK STRINGER.

The deck stringer was generally found to be in very poor condition from stem to stern. As it was a major structural member, it was decided to replace it over its whole length. This is shown in Figure 16. For the greater proportion of its length, the 'Waratah's' deck stringer was constructed from a stringer plate, sheer angle and waterway angle riveted together and to the surrounding structure (See Figure 3). Around the stern, its construction differed. A description of the work carried out upon this deck stringer around the stern will follow in Section 7.7.

7.4.1 Removal.

The old sections of the deck stringer were removed by cutting away the countersunk points from above and the pan heads along the sheer angle, knocking out the rivets and cutting across the stringer plate so that it could be lifted in managable sections. The countersunk points in the stringer were cut in preference to the pan heads underneath so as to avoid having to work overhead.

7.4.2 Construction and Assembly.

7.4.2.1 Stringer Plate.

The new stringer plates were cut to the shape of the deck edge and their edges ground smooth. They were then clamped in position over the deck beams and the rivet holes passing through the deck beams were marked from beneath. The stringer plates were then removed to be drilled and countersunk where necessary. (See Plate XXXVI) After they were drilled, the stringer plates were then bolted back into position over the deck beams.

7.4.2.2 Sheer and Waterway Angles.

The sheer and waterway angles, once fitted, had to follow the curvature of the deck edge in plan. This curvature varied from very slight midships to severe at

PLATE XXXVI. (right)
NEW STRINGER PLATES CUT AND DRILLED PRIOR TO BEING BOLTED IN POSITION
(Author, 1978)

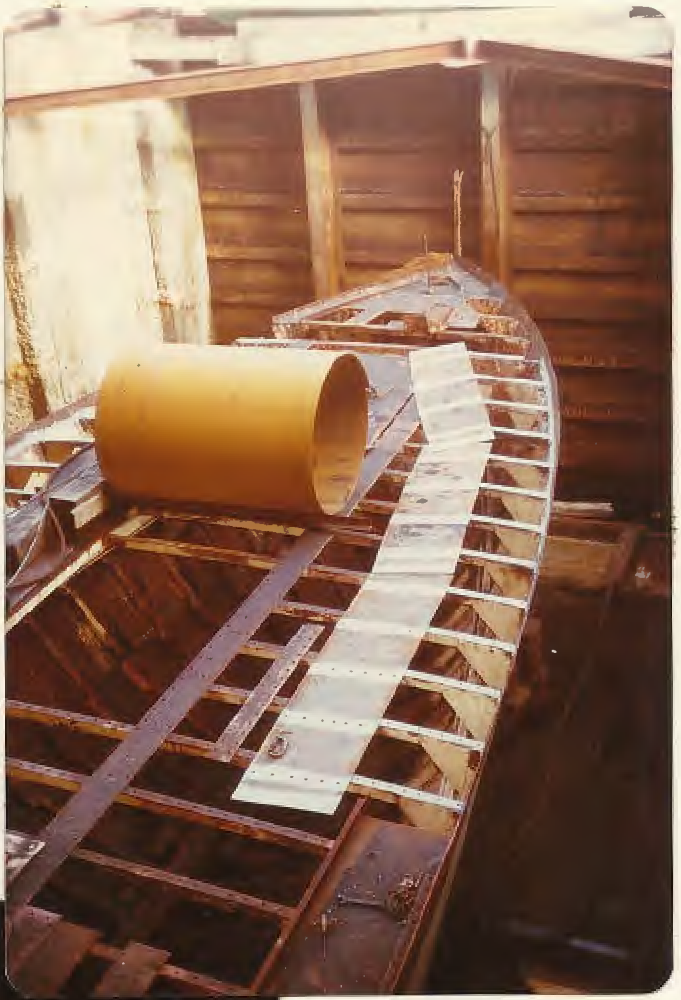


PLATE XXXVII. (left)
RIVETING DECK STRINGER
(Author, 1978)

the bow and stern. A number of techniques were used to set these angles to the required curvature.

Amidships, the angles did not require presetting to follow the deck edge. Wedges and clamps were used to force the angles into position ready to be drilled where they lay. As the curvature became more pronounced towards the extremities of the vessel, the sheer and waterway angles had to be preset before fitting. To obtain the moderate curvature required at the quarters of the 'Waratah', the angles were worked cold by striking them with a sledge hammer over the bending jig. At the extreme bow and stern, more powerful techniques had to be used. The extreme curvature was set using a device called a 'jim-cro' which is used extensively to bend railway tracks. (See Figure 22a).

Once the correct curvature had been set, the angles were drilled and bolted in way of the deck beams. The flanges of both the sheer and waterway angles which were in contact with the stringer plates were then marked for the rivets attacking them to the stringer plate between the deck beams. These holes were then drilled by first passing a pilot hole through both angle flange and stringer plate and then following this by the final sized drill bit driven by an electric drill held in the magnetic base. The subsequent countersinking was also done using the magnetic base and drill.

Towards the bow and stern, the sheer angle had to

FIG 22

DECK STRINGER REPAIR DETAILS

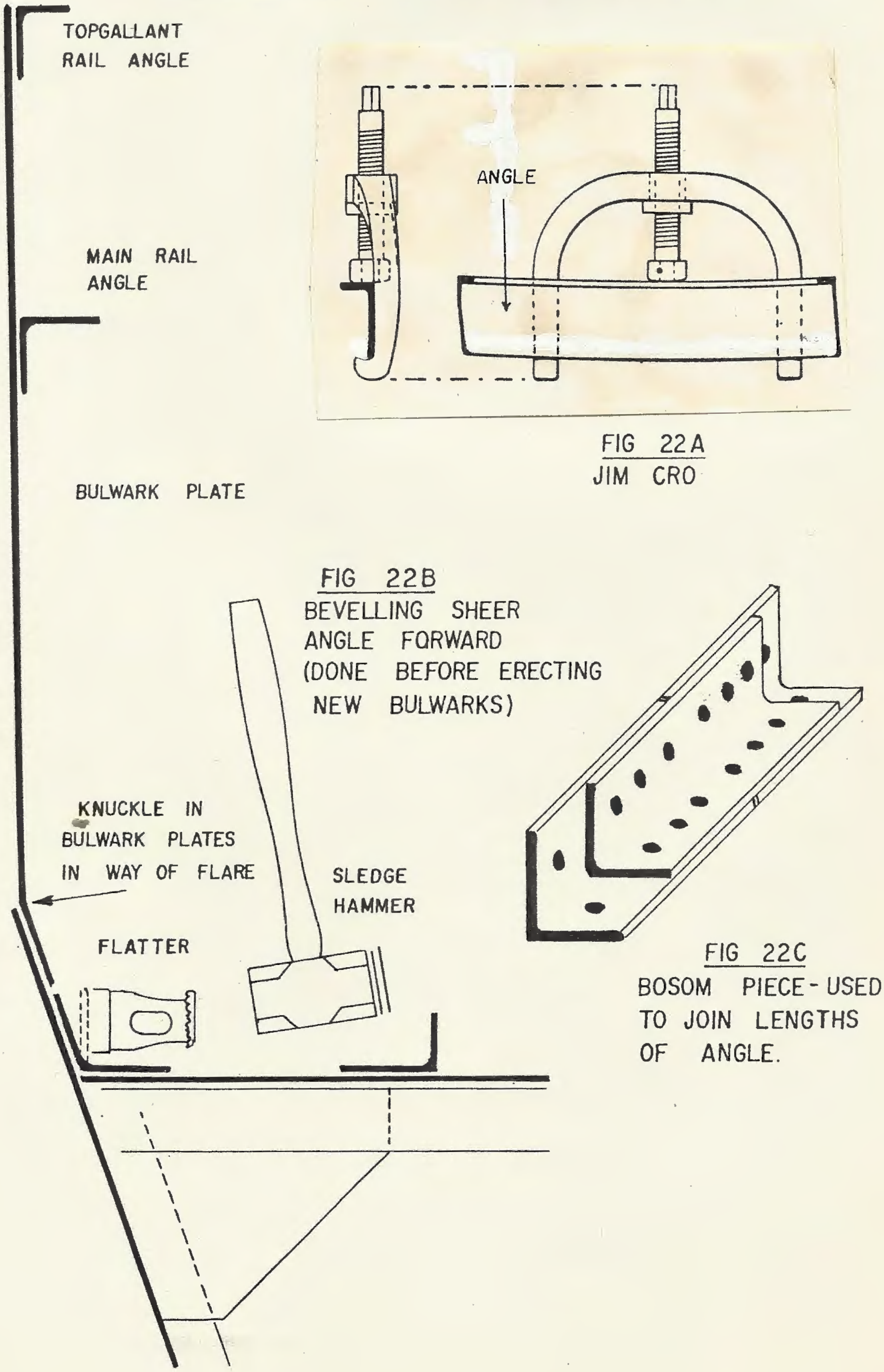


FIG 22A
JIM CRO

FIG 22B
BEVELLING SHEER ANGLE FORWARD (DONE BEFORE ERECTING NEW BULWARKS)

FIG 22C
BOSOM PIECE - USED TO JOIN LENGTHS OF ANGLE.

be bevelled out to follow the flare of the sheer strake. (See Figure 22b). Bevelling was done once the sheer angle had been securely bolted to the stringer plate. About 30 cm of the vertical flange and root of the angle was heated at a time with the oxy-propane heating torch. Once this had attained a bright red heat, it was worked to the correct bevel by striking the vertical flange with a sledge hammer and flatter until it lay snugly against the sheer strake. The same operation was then carried out to adjoining sections progressively bevelling the angle along its whole length.

7.4.2.3 Assembly.

Once the sheer angle had been bolted into position and bevelled where necessary, the rivet holes passing through its vertical flange were marked from those in the sheer strake. The sheer angle was then removed and these holes drilled on the drill press. The waterway angle was also removed and the burrs ground off the faying surfaces of both the waterway and sheer angles. The faying surfaces of these angles were then liberally coated with red lead primer, prior to being reassembled with strips of saturated felt between the joints. Various buttstraps for the stringer plates and 'bosom pieces' for the angles (See Figure 22c) were manufactured and fitted once the necessary holes had been drilled in the various components of the deck stringer. All the rivet holes in the deck stringer were then reamered in preparation for riveting.

7.4.3 Riveting.

The major problem that had to be overcome to enable the deck stringer to be riveted was the holding up of the rivets from beneath the deck stringer. To enable the pneumatic jack to be used special scaffolding was built beneath the deck stringer for it to be braced against. (See Figure 17). Although this was quite successful, difficulties were encountered in those areas where the flare of the shell plating was excessive in the bow and stern. (See Figure 2 and 22b). In the extreme stern, these difficulties became so serious that alternative methods had to be used to hold up the rivets. These alternative methods will be discussed in Section 7.7.

When riveting the deck stringer, the hot rivet was placed into the rivet hole from beneath using tongs. The riveter above the stringer plate then held the rivet in position by applying a side ways force to the protruding shank of the rivet with his rivet gun, jamming it in the hole. The tongs were then released and the pneumatic jack was positioned and put into operation holding the rivet in position. The riveter then drove the rivet in the normal manner (See plate XXXVII).

7.5 BULWARKS.

The 'Waratah's' bulwarks were in very poor condition before restoration. Corrosion had been extensive and the years of hard service had left the bulwarks badly dented and buckled. In addition, there had been numerous repairs and alterations to the bulwarks over the years, these being far from authentic. It was felt, in view of their terrible state, that complete replacement was the only feasible solution. (See Plate XXII).

Research had to be undertaken to determine the original form of the 'Waratah's' bulwarks. Fortunately, much useful information was still available on the bulwarks themselves and from the vessel's original plans. There were some features, however, which had to be determined from the secondary sources discussed in section 6.4.3.

The old bulwarks and staunchions were removed at an early stage to facilitate the replacement of the deck stringer. The construction of the bulwarks in the midship length of the ship is shown in Figure 3. The forward and after regions were extended in height to form a solid topgallant bulwark as shown in Figure 22B. The following is a description of the bulwark replacement with the exclusion of that around the stern which will be described in Section 7.6.

The first component of the bulwarks to be positioned was the main rail angle. Lengths of angle were drilled along one flange for the rivet holes. They were then preset to the correct curvature (following that of the deck edge in plan), using the methods discussed in Section 7.4.2.2 for the sheer and waterway angles. The lengths of main rail angle were then set up in position on temporary welded staunchions to obtain the correct height and curvature. At this stage, the angles were then checked for fairness; viewed by eye from as many positions as was possible and the necessary adjustments made.

The bulwark plates, which were then cut to size, were temporarily fixed in position along the main rail and the rivet holes in way of main rail angle and the sheer strake marked for drilling. These holes were drilled, together with those necessary for the butt straps and, if the plates were from forward, those necessary for the topgallant rail angle. A number of the bulwark plates had to be set with a knuckle near their lower edge before drilling to provide a transition from the flare of the sheer plates to the vertical line of the bulwark plates (See Figure 22b). The knuckle was formed by heating along the line of deformation required and bending it by working with a hammer over the edge of a bending slab. Once the plates had been drilled, the faying surfaces were ground and coated with red lead before being bolted back into position on the ship. The necessary butt straps, bosom pieces and lengths of topgallant rail angle were then made and fitted. (See Plate XXXVIII)

PLATE XXXVIII. NEW SECTION OF BULWARK UNDER CONSTRUCTION SHOWING MAIN AND TOPGALLANT RAIL ANGLES AND TEMPORARY STAUCHIONS. (P. Jones, 1978)

PLATE XXXIX. UPPER PORTION OF COUNTER CUT AWAY SHOWING CANT BEAMS AND STUBS OF CANT FRAMES. (P. Jones, 1978)

The permanent spur staunchions were then made. It was not known whether these had been originally fire welded from stock or forged from the solid. Unfortunately, neither method was practical within the limitations of the Museum's resources at that time. The spur staunchions were, therefore, electric arc welded from stock and ground smooth at their joints to present an authentic appearance. Each staunchion had to be specifically manufactured to suit each particular position along the 'Waratah's' bulwarks. Once these permanent staunchions had been fitted, the temporary stanchions which had been fitted earlier were removed.

The bulwarks were bolted and reamered in preparation for riveting using the same methods as described earlier. Final adjustments were made to ensure that the main rail had a fair appearance and then the bulwarks were riveted. Rivets were finished in the same manner as discovered was authentic on the vessel originally; that is, with snap points in way of the main and topgallant rails and countersunk points elsewhere.

7.6 UPPER PORTION OF COUNTER STERN.

The bulwark around the stern of the 'Waratah' differed from the rest of her bulwarks in that it was actually a continuation of the lines of the hull (See Figure 2).

Because of its complex nature, the repair of this area of the ship involved the most difficult steelwork attempted during the restoration.

The stern, as a result of years of neglect and abuse, was in very poor condition before restoration was commenced. It had taken the brunt of countless collisions and had corroded in some areas. Within the last thirty years the stern had been extensively repaired, a result of a possible major collision in the past. These repairs had only been of a temporary nature and had resulted in the stern having a distorted, unfair shape, full of extensive welds and with little thought having been given to its final appearance. As was the case with the rest of the bulwarks, the only effective method of repair was complete replacement.

7.6.1 Shape.

Unfortunately, because the stern differed so greatly from the original in both shape and detailed construction; its various components could not be used as templates for the fashioning of replacements.

It was at first planned to take offsets directly from the original line plan to determine the shape of the various components. The existing plans were to a scale of 1:24. It was felt that they would have to be enlarged to a scale of 1:10 to be of any practical assistance for obtaining offsets. Once the drawing of this enlarged lines plan in the region of the stern had commenced, the following problems were encountered:

i) The lines plan from which the enlargement was drawn, had been, itself, the product of a number of copying processes including microfilming. The result of all these copying processes was that the edges of the drawing had distorted. The lines of the stern, being in the upper, left hand corner were no longer sufficiently accurate.

ii) There were very few waterlines and sections defining this region of the stern on the original lines plan.

iii) There were marked differences in detail between the lines plan and the vessel, particularly with regard to the shape and position of the deck edge around the stern.

As a result of the above problems, this method of obtaining the necessary offsets had to be abandoned and another alternative sought. The method which was actually used in practice was to use the offsets on the lines plan to set the shape of the topgallant rail and to obtain the correct shape of the various other components directly from the ship by eye. This will be discussed further in the following sections.

Not only had the shape of the upper portion of the counter been altered in past, but also its construction. Fortunately, sufficient detail remained of the original riveted structure in the otherwise welded structure, from which to determine the probable authentic construction as shown in Figure 23.

7.6.2 Removal.

Work commenced on the upper portion of the counter with the removal of the old steel work. This necessitated the removal of the deck stringer around the stern; this being of no major consequence as it too had to be replaced. The plating was removed down to the major athwartships butt joint which formed the extreme aft end of a number of the strakes of shell plating (See Figure 23). The cant frames were also cropped at or below deck level to remove the deteriorated sections (See Plate XXXIX).

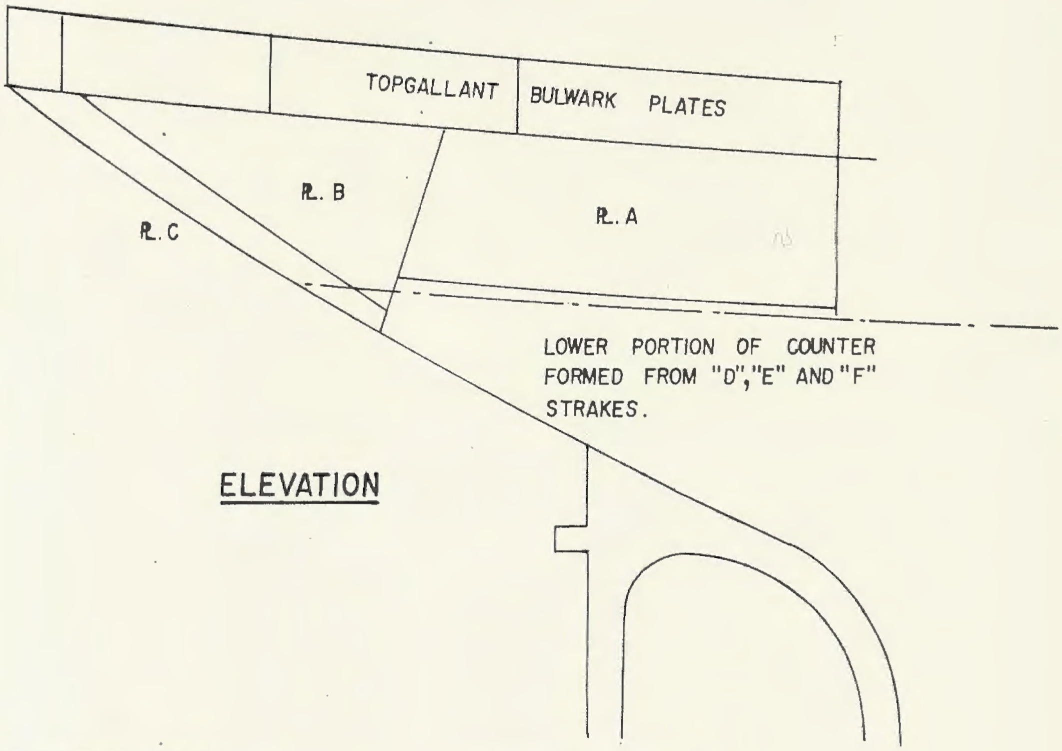
7.6.3 Topgallant Steelwork.

7.6.3.1 Topgallant Rail Angle.

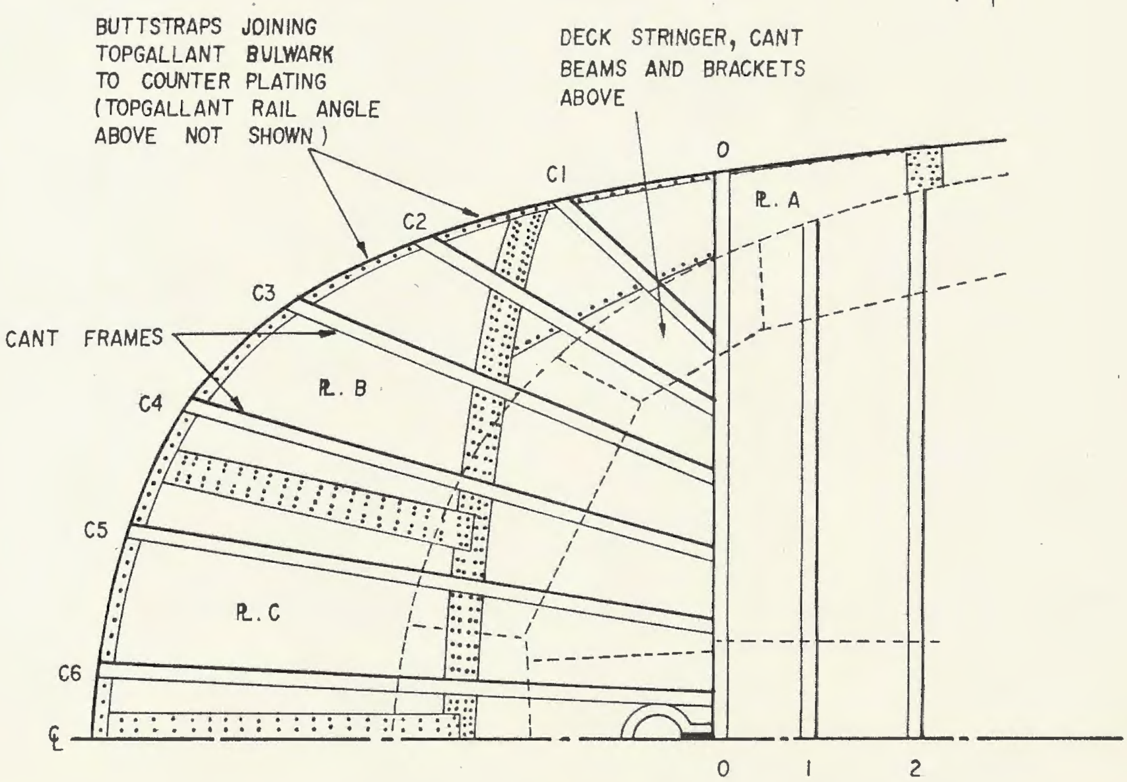
The topgallant rail angle was the first component of the stern to be manufactured and set into position. Unlike the rest of the bulwarks which had commenced with the main rail angle, the stern was constructed without this angle, its place being taken by intercostal butt straps set

FIG 23

CONSTRUCTION OF COUNTER



ELEVATION



PLAN

between the cant frames. A template of the shape in plan of the topgallant rail angle was made using offsets taken directly off the 'Waratah's' lines plan. Lengths of angle were bent cold on the hydraulic press to progressively form the shape of the rail as given by the template. The topgallant rail angle was then placed over the stern of the ship and its position adjusted to take into account the following factors:

i) The position of the aftermost portion of the rail at its centreline in a fore and aft direction had to be adjusted so that the intersection of a fair line struck off the rising tuck of the remaining portion of the counter and a vertical line struck downward from the topgallant rail angle representing the topgallant bulwark was at a level which was fair with the line of the main rail in elevation.

ii) The forward end of the topgallant rail angle had to be positioned at the correct distance above the main rail angle.

iii) The line of the topgallant rail had to be set parallel to that of the main rail when viewed in elevation.

iv) The topgallant rail angle, when viewed in plan, had to be symmetrical about the vessel's centreline.

v) The topgallant rail angle had to be directly above and fair with the main rail angle when viewed from above.

vi) The topgallant rail angle had to appear fair when viewed from all angles.

During its positioning, the topgallant rail angle was supported at a number of points along its length by temporary staunchions which allowed the various adjustements to be made. The positioning of this rail to fulfil the points i) to vi) above was a difficult operation which took time and patience. Great difficulty was encountered viewing the stern from a sufficient number of different angles so that it could be sighted for fairness; largely because of the confined nature of the dock.

Once the topgallant rail had been set to the desired shape and position, it was more securely attached to the temporary staunchions.

7.6.3.2 Topgallant Bulwark.

The topgallant bulwark was the next to be made and fitted. The topgallant bulwark plates were first cut and then preset to the shape of the topgallant rail angle with the use of the hydraulic press. The rivet holes were marked off the topgallant rail angle and then drilled on the drill press, as were the holes necessary along the lower edge. When drilling had been completed, the topgallant bulwark plates were bolted in position along the topgallant rail angle.

The topgallant bulwark plates were then set vertical by fitting temporary stays made from 12 mm rods.

7.6.4 Cant Frames.

7.6.4.1 Traces.

The shape of the various cant frames was determined through the use of 'traces'. In way of each cant frame, a trace made from 12 mm rod was fitted. Each trace had been bent to provide a fair continuation of the line of the shell plating and also to ensure that it intersected the topgallant bulwark along its lower edge. After the traces had been tack welded in position, they were checked for fairness by the use of long timber battens which were run around the outside of the traces and the remaining portion of the stern at a variety of positions and angles. The curvature of the traces was adjusted until the traces remained in contact with the battens for all combinations of positions (See Plate XL).

7.6.4.2 Forging.

Once the traces were fair and fixed in position, work began making the new cant frames. Because it was found

PLATE XL. TOPGALLANT RAIL ANGLES AND BULWARK PLATES FITTED. STAYS AND FAIRING TRACES ARE ALSO FITTED.(P.Jones, 1978)

PLATE XLI. FITTING NEW CANT FRAMES AROUND THE STERN.(Author, 1978) that the complex combination of bend, bevel and twist in each cant frame was impossible to envisage directly from its trace, a welded template was first made from plate for each cant frame. These templates also served as a former during the working of the cant frame itself.

The piece of angle for the cant frame was cut to be slightly longer than the finished length. It was heated in the coke forge and progressively worked to shape with a sledge hammer and flatter over the template. Each cant frame required many heats and took a full-day for two men to work into shape. The shape of the angle was checked by holding it in position on the stern to see that it lay snugly.

When the cant frame had acquired the desired shape, it was allowed to cool after which it was cut to length and the necessary rivet holes drilled. The cant frame was then placed into position, bolted to the topgallant bulwark and welded to the stub of the old cant frame. (See Plate XLI).

7.6.5 Counter Plating.

The plating replaced in this region were the six plates which made up the upper portion of the counter, designated as A, B and C port and starboard as shown in Figure 23.

The first plates, plates 'C', had moderate double curvature. This was preset using the hydraulic press. The tighter of the two curves was set first, followed by the shallower curve. Once preset, these plates were forced into position with bolts, clamps and dogs to attain the final shape.

The plates 'B' were found to be the most difficult plates, each having a large extent of double curvature to be dealt with. These plates could only be preset with single curvature on the hydraulic press because they were too large across one dimension to pass through the throat of the machine. These plates were then secured to the stern and progressively pulled into shape with long bolts until they could go no further. The remaining double curvature required was set into these plates by working them hot in position. Oxy-propane and oxy-acetelyne heating torches were used to heat large areas of plate at a time. The double curvature was then progressively worked into the plate by striking it with numerous light hammer blows. The hot working of these plates required a number of hours before the correct shape was obtained.

Plates 'A' were comparitively simple to fit. The curvature in these plates was only slight and nearly conical, allowing them to be fitted without presetting.

As most of these plates had been forced into position on the cant frames, it was felt unwise to release them for drilling of the necessary rivet holes. These holes were drilled in position by first passing a pilot drill through the plates and then reamering in two steps to attain the finished sized holes. These rivet holes were also countersunk in position, three men being necessary to operate the electric drill. The large numbers of butt straps, tapered liners and bosom pieces required to complete these repairs were also made and fitted. The stern was then finally adjusted for fairness before being riveted in a manner similar to the rest of the bulwarks.

7.6.6 Observations of the Finished Result.

The shape of the repaired stern was a marked improvement over its shape prior to restoration. See Plates XLII and XLIII. There were a few faults in the new sections, however, these being:

i) The topgallant rail angle had a slight sag at its corners when viewed from aft. This was probably due to insufficient support during construction.

ii) There was an area of local unfairness in way of cant frame 3 at the upper edge of the counter where the butt straps joining the topgallant bulwark to the counter plating underwent a transition from bevelled angles to knuckled plates.

PLATE XLII. NEW SECTION OF COUNTER AND DECK STRINGER AS COMPLETED. (Author, 1979)

PLATE XLIII. "WARATAH" — UNDOCKING CEREMONY, MAY 1979. (Sydney Maritime Museum)

iii) There was some local unfairness in 'B' plate port due to double curvature.

iv) Where the plates had been worked hot, they had gained a slightly dimpled appearance from the hammer blows.

These defects, noticable to the critical eye, were not noticable to the more casual observer.

7.7 DECK STRINGER AFT .

The original form of the deck stringer was as shown in Figure 24A. Portions of this deck stringer had been replaced in the past by welding a new stringer plate along its intersection with the sheer strake. The complete length of the deck stringer around the stern was removed to allow the repairs to the upper portion of the counter. Once these repairs had been completed, work commenced on fitting a new deck stringer around the stern.

Templates were first made to fit over the cant frames which ran past the deck stringer. The new plates were cut to size with slots in way of these cant frames. They were then flanged by heating with gas torches and working them in position using the flatter and sledge hammers. Some of the stringer plates were then removed to

FIG 24

RIVETING AFT DECK STRINGER

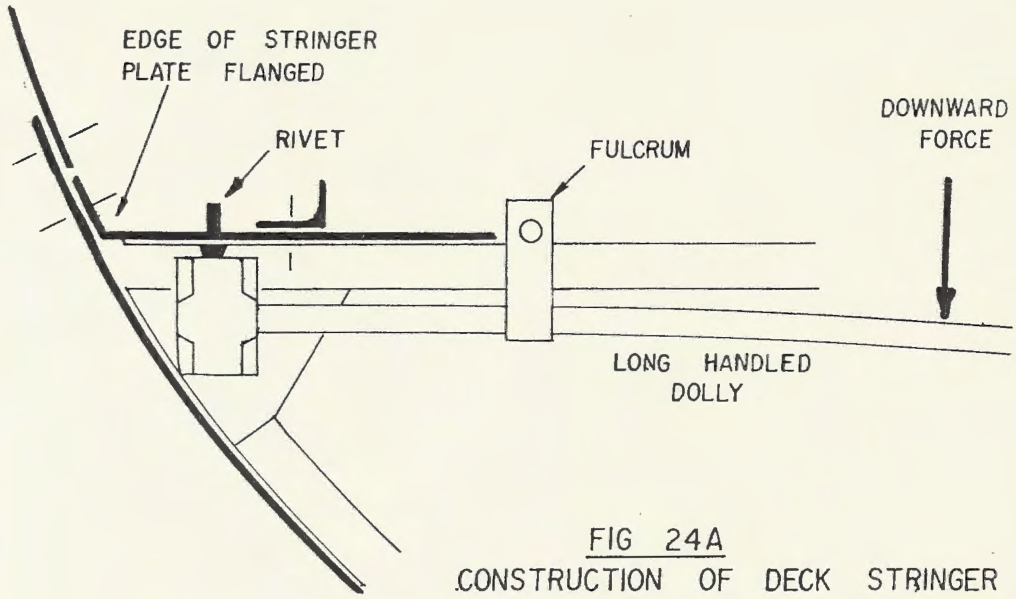


FIG 24A
CONSTRUCTION OF DECK STRINGER AFT SHOWING USE OF THE LONG HANDLED DOLLY.

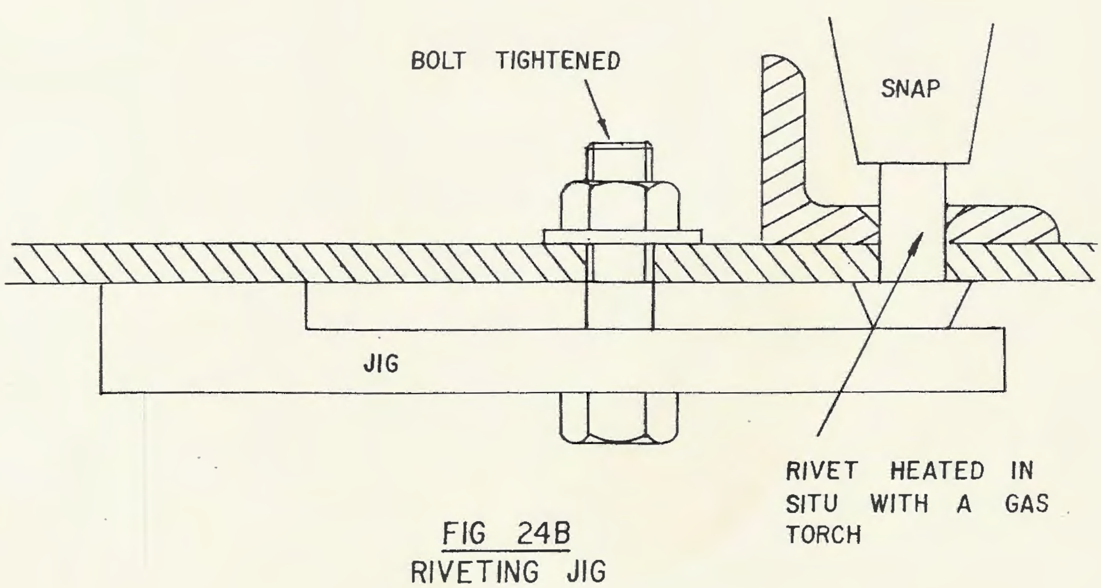


FIG 24B
RIVETING JIG

be drilled. Others could not be removed and had to be drilled in situ. The stringer plates were then bolted back into position and the waterway angle fitted as was described in Section 7.4.2.

Because of the flare of the hull around the stern (See Figure 2), the methods used previously to rivet the rest of the deck stringer were found not to be suitable. This was mainly because the clear space between the hull and the deck stringer was neither sufficient for the pneumatic jack nor level enough for its use. Two alternative methods of holding up rivets were used:

i) Where the clear space was sufficient, a dolly at the end of a long handle which acted around a fulcrum was used. (See Figure 24A). This method dated back to the era before the use of pneumatic tools in shipyards and was extensively used for work such as the riveting of hollow iron spars. In many ways, this method was found to compare favourably to the use of the pneumatic jack even in more open areas.

ii) There were a number of cases where the method of holding up described in i) above could not be used, particularly in way of the cant framing and close alongside flared sheer plates. In these cases, the method shown in Figure 24B was used. A cold rivet was placed into the rivet hole and the jig bolted in position to hold the rivet. The rivet shank was then heated from above with an oxy-acetylene torch and, once sufficiently hot, the rivet was driven in the normal manner. Although this method appeared to have been practised in more recent times, it is doubtful that it could be considered authentic for the turn of the century. It was difficult to determine the methods which had been originally used but it was probable that the shipyards of the past had hundreds of specialized dollies in store for just this sort of purpose. Even so, it was interesting to note that a number of rivets in the more inaccessible regions of the original ironwork had been poorly driven or had been missed completely.

7.8 OTHER STEELWORK.

The most major areas of steelwork have been described in the previous section. Many other items of steelwork were undertaken during the restoration, these too numerous to discuss in this thesis; including the repairs to the bulkheads, keelson, stringers, tie plates, coamings, bunker casing and deckhouses to name but a few. More information on some of these appears in Figures 15 and 16. These repairs were mostly carried out with techniques similar to those already discussed.

7.9 CORROSION PROTECTION.

In general, all the metal structure of the hull, both old and new, was abrasive blasted back to bare metal during the restoration. The bare metal was then immediately given a coat of two pot inorganic zinc primer to prevent further corrosion. (See Plate XLIV) This was later followed by a number of coats of paint, the type depending upon the future conditions of service.

The immersed hull was given two coats of two pot inorganic zinc primer followed by a coat of vinyl antifouling. The freeboard area was given four coats of chlorinated rubber followed by a gloss alkyd finishing coat. Those surfaces of the deck structure which were to be later sheathed over by the deck timber were given two coats of a two pot tar epoxy. Elsewhere in the ship, including the interior of the hull, the metalwork was given five coats of chlorinated rubber which included a gloss finishing coat where it was necessary. (Sname, T., & R. Bulletin, 1973).

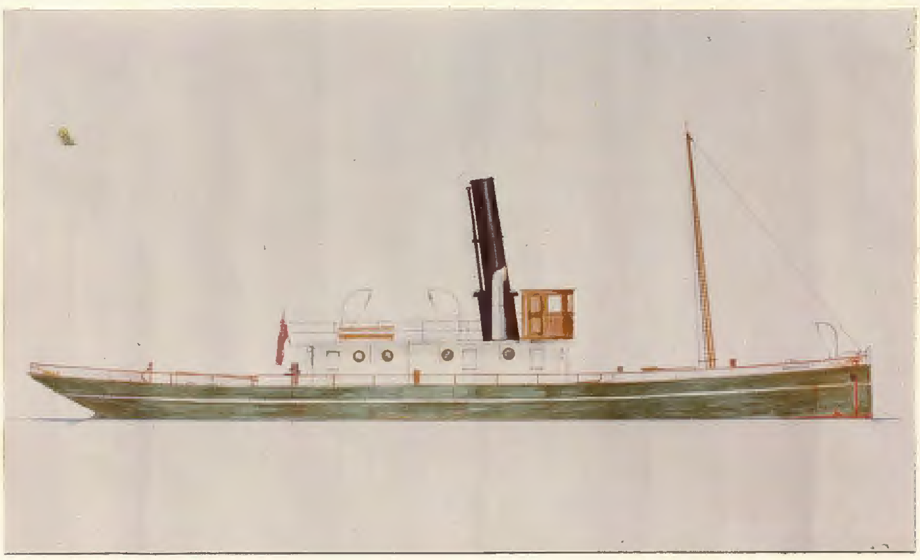
Cathodic protection of the hull was achieved by fitting eight aluminium anodes to the immersed hull. These anodes were placed one on each side of the bow and three on each side of the stern at about half draft level. They were purposely positioned to be attacked on newer steel plates for two reasons:

a) The steel plates would be more prone to electrolytic corrosion than the original iron plates.

b) The steel plates were more suitable for the attachment of the anodes by welding.

PLATE XLVI (left)
PORT WING BUNKER AFTER HAVING BEEN REPAIRED BLASTED AND PAINTED WITH INORG. ZINC. COMPARE WITH PLATES XVIII AND XXXIII
(Author, 1978)

PLATE XLV. (below)
ARTIST'S IMPRESSION OF "WARATAH" AS COMPLETED
(Drawing, M. Nelson)



CHAPTER 8

OBSERVATIONS AND CONCLUSIONS.

Prior to the commencement of work on the 'Waratah', the Museum did not have previous experience in the restoration of metal hulled ships on a large scale. The 'Waratah' restoration, therefore, provided invaluable experience in this field as problems were overcome and the various concepts of restoration evolved. Concepts of a more philosophical nature have been discussed in Chapters 2 and 3 while those of a practical nature have been discussed in Chapter 6. In this Chapter, some of the more general observations gained through the restoration will be briefly discussed.

8.1 RESOURCES.

8.1.1 The Restoration Site.

The circumstances which surrounded the choice of the restoration site have been discussed in detail in Chapters 4 and 5. The Blackwattle Bay site was in use for the restoration for three years during which time the following observations were made.

8.1.1.1 The Dock Site.

The significance of the Museum operated dry restoration berth to the feasibility of the 'Waratah's' restoration could not be overstated. The long term use of a facility such as the Blackwattle Bay Dry Dock was one of the major factors which made the restoration of 'Waratah' possible. Those costs which were incurred during the recommissioning of the dock, were easily justified, having made possible savings many times their magnitude on all aspects of the work.

Apart from the various pros and cons associated with the use of the dry dock which were discussed in Chapter 4, the following problems were encountered:

i) Because the dock was only marginally larger than the ship herself (See Figure 8), it was found difficult to scaffold around the ship. The restricted space available also made it difficult to sight the fairness of new work on 'Waratah' from a sufficient distance and number of positions.

ii) Although the dock gate served the project well, its arrangements for positioning and removal were found to be unsuitable for anything more than occasional use. The major fault was the need to dismantle and assemble the gate in position, a result of the original design of the sill.

iii) The dock floor quickly became covered by dirt, blasting grit and scrap. This had to be regularly removed to allow movement on the dock floor.

8.1.1.2 Working Space.

The fact that a large proportion of the dry dock was under the cover of a building was found to be of great assistance during the restoration. Work was able to continue on the ship regardless of the weather. With the exception of the forward portion of the ship, there was no need to secure her against the weather to protect tools, materials or partially completed work between working periods. The building also protected most of the shore-side installation from the weather enabling these areas to also be left open. One disadvantage of the building, however, was that it held the dust and grit during the abrasive blasting operations on the hull making it uninhabitable during these periods. Even after the blasting had ceased, the dust and dirt remained for years.

The actual working areas in the site were not found to be ideal. Most of the on-shore work was carried out at the level of the top of the piers. The top of the piers at this level were narrow and congested, being only about 3 m wide. Although there was more floor area on an upper level in the building, this could only be used in a limited way because of the difficulties of moving materials up to this level. As a result of the limited working area, the main and boat decks on the 'Waratah' and even the dock floor, itself had to be utilized for working and storage purposes.

About 800 m^2 of working and storage space (excluding the dock floor) were used for the project. Of this about 600 m^2 was under the cover of the building.

8.1.1.3 Materials Handling.

The extent of cranage on the Blackwattle Bay site is shown in Figure 8. The two cranes were to prove invaluable during the restoration project, being used to move most of the items to and from the site, ship and dock. It was unfortunate, however, that there were a number of areas which were not serviced by cranes including the space between the building and the monorail crane. In these areas, the movement of materials was much more difficult. Problems were also encountered transferring goods on and off trucks from under the monorail as this installation was never designed to take deliveries. For this reason, some materials were brought in on trolleys and by hand around the tops of the narrow piers. This was often quite difficult as the piers, being used for working space, were usually congested. The ability to drive vehicles directly alongside the vessel in the dock would have been advantageous, saving much double handling of the materials.

8.1.2 Capital Equipment.

8.1.2.1 Tools.

Without the various necessary tools, the restoration of the 'Waratah' within the Museum would have been impossible. The funds used to purchase the tools necessary were an investment, not only in the particular project but also in the Museum's ability to maintain and restore its fleet as a whole. When the restoration commenced, the Museum did not own any capital equipment worth mentioning; all the tools being purchased or obtained as the work progressed.

Because of limits to the funds available, it was not always possible to obtain all the tools for every job. Unless a tool was to be extensively utilized throughout the project, so as to justify its cost, its purchase had to be carefully considered. There were a number of cases where it was found more economical to use one of the following three alternatives (Section 6.4).

- hire the equipment necessary,
- have the job done by outside contractors,
- if no reasonable alternative was available, to duplicate the job using less authentic methods.

In circumstances where the purchase of the necessary tools for a task was only slightly more expensive than having the task done using either of the first two alternatives above, the purchase of the tools could be usually be justified on the basis that they could be used for other work in the future. The main exceptions were where tools for authentic restoration were well beyond the Museum's resources at which time the third alternative might have to be applied.

To ensure that some of the more expensive tools were suitable for the tasks expected of them, they were often hired or obtained on loan before purchases were made.

Both pneumatic and electric power tools were used during the restoration. For most applications, the compressed air tools were found to be superior to the electric. They were safer, lighter and more durable with the higher loadings. They did have disadvantages, however, requiring an expensive compressor and usually being more expensive to purchase initially. They were also prone to damage from the grit used for abrasive blasting.

Where particular tools were in great demand during the project, more than one was purchased, often each with a differing power source (pneumatic or electric) to provide flexibility in case of breakdown. In general, it was found that only the best industrial models of tools were able to meet the harsh demands of the restoration. Those tools of inferior quality usually failed within only a short period.

8.1.2.2 Scaffolding.

The scaffolding used during the restoration was rarely better than just adequate. The importance of scaffolding had not been realised before the restoration had commenced. As a result, makeshift arrangements persisted for most of the 'Waratah's' restoration. Had the 'Waratah' been a larger vessel, these makeshift scaffolds would not have been adequate.

Difficulties were encountered erecting scaffolding along the midships length of the 'Waratah' because of the proximity of the dock walls in this region. At the bows and particularly at the stern, it was found necessary to provide extensive scaffolding of a substantial nature to enable the work in these areas to be carried out with reasonable safety. It was while working in these areas that an appreciation of the benefits of good scaffolding was obtained.

Because of her large deadrise, only occasional scaffolding was required inside the 'Waratah's' hull. However, it would appear that; if restoration were to be carried out on a larger vessel, internal scaffolding would be a significant factor.

8.1.3 Materials.

A large amount and variety of materials was used during the restoration. Despite the desirability of having large stocks of materials at hand to ensure continuity of work; material stocks were usually kept to a minimum. Stocks of material meant that funds were tied up; funds which would not be used for more pressing immediate purposes. Ordering of large stocks required long range detailed planning of each specific job; a very difficult task in view of the nature of the work, the inexperience of the Museum and the changing concepts of restoration. Where it was practical, ordering on a job by job basis was preferred because of the lesser risk of error and resulting wastage.

A number of materials did require ordering and delivery well in advance of their use. The most important of these was timber. Timber had to be obtained well in advance for two reasons; firstly, to allow the timber to season before use and secondly, to ensure that the correct species and size of timber was available. Certain special orders, for example rivets, were also ordered well in advance to ensure supply. Most other materials such as steel stock, paints and engineering supplies were ordered as and when necessary, the delivery usually taking only a week or two.

Although materials were purchased for specific tasks; they were sometimes found to be insufficient by the time they were required for the job. This was because portions of material had been used for other, unplanned, tasks; particularly for such items as special forming jigs, scaffolds and braces. This problem was, in part, remedied by the purchase of a stock of second hand steel specifically for these purposes.

8.1.4 Labour.

A very major component of the restoration was labour. Many thousands of man-hours were required, the labour coming from three main sources.

8.1.4.1 Voluntary.

Volunteer labour was the major factor that set apart the Museum's resources from those of a commercial shipyard. It was this volunteer labour that made the restoration of the 'Waratah' feasible by lowering the restoration costs greatly. A very significant proportion of all the labour on the 'Waratah' was donated; over 120 volunteers having worked on her in the last three years. In addition, there were many more people who donated their time behind the scenes; researching, raising funds and so on.

The people who volunteered on the ship came from all walks of life, from tradesmen to housewives, students to clerks. Their contribution covered a wide range of the work on the ship and their presence was essential to the success of the project.

Volunteers tended to fall into two categories:

i) Regular - about one day per week if not more.

ii) Occasional - about one day per month.

Although both types were of great assistance, they had to be utilized in different ways. The regular volunteers often became amateur tradesmen. Their regular appearance made it worthwhile to teach them the various skills of specialized work. It also enabled them to practice these while making a valuable contribution to the project. The attainment of these skills resulted in volunteers gaining a sense of achievement, reinforcing their dedication to the project. In time, these volunteers (and, of course, volunteer tradesmen) were often capable of taking a major responsibility for the completion of specific jobs.

Unfortunately, the more occasional volunteers could not be utilized in the same manner. It was not usually possible to train these people for specialized work in the short time available. These people made an important contribution doing the more unskilled jobs of painting, bilge cleaning, drilling holes and so on. It was important, however, to ensure that these volunteers maintained interest in the project despite the more mundane nature of their jobs. This was achieved by working with them on the jobs and where possible, having them assist those carrying out more skilled work.

Comparitively few engineers, seamen and tradesmen from the ship repair and shipbuilding trades appeared as volunteers during the 'Waratah' project, probably because the work was too similar to their usual employment. However, a number of retired tradesmen did donate their services, partly, so that they could maintain a connection with their trade.

It was found that the best volunteers were those who had some degree of flexibility with respect to the work which they were prepared to do. Although specialist labour was required for many of the jobs on the 'Waratah', there were few jobs which continued for great periods of time. Once one type of work was finished, there was always a need to move onto other types of work, requiring different skills.

The use of volunteers was hard on equipment. Breakages, especially of consumables such as drills and oxy-acetelyne tips, were common. In addition, there was often more wastage of materials, particularly during the learning stages. These extra costs were found to be of little consequence compared to the amounts which were saved in labour costs.

8.1.4.2 Museum Staff.

The Museum employed a full time restoration manager on the 'Waratah' project, plus additional staff as the need arose and funds became available. With a combination of paid staff and voluntary labour working on the same project, there was a possibility of conflict between the two. Fortunately, this was not the case, as the paid staff were as dedicated as the volunteers, and worked long hours for low rates of pay. The staff not only directed the volunteers but also worked alongside them, regardless of the task. For this reason relations between the Museum staff on site and the volunteers were generally very good, an important factor in view of the nature of the workforce and the extent of their contribution.

An important feature of the restoration staff was that they had to be flexible. There were insufficient funds to carry specialists within this staff who were not prepared to become involved in aspects outside their specialization. Staff had to be involved in all aspects of the restoration, from ordering materials, preparing work, maintaining tools and supervising the volunteers to the actual restoration work itself.

8.1.4.3 Contracted Labour.

Contracted labour was used on occasions during the restoration for a number of specialized tasks. The Museum was fortunate to find contractors who had an interest in the project. Even so, the cost of such labour was comparatively high and so its employment had to be carefully considered. Contractors were used for a variety of reasons. There were some jobs which had to be done during the restoration in which neither the volunteers nor the Museum staff had any previous experience. These jobs were usually commenced by contractors. After a time, the skills were progressively learnt by the staff and volunteers who would then take over the completion of the job. The second reason contracted labour was brought on site was to provide additional labour to speed up the project. (See Section 8.1.6).

One problem that was encountered with contracted labour was that it was difficult to bring across some of the basic concepts of the restoration when discussing their work. There was always a temptation for these contractors to use modern techniques, particularly where it was to be hidden in the future. It was difficult for these men to disregard modern notions of repair and actually progress backward, even though they showed an interest in the project.

8.1.5 Management.

The management of the 'Waratah' restoration project was the responsibility of a number of people, some of which were paid staff and the others volunteers. Apart from the obvious responsibility of the project management to fulfil the aims of the restoration as mentioned in section 6.2.2, the following areas of responsibility had to be covered:

- Surveys and determination of the extent of work.
- Planning and cost estimation.
- Scheduling of work and ordering of tools and materials.
- Confining expenditures to those allowed by the Museum's finances.
- Maintenance of the standards of authenticity and quality control.
- Direction and supervision of labour, both voluntary and paid.
- Ensuring reasonable standards of safety.
- Maintaining morale in the workforce.
- Maintenance of the site, tools and equipment.
- Keeping of time schedules.

From the above, it can be seen that the management of the project was a large and complex task. The paid restoration manager was responsible to the Museum's administration for the expenditures during the restoration. The amount which could be spent per month on the 'Waratah' was set by the Museum's Board of Directors on the basis of the Museum's expected income. Apart from the responsibility of the restoration manager for the monthly expenditure, most of the various other facets of responsibility were spread among four people who worked together. All these people were directly involved in the restoration work and all shared the responsibility to direct and supervise the volunteer workforce. More specifically these four people were as follows:

i) The Restoration Manager who had a general responsiblity for the project through his concern with the expenditures. He was also involved in the ordering of materials, purchasing of tools, hiring of labour, planning and maintenance of work schedules, various practical aspects of the restoration and the smooth running of the project generally.

ii) A person who was responsible for the technical matters of the restoration including the design of the dockgate, docking and undocking of the ship, surveys, authenticity, quality control and planning.

iii) A person who was responsible for the restoration of the 'Waratah's' machinery including the technical aspects, authenticity, work scheduling, materials lists, surveys and the like.

iv) A person who managed items such as the preparation of work, maintenance of equipment, scaffolding and a number of other miscellaneous items.

The various decisions and ideas of these people were discussed amongst each other, and with the volunteers in general. Where insufficient knowledge was available within the Museum, outside sources were consulted. Although the restoration manager had last say on all decisions by virtue of his control of the expenditures; he was not autocratic in nature, enabling this system to work effectively. It was important that the management should not be remote from the site and the people involved, firstly, so that morale could be maintained and secondly, so that it would remain well informed and responsive to problems within the project.

8.1.6 Time.

When the 'Waratah' was initially docked, no specific dates were set for her undocking or for the completion of her restoration. Because the Museum's tenure in the dock was uncertain; there was a vague goal that work on the hull had to be given precedence so that it would have been,at least, near completion in the event that the Museum was asked to vacate the premises. There was also a longer term goal of completing the ship to a condition where it could be displayed to the public in time for the opening of the Museum's premises at Birkenhead Point in October 1978.

Restoration in the earlier stages of the project preceeded at a steady pace, without major consideration for the second goal mentioned above. Instead, a number of intermediate goals were set such as the docking of the ship and abrasive blasting of the ship's interior in three distinct stages - midship length, forward portion and after portion respectively. To enable each of these intermediate goals to be fulfilled, the pace of work had to be maintained. However, in no case was it possible to complete all the preparations before the vessel was docked or blasted. By setting of these goals, the activity on the vessel was kept at a reasonably high level over long periods of time.

By mid 1978, it became obvious that the 'Waratah' could not be floated in time for the opening of the Museum's new premises. Although contracted labour had been used to some extent earlier in the restoration, its use was expanded in an attempt to have her on display as soon as possible. Unfortunately, the increased use of contracted labour not only significantly increased the costs of the restoration, but also made it more difficult to maintain a reasonable standard of authenticity at this time. Circumstances changed however, as there was to be a delay in the opening of the Museum. The urgency to undock the 'Waratah' therefore reduced and the contracted labour was progressively laid off. Work continued at a slower pace on the 'Waratah' until; in early 1979, the Electricity Commission of N.S.W., the owners of the restoration site, indicated that they wished the Museum to vacate the premises. Accordingly the activity was increased until May 1979 when the 'Waratah' was undocked. After the undocking, activity was again reduced to conserve the Museum's then dwindling funds.

There were two conflicting effects of time on the restoration. The first was that the standards of restoration tended to suffer and costs escalated when the project was subjected to tight time scheduling. This conflicted with the need to provide tangible results so that interest was maintained both within and outside the Museum. It would appear that the best compromise would have been to exhibit the restoration of the vessel as it progressed, maintaining a certain number of goals which would be liberal in nature, thereby reducing the costly effects of an urgent rush, yet maintaining interest in the project.

8.2 EXPENDITURES.

8.2.1 The 'Waratah' Project.

Before the Museum could commit itself to the in-house restoration of the 'Waratah'; projected estimates of the probable cost had to be prepared. The preparation of these estimates was found to be very difficult because the Museum had not previously undertaken a similar restoration before and, therefore, could not draw on its experience.

The first indications of the cost of restoring the 'Waratah' came from the earlier discussions with surveyors and commercial yards (See sections 4.1.2 and 4.1.5). It was felt, however, that the Museum could carry out the restoration itself for considerably less than these initially estimated figures, although how much less was not known.

The initial estimates, therefore, had to be determined in a rather arbitrary manner by estimating the total cost of materials and equipment required for the work which was then known to be necessary and adding a labour component for those jobs which had to be contracted. This figure was increased by a factor to allow for a certain amount of job growth.

The actual cost of the restoration exceeded the figures which had been initially estimated. This was mainly due to the much expanded labour component in the period where it was felt urgent to complete the 'Waratah' and also it was due to the changes in the approach to the work as the various concepts discussed in Chapters 2, 3 and 6 were developed. It was interesting to note, however, that for a period during which restoration proceeded at its optimum pace, the actual costs were actually well below those estimated, the best example being the replacement of the shell plates.

Despite the actual costs exceeding the costs which the Museum had estimated, they were much less than those which were initially offered by the commercial yards, especially as those commercial estimates were for repairs of a much less authentic and less extensive nature than the repairs which were actually accomplished.

8.2.2 Cost Components.

The costs of the restoration were found to be made up of four main components.

i) Capital costs.

These costs included all those incurred in the recommissioning of the dock and cranage, and the purchase of tools, scaffolding, workshop furniture and installation of services and lighting. Most expenditures on capital equipment were made comparatively early in the project when the Museum was preparing to undertake the work.

ii) Materials.

There was a wide range of materials required for the restoration including steel sections, timber, fasteners, copper pipe and paints. When ordering materials, a slight addition was made to the estimated quantity required, to allow for waste.

iii) Labour.

Paid labour was either contracted or Museum staff. Work contracted outside the Museum to provide a specialized product such as castings was both a material and labour component. (Although the labour component was usually by far the greater).

iv) Miscellaneous.

The miscellaneous component covered a wide range of items such as consumables, transport, power, telephone, correspondence, courier services and maintenance costs on the site and equipment.

8.2.3 Factors Influencing Cost.

The amounts expended on each of the above components of cost were influenced by a number of factors during the restoration. These factors were:

i) The proportion of the work which was to be carried out by volunteers. This depended upon their number, aptitude and degree of dedication.

ii) Whether there was a need for urgency in the completion of specific tasks during the restoration.

iii) The amount of job growth during the restoration.

iv) The extent of donations from companies and individuals in the form of tools, materials or services.

v) The changing of concepts through the gaining of experience as the project progressed particularly with regard to authenticity and the need to provide for future maintenance.

As each of these factors only became apparent during the restoration, and determined to a large extent, the value of the total cost of restoration; it was very difficult to make accurate estimates prior to the commencement of work, particularly as there was no previous experience to draw from.

8.3 ERRORS IN THE RESTORATION.

Because of the many thousands of decisions to be made and jobs to be done over the period of the restoration, it was inevitable that errors would be made. These errors were of two main types.

8.3.1 Conceptual Errors.

When the project began the various concepts which were to determine the work were vague and incomplete. It was only after experience had been gained on the project itself, that these concepts were clarified. While gaining this experience, a number of conceptual errors were made, including the following:

i) Much of the old structure of the ship which had been removed was discarded before the job was completed. Although a number of sketches had been made and photographs taken of the details of the vessel before restoration commenced, the situation often arose where the information at hand was not sufficient to accurately duplicate the original Reference to the old pieces may have been of assistance. It was found that the significance of all the detail on the old structure was not always appreciated until the new components had to be made. This was particularly the case with remnants from long-gone original fittings and altered structure. From the experiences of the 'Waratah' project, it would be wise to store all items which had been removed from a ship undergoing restoration, at least, until the repairs had been completed.

ii) When work commenced on the ship there was a temptation to improve upon the vessel's original design and materials. The years of service had plainly illustrated those areas on the ship which were the most prone to deterioration (See Appendix K). It was hard to resist altering the ship when repairing these areas to overcome the particular problems in the area. Alterations of this type were carried out on a number of occasions, particularly in the earlier stages of the restoration. Examples were the use of metallic packings in the condenser, teak in the new wheelhouse and 'densotape' beneath the timber decks. Most of these were later regretted, although there were a number of such alterations which are still justifiable. One was lagging of the boiler with fibreglass rather than absestos, because of the health hazards associated with the use of the latter material (Gardner, National Fisherman, June, 1979, p. 8). Another exception was the use of modern anticorrosive coatings on the vessel. A number of the steel and iron components on 'Waratah's' hull were just on the border of acceptability. The original coatings relied upon constant maintenance and a hefty corrosion allowance. As much of the latter was now gone and the former would have meant an incredible future burden on the Museum, it was decided that modern systems would be the only reasonable compromise.

iii) In a few cases the Museum failed to commit itself completely to the restoration, it being wary of becoming over-commited. For this reason, the boiler and the castings of the main engine of the 'Waratah' were not lifted clear of her hull. Later experience was to show that it might have been advisable, particularly in view of the amount of work that was or would otherwise have been done to the hull beneath them.

iv) There have been some thoughts that the 'Waratah' should have been repaired using repair methods of the turn of the century such as riveted insert plates, new sections of frame angles joined by bosom pieces and so on. As much as this was correct in principle, it was not practical because these methods, used to the large extent that was necessary on the 'Waratah', would have been comparitively weak because of the lines of weakness which exist along a series of unstaggered riveted joints. It would, however, have been a good idea to incorporate examples of such methods where it was acceptable on strength grounds. Another problem would have been that the vessel would have appeared like a 'patchwork quilt' after a long period of time which would have been quite unacceptable for vessels of the era when in service.

8.3.2 Managerial Errors.

Managerial errors were usually associated with the need to make on site decisions and a lack of experience with particular tasks or skills. The following were two of the more common types of managerial error.

i) Materials had to be ordered, often before the Museum had had any experience in a particular type of of work. Although a number of items were ordered to incorrect sizes or scantlings, these, fortunately, were ususally able to be exchanged. Where items ordered were not "off the shelf" items but were made specially for the job, the problems of error were much more serious. Two cases of such materials being delivered the incorrect size occurred during the restoration. In both cases, the supplier had been given a sample of the old material to work from and even so, errors had occurred. When obtaining materials; it was important that; the sizes were checked carefully before ordering, the information was clearly and specifically stated in the order and the sizes varified upon delivery.

ii) Mistakes were made by people working on the job (both paid and voluntary) because they either did not clearly understand the job or had preconceived ideas on how it should be done. It was up to the management to closely supervise the workforce so that occurances of such errors were minimized.

Mistakes and errors during the restoration, although inevitable, were not desirable. Because it is a Museum's responsibility to maintain authenticity of its exhibits, a Museum is required to:

i) Recognise the occurrence of mistakes.

ii) Record their existence.

iii) Attempt their rectification when the opportunity arose.

iv) Learn something from them so that they were not repeated.

Errors in a restoration which have been repaired so that they are reversible are not particularly serious as long as the points above are heeded. However, ignoring the existence of errors within a restoration will in time be the biggest error of them all.

8.4 CONCLUSION.

At the time of writing (November, 1979), the restoration has not been completed. It had progressed sufficiently far, however, to see that the work which had been done had been a success. The various aims of the restoration project as were discussed in Section 6.2.2 were at this time well in hand with most of the hull work already completed and work on the outfit and machinery well underway.

The risks the Museum took, undertaking such an ambitious restoration, paid off dividends far better than was originally envisaged. The Museum not only successfully restored one of its ships for a fraction of the usual commercial cost, but also gained important and valuable information, and confidence to work on its other ships.

The various restoration concepts discussed in this thesis only evolved after years of work restoring the 'Waratah'. For this reason the emphasis in the thesis has been on these concepts rather than a detailed description of the work. Only the work on the hull and recommissioning the dry dock have been discussed in some detail, because of the significance of these two areas to the success of the whole project, as was discussed in Section 6.6.

The body of this thesis has been designed to be of use to future similar restoration projects. As was mentioned in Chapter 3 there are a number of varying ideas on how ships should be preserved, this being only one.

The use of other methods to preserve ships will have advantages and disadvantages of those used to restore the 'Waratah'. Whichever method is used however, it is of primary importance that the ship is preserved with thought given to the long term as well as the immediate future; both along the technical and philosophical lines.

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PLANS.

S. T. 'Burunda' (Waratah) Plans drawn 1902,

Lines Plan

General Arrangement

Machinery Arrangement

Boiler Drawings

Engine Drawings

Shell Expansion.

Ash Loading Facility, Blackwattle Bay Plans drawn between 1949 and 1953 including

Dock Gate Construction Plans

Dock Construction Plans

General Arrangements.

APPENDIX A

BRIEF HISTORY OF S. T. 'WARATAH'.

BRIEF HISTORY OF S. T. 'WARATAH'.

The 'Waratah' was built as the 'Burunda' in 1902 for the Public Works Department of N.S.W. Her primary duty was that of coastal tug in the Department's Dredge Service; towing their dredging plant between the numerous ports then in use along the N.S.W. coast.

She also performed a number of other roles which included ocean surveying and substitute tug for Newcastle and the northern rivers. As the PWD's flagship, she was used for VIP duties on Newcastle harbour and she was also used as relief pilot ship for both Sydney and Newcastle.

In the late forties, the 'Waratah' was restricted to Newcastle Harbour, towing their dredging plant within the port. In 1956, she was altered to serve as a bouy tender. She continued in these roles until 1968 when she was handed over the the Museum.

CHRONOLOGY.

1901-1902 Built in Fitzroy Dock, Cockatoo Island, Sydney for a cost of £4539/8/5 as the 'Burunda' (PWD, 1903, p. 100).

1913 (March) While acting as relief pilot vessel 'Burunda' rescued the crew of the yacht 'Thelma' off Middle Head, Sydney, during a fierce gale. (Sydney Mail, March 12, 1913, p. 25).

1918	Name changed from 'Burunda' to 'Waratah'. Forced draught machinery removed.
1920's	Believed to have steamed as far as the Great Australian Bight to search for and retrieve two hopper barges which were adrift. One was found, the other became wrecked on the South Australian Coast.
1930	Forced into Port Stephens towing a string of pontoons after one was lost during heavy weather (Sydney Morning Herald, 10th July, p. 16).
1939-1945	As well as coastal towing, 'Waratah' was used for target towing, examination vessel and port emergency ambulance on occasions during this period.
1942	(April) Hit by shell fire off Port Stephens, evidently after failing to answer a signal. Deckhouse damaged in way of the galley. One man injured. ('Waratah', 1940-1944, 26th April 1942).
1948	Restricted to Newcastle Harbour.

1956 Underwent major refit which included the fitting of a replacement boiler and a diesel generator and the modifications for service as a bouy tender.

1966 Last slipping while owned by the PWD.

1968 (March) Handed over to the Lady Hopetoun and Port Jackson Marine Steam Museum by the then Minister of Public Works, Mr. Davis Hughs, in Newcastle. Subsequently steamed to Sydney. (NMH, 1968, March 23rd, pp. 1 and 3).

1968-1971 Operated on numerous occasions by the Museum including a voyage to Broken Bay for the T.V. series 'Riptide' (SMH, Oct. 13th 1968, p. 43).

1972-1976 Laid up at Blackwattle Bay Sydney.

1975 Preliminary surveys.

1976 Ultrasonic survey and preliminary slipping at Cockatoo Island, Sydney.

1977 (September) Docked in Blackwattle Bay Dry Dock.

1977-1979 Major Repairs to hull undertaken.

1977- Major repairs of machinery and outfit.

1979 (May) 'Waratah' undocked.

1979 (October) Displayed at Circular Quay Sydney in unfinished state.

APPENDIX B

TECHNICAL DESCRIPTION.

TECHNICAL DESCRIPTION.

HULL:

The 'Waratah' was built as a single screw steam tug with riveted iron hull and timber decks. Her arrangement, body plan and midship section are shown in Figures 1, 2 and 3 respectively. The 'Waratah', which was built with transverse frames and with a single bottom, has the following particulars,

LOA	33.08 m
LBP	30.48 m
Beam	6.15 m
Depth	2.98 m
Draught aft (Loaded) approx.	3.05 m
Displacement (Loaded) approx.	163.0 tonnes.
Gross Tonnage	132.0 tons
Fresh Water Capacity	16.2 tonnes
Coal Bunkers	40.0 tonnes

MACHINERY:

The machinery is of the steam reciprocating type driving a single screw.

a) Boiler.

The original boiler was a two furnace, coal fired scotch marine type of 2.9m diameter by 2.74m long. This boiler, which was built by Blackwood and Sons, London, U.K., was replaced in the 1950's by another boiler of similar type of 2.74m diameter by 3.05m long, believed to have originally been from the dredge 'Ballina' which was built in 1893. The working pressure of both boilers was 827 kPa. Originally, the 'Waratah' was fitted with forced draught for the boiler using a pressurized stokehold system. This was subsequently removed and the funnel lengthened to compensate for the loss of draught.

b) Marine Engine.

The 'Waratah' is propelled by a double acting two cylinder compound steam reciprocating engine of 205 kilowatts, indicated power (275 lHP) at 125 r.p.m. The engine was built in 1901 by Ross and Duncan of Glasgow; Engine number 522. It has cylinders of 330mm and 660mm bore and 457mm stroke. The engine is of the open type, lubricated by hand and by oil syphons. Reversing is by Stephenson's link motion and the engine cylinders were originally wood lagged.

The main engine is fitted with a surface condenser cast integral with engine back columns. Circulating, air, bilge and boiler feed pumps are driven off the L.P. crosshead.

c) Auxilaries.

Apart from those auxilaries driven off the main engine, the 'Waratah' was originally equipped with a Worthington type general service pump, a Sentinel steam steering engine, steam windless and the forced draught fan mentioned earlier. Over the years, there had been a number of additions including a fire and bilge pump, an injector and an ejector.

Lighting was originally by oil lamps; a diesel generator being fitted in 1956. Most of the additional services were retained during the restoration with the exception of the generator.

d) Propeller.

The 'Waratah' is fitted with a four bladed cast iron propeller, 1.83 m diameter by 2.59 m pitch. The propeller is directly driven by the main engine via a thrust bearing of the multi collar type and a 152 mm diameter shaft.

LLOYDS, 1905 - 06.

1061 99589 NBDK	Burton SteelScSr G.H.Dawson -04 ssShl.No.2-01 (exBurtonConstable) 1Dk(Irn)&Web frames&ptAwngdk(Irn)	1966 1455 1271	✠100A1 pt Awng dk withfreeboard 8.04 ✠LMC	Hpl	r	1892 10mo	Edward's S.B.Co.(Lim) Newcastle A&CP	DeddingtonS.S.Co.Ld. (H.Samman&Co.Mgrs.) WB	275·5|36·7|16·6 Q107' ptAwngdk168' FK = CellDB284'406t	Hull British 4BHCem APT39t	T.3Cy.20½",33½"&55"-36" 160lb 70lb (s) 176NHP 2SB,4cf,GS65,HS2561 Blair&Co.(Lim.),Stockton	19 · 0 s 8 · 3½		5,04
1062 93406 LKDW	— SteelScSr R.H.Gent -05 ssSws.No.3-1,02 1Dk(Irn)	649 492 344	✠100A1 2,05 BS ✠LMC	Sws	j	1889 10mo	R.Craggs &Son Stockton A&CP	HarriesBros.&Co.	195·0|28·4|11·8 Q84'B15'F20' BK7½" WB=Cell	Swansea British 4BHCem DB160'172t	T.3Cy.16½",26"&44"-33" (s) 160lb 75lb NDB99 99RHP 1SB,3rf,GS47,HS1797 Wstgrth,English&Co.Mdb	14 · 1 s 1 · 4		8,04
1063 101884 RSNM	Burton Port SteelScSr G.Matthias -04 ssLdy.No.1-03 Well deck 1Dk(Stl) Elec.light	299 208 80	✠100A1 2.04 ✠LMC	Gls	e	1899 6mo	J Fullerton &Co. Paisley A&CP	StephanBros.	135·0|23·1|9·7 Q74'B9'F24' BK6" WB=FPT	CapeTown British 4BHCem 17tAPT8t	C.2Cy.17½"&36"-24" (s) 120lb 80lb 53RHP 1SB,2pf,GS37,HS1168 Muir&Houston,Ld.Gls	10 · 2 s · 6		12,03
1064	Burunda IronSc D.Smith90-02 (Tug)	165 121 —				1902	Govt. of N.S.W. Sydney,NSW	Government of NewSouthWales	100·0|20·2|9·8	British	C.2Cy.13"&26"-18" Ross&Duncan,Ld.Gls.			
1065 115290 TKDW	Burutu SteelScSr J.S.Hely81-02 1Dk(Stl-ptws)&Spar dk(Stl-ws) Ref.Mchy. &deep framing Elec.light	3805 2827 2441	✠100A1 Spar dk 11,04 ✠LMC	Lpl	w	1902 5mo Lloyd	A.Stephen &Sons,Ld. Glasgow 'sA&CP	British&African S.N.Co.(1900),Ld. (Elder,Dempster&Co.Mgrs.) WB=CellDBa70'	360·0|44·2|14·5 P&B242'F48' 23·3 FK uE&B44' f170'696t	Liverpool British 6BHCem FPT69t	T.3Cy.27",45"&72"-48" (s) 180lb 526NHP 2SB&1AuxSB,11cf,GS196, HS7863 FD A.Stephen&Sons,Ld.Gls.	16 · 9 s 4 · 1		
1066 83789 QHVL	Burwah SteelScSr C.McLeod -03 ssMel.2ndNo.3-12,99 ssMel.No.1-03 Elec.light 2Dks	982 934 568	✠90A1 5,04 ✠LMC	Bsb	m	1883 6mo Lloyd	J.Key& Sons Kinghorn 'sA&CP	HowardSmithCo. Ld. WB=DBa42'&	220·4|30·1|19·6 B38' BK7" uE&B50'150tFPT	SydnyNSW British 4BHCem 33tAPT17t	C.2Cy.31"&63"-42" (s) 100lb 100lb 212NHP 2SB,6cf,GS108,HS3382 J.Key&Sons,Kirkcaldy			N6,03
1067 96366 LWDO	Bushmills SteelScSr R.L.Blight -04 ssNpt.No.3-7,02 1Dk(Irn)&Webframes &ptAwngdk(Irn) Elec.light	2466 1889 1589	✠100A1 pt Awng dk withfreeboard 11,04 BS11.03 ✠LMC	Shl	t	1890 8mo Lloyd	E.Withy &Co. W Hartlepool 'sA&CP	J.Weatherill WB=CellD	300·0|38·5|20·6 P33'Q90' ptAwngdk177' FK B276'440tAPT24t	Dublin British 5BHptAsp ptCem	T.3Cy.22",36"&60"-39" (s) 150lb 60lb 217NHP 2SB,6rf,GS90,HS3280 CentralMar.E.Wks,WHpl.	23 · 2 s 8 · 7		11,04
1068 118077 VPFL	Busiris SteelScSr W.Gaskill -04 Elec.light 2Dks	2720 2549 1712				1904	J.Blumer &Co. Sunderland	MossS.S.Co.Ld.	316·0|44·9|23·0 P30'B94'F34'	Liverpool British WB	T.3Cy.28",38"&63"-42" 257NHP N.E.MarineEng.CoLd.Sld.		G	
1069 RNGM	Bussard SteelSc H.Wagener -04 (Trawler) 1Dk	142 130 27				1904	J.C.Tecklenborg A.G. Geestemünde	Gebr.Thomas	107·7|20·7|9·9 F15'	Hamburg German WB	T3Cy.11⅛",17¾"&29⅜"-21⅝" 40NHP J.C.TecklenborgA.G.Gst.		G	
1070 118917 VKGW	Bustard SteelScK T.Stafford -03 1Dk	207 185 72	✠100A1 StmTrawler 2,05 ✠LMC	Gms		1903 11mo Lloyd	G.Cooper Hull 'sA&CP	T.Baskcomb	114·5|21·5|11·2 Q59'F19' BK7½"	Grimsby British 4BHCem	T.3Cy.11½",19½"&32"-23" 180lb (s) 55RHP 1SB,2cf,GS29,HS972 C.D.Holmes&Co.Hull	12 · 1		

APPENDIX C

PRESERVED SHIPS.

PRESERVED SHIPS.

The following is a list of ships preserved around the world. Although for reasons of brevity, some ships have not been included; this list is intended to illustrate the range of type, age and size of ships held for preservation. Not all the vessels listed have been restored or have even, as yet, had their condition stabilized. Some are deteriorating faster than they are being maintained, whilst others are presently undergoing major restoration. In addition to preserved ships, there are a number of old ships still operating in the more remote areas of the world for reasons other than historical; the main difference being that there is no conscientious effort to preserve these ships for future generations.

Notes on the list.

Column 2 MTL = Material, W = Wood, C = Composite, I = Iron, S = Steel.

Column 5 The method of preservation shown is that presently used. A number of cases have occurred where the method of preservation of a ship was changed, such as the dry berthing and then subsequent refloating of the Charles W. Morgan at Mystic Seaport.

Some of the more specialized uses of preserved ships have resulted in a degree of unauthentic modifications, for example, those used as restaurants and for sail training.

The years preserved refers to the length of time since the vessel was acquired for preservation.

The reference refers to the major sources of information used for each vessel which can be found in the Bibilography.

NAME	YEAR BUILT	TYPE OF SHIP			COUNTRY	METHOD OF PRESERVATION	
	MATERIAL	LEN. (M)	(DISPL) (TONNES)	GROSS (TONS)	CITY	YRS PRESERVED	REF
KYRENIA SHIP	300BC	MERCHANT SHIP			CYPRUS	DRY IN BUILDING	
	W	15.9m			KYRENIA	11	B,G
OSEBURG SHIP	800AD	VIKING SHIP			NORWAY	DRY IN BUILDING	
	W	21.3m			OSLO	75	B,G
GOKSTAD SHIP	850AD	VIKING SHIP			NORWAY	DRY IN BUILDING	
	W	24.4m			OSLO	98	B,G
COG OF BREMEN	1380	TRADING VESSEL			GERMANY	DRY IN BUILDING	
	W	23.5m		140	BREMEN	17	B,G
VASA	1623	1ST RATE WARSHIP			SWEDEN	DRY IN BUILDING	
	W	45.7m	(1321dwt)		STOCKHOLM	19	B,G
VICTORY	1765	1ST RATE WARSHIP			U.K.	DRY IN DOCK	
	W	56.6m		2162	PORTSMOUTH	57	N,G
CONSTITUTION	1794	SAILING FRIGATE			U.S.A.	AFLOAT	
	W		(1600)		CHARLESTOWN	71	G,J
FOUDROYANT	1817	SAILING FRIGATE			U.K.	AFLOAT	
	W	47.5m		1066	PORTSMOUTH	20	N
UNICORN	1824	SAILING FRIGATE			U.K.	AFLOAT	
	W	46.3m		1080	DUNDEE	17	N
CHARLES W.MORGAN	1841	WHALING SHIP			U.S.A.	AFLOAT	
	W	34.4m		351	MYSTIC	38	G
GREAT BRITAIN	1843	SAIL/STEAM SHIP			U.K.	DRY IN DOCK	
	I	98.1m		3270	BRISTOL	9	N,G,F
RIGI	1847	LAKE PADDLE STEAMER			SWITZERLAND	DRY AS RESTAURANT	
	W	42m	(91.5)		LUCERNE	17	O

NAME	YEAR BUILT / MATERIAL	TYPE OF SHIP / LEN. (M)	(DISPL) (TONNES)	GROSS (TONS)	COUNTRY / CITY	METHOD OF PRESERVATION / YRS PRESERVED	REF
SKIBLANDER	1856	LAKE PADDLE STEAMER			NORWAY	COMMERCIAL	
	I	50.3m		246	EIDSVOLL	42	O
HJEJLEN	1861	RIVER PADDLE STEAMER			DENMARK	COMMERCIAL	
	I	26.9m		39	SILKEBORG	-	O
WARRIOR	1861	IRONCLAD IST RATE			U.K.	AFLOAT	
	I	115.8m	9,210		-	O	N
STAR OF INDIA	1864	FULLY RIGGED SHIP			U.S.A.	OPERATIONAL	
	I	51.2m		646	SANDIEGO	20	X,M
ADELAIDE	1866	RIVER PADDLE STEAMER			AUSTRALIA	DRY ON LAND	
	C	23.1m		58	ECHUCA	13	A,P
MAY QUEEN	1867	TRADING KETCH			AUSTRALIA	AFLOAT	
	W	20.1		36	HOBART	4+	T,A
BUFFEL	1868	IRONCLAD RAM			NETHERLANDS	AFLOAT	
	I				LEUVEHAVEN		G
CUTTY SARK	1869	TEA CLIPPER			U.K.	DRY IN DOCK	
	C	64.6m		963	GREENWICH	57	I
ANNIE WATT	1870	TRADING KETCH			AUSTRALIA	DRY ON LAND	
	W	19.7m		42	ADELAIDE	7	A,T
GISELA	1872	LAKE PADDLE STEAMER			AUSTRIA	COMMERCIAL	
	I	52m			EBENSEE	-	L
JAMES GRAIG	1874	3 MASTED BARQUE			AUSTRALIA	AFLOAT	
	I	54.6m		641	HOBART	7	A
GEM	1876	RIVER PADDLE STEAMER			AUSTRALIA	AFLOAT	
	C	40.5m		228	SWAN HILL	17	A,P

NAME	YEAR BUILT / MATERIAL	TYPE OF SHIP / LEN. (M)	(DISPL) (TONNES)	GROSS (TONS)	COUNTRY / CITY	METHOD OF PRESERVATION / YRS PRESERVED	REF
ELISSA	1877	3 MASTED BARQUE			U.S.A	AFLOAT	
	I	45.6m		431	GALVESTON	U/K	Q
GANNET	1878	STEAM SLOOP			U.K.	AFLOAT	
	C	51.8m		1230	GOSPORT	8	N
FALLS OF CLYDE	1878	4 MASTED BARQUE			U.S.A.	AFLOAT	
	I	81.1m		1748(nett)	HONOLULU	16	G
JOSEPH CONRAD	1882	FULLY RIGGED SHIP			U.S.A.	AFLOAT	
	I	30.7m		202	MYSTIC	32	E
SEGUIN	1884	STEAM TUG			U.S.A.	AFLOAT	
	W	27m			BATH	U/K	D
MEISSEN	1885	LAKE PADDLE STEAMER			EAST GERMANY	COMMERCIAL	
	-	64.35m			DRESDEN	-	L
PIONEER	1885	SCHOONER			U.S.A.	SAIL TRAINING	
	W	17.8m		43.23	NEW YORK	9	
POLLY WOODSIDE	1885	3 MASTED BARQUE			AUSTRALIA	AFLOAT	
	I	57.6m		646	MELBOURNE	14	A
WAVERTREE	1885	FULLY RIGGED SHIP			U.S.A.	AFLOAT	
	I	85.0m		2170	NEW YORK	11	G
BALCLUTHA	1886	FULLY RIGGED SHIP			U.S.A.	AFLOAT	
	I	78.0m		1689	SAN FRANCISCO	24	G
EUREKA	1890	PADDLE FERRY			U.S.A.	AFLOAT	
	W	91.3m		2420	SAN FRANCISCO	21	O
OLYMPIA	1892	CRUISER			U.S.A.	AFLOAT	
	S	103.6m(5963)			PHILADELPHIA	56	Y,G
RESULT	1892	SCHOONER			U.K.	DRY ON LAND	
	I	31.3m		125	ULSTER	U/K	Q,S

NAME	YEAR BUILT / MATERIAL	TYPE OF SHIP / LEN. (M) (DISPL) (TONNES) GROSS (TONS)		COUNTRY / CITY	METHOD OF PRESERVATION / YRS PRESERVED	REF
LETTIE G.HOWARD	1893	FISHING SCHOONER		U.S.A.	AFLOAT	
	W	25.6m		NEW YORK	11	J
TURBINIA	1894	EXPERIMENTAL VESSEL		U.K.	DRY IN BUIDLING	
	S	30.5m (45)		NEWCASTLE	52	O
C.A.THAYER	1895	SCHOONER		U.S.A.	AFLOAT	
	W	47.5m		SAN FRANCISCO		J
YARMOUTH	1895	PLEASURE STEAMER		U.K.	AFLOAT	
	S	22.6m	56	LONDON	6	H
ROBIN	1897	STEAM COASTER		U.K.	AFLOAT	
	S	43.6m	366	LONDON	5	H
PRESIDENTE-SARMIENTO	1897	AUXILARY TRAINING SHIP		ARGENTINA	AFLOAT	
	S	(2794)		BUENOS AIRES		Y
ETONA	1898	RIVER PADDLE STEAMER		AUSTRALIA	OPERATIONAL	
	C	18.3m		ECHUCA	18	A,P
CAROLA	1898	STEAM YACHT		U.K.	OPERATIONAL	
	S	21.5m	40	SOUTHAMPTON	9	H
MATHILDA	1899	STEAM TUG		U.S.A.	OPERATIONAL	
	S	21.9m	114	NEW YORK	9	Q
AURORA	1900	PROTECTED CRUISER		USSR	AFLOAT	
	S	125m (7720)		LENINGRAD		Y,G
SIR WALTER SCOTT	1900	LAKE STEAMER		U.K.	COMMERCIAL	
	S	33.7m	115	LOCH KATRINE	-	H
KATHLEEN & MAY	1900	TOPSAIL SCHOONER		U.K.	AFLOAT	
	W	30.0m	140	LONDON	13	N,J
DISCOVERY	1901	POLAR EXPLORATION SHIP		U.K.	AFLOAT	
	W	52.4m (1640)		LONDON	72	N
MIKASA	1901	BATTLESHIP		JAPAN	SET IN CONCRETE	
	S	126.5m(15,440)		YOKUSUKA	50+	Y,G

NAME	YEAR BUILT / MATERIAL	TYPE OF SHIP / LEN. (M)	(DISPL) (TONNES)	GROSS (TONS)	COUNTRY / CITY	METHOD OF PRESERVATION / YRS PRESERVED	REF
WARATAH	1902	STEAM TUG			AUSTRALIA	AFLOAT	
	I	33.1m		132	SYDNEY	11	A
LADY HOPETOUN	1902	STEAM LAUNCH			AUSTRALIA	OPERATIONAL	
	W	23.5m		38	SYDNEY	14	A
ALMA DOEPEL	1903	TOPSAIL SCHOONER			AUSTRALIA	SAIL TRAINING	
	W	33.3m		151	MELBOURNE	3	Q,A
POMMERN	1903	4 MASTED BARQUE			AALAND	AFLOAT	
	S	94.5m		2376	MARIEHEIM	26	U,K
RESOLUTE	1903	PLEASURE STEAMER			U.K.	AFLOAT	
	S	22.3m		71	THE BROADS	11	H
MEDEA	1904	STEAM YACHT			U.S.A.	OPERATIONAL	
	S	33.4m		112	SAN DIEGO		R
MOSHULU	1904	4 MASTED BARQUE			U.S.A.	FLOATING RESTAURANT	
	S	96.3m		3116	PHILADELPHIA		U,K
TICONDEROGA	1906	PADDLE FERRY			U.S.A.	DRY ON LAND	
	S	67.1m		892	BURLINGTON	16	O
CAMBRIA	1906	THAMES BARGE			U.K.	OPERATIONAL	
	S	27.7m		109	LONDON	8	N
VIKING	1907	4 MASTED BARQUE			SWEDEN	AFLOAT	
	S	89.6m		2670	GOTHENBURG	U/K	K,E
LYTTLETON	1907	TWINSCREW STEAM TUG			NEW ZEALAND	COMMERCIAL	
	S	38.2m		292	LYTTLETON	6	Q,A
RELIANT	1907	PADDLE TUG			U.K.	DRY IN BUILDING	
	S	30.5m		156	GREENWICH	11	H
HERCULES	1907	STEAM TUG			U.S.A.	AFLOAT	
	S	41.4m		409	SAN FRANCISCO	17	Q
AMBROSE	1907	LIGHTSHIP			U.S.A.	AFLOAT	
	S	41.4m	(683)		NEW YORK	11	

NAME	YEAR BUILT / MATERIAL	TYPE OF SHIP / LEN. (M)	(DISPL) (TONNES(	GROSS (TONS)	COUNTRY / CITY	METHOD OF PRESERVATION / YRS PRESERVED	REF
SABINO	1908	PLEASURE STEAMER			U.S.A.	COMMERCIAL	
	W	17.7m			MYSTIC	U/K	D
OSCAR W	1908	RIVER PADDLE STEAMER			AUSTRALIA	COMMERCIAL	
	C	31.5m		83	MURRAY BRIDGE	-	A,P
STADT ZURICH	1909	LAKE PADDLE STEAMER			SWITZERLAND	COMMERCIAL	
	S	56.0m			ZURICH	-	L
PEVENSEY	1910	RIVER PADDLE STEAMER			AUSTRALIA	OPERATIONAL	
	C	34.0m		130	ECHUCA	6	A,P
PEKING	1911	4 MASTED BARQUE			U.S.A.	AFLOAT	
	S	98.5m		3191	NEW YORK	3	N,K
EARNSLAW	1911	LAKE STEAMER			NEW ZEALAND	COMMERCIAL	
	S	70.1m		330	WAKIPITU	-	A
PASSAT	1911	4 MASTED BARQUE			GERMANY	AFLOAT	
	S	98.5m		3130	TRAVEMUNDE	22	K
INDUSTRY	1911	RIVER PADDLE STEAMER			AUSTRALIA	AFLOAT	
	C	32.3m		91	RENMARK	5	A,P
TRINITY BAY	1912	SUCTION DREDGE			AUSTRALIA	FLOATING RESTAURANT	
	S	65.2m		1054	CAIRNS	2	Q
VIERA Y. CLAVIJO	1912	CARGO/PASSENGER STEAMER			NETHERLANDS	AFLOAT	
	S	67.1m		862	ZIERIKZEE	1	Q
KERNE	1913	STEAM TUG			U.K.	OPERATIONAL	
	S	23.5m			LIVERPOOL	8	H
EPPLETON HALL	1914	PADDLE TUG			U.S.A	AFLOAT	
	S	32.0m		166	SAN FRANSISCO	11	Q
BELLE OF LOUIS-VILLE	1914	RIVER STERNWHEELER			U.S.A.	OPERATIONAL	
	S	48.0m			LOUISVILLE	17	O
SKJELSKIOR	1915	FERRY STEAMER			DENMARK	OPERATIONAL	
	S	18.7m		49	COPENHAGEN	16	O

NAME	YEAR BUILT / MATERIAL	TYPE OF SHIP / LEN. (M)	(DISPL) (TONNES)	GROSS (TONS)	COUNTRY / CITY	METHOD OF PRESERVATION / YRS PRESERVED	REF
WAPAMA	1915 / W	STEAM SCHOONER / 62.5m		951	U.S.A. / SAN FRANCISCO	AFLOAT / 21	O
NEW ENDEAVOUR	1919 / W	TOPSAIL SCHOONER / 31.3m		138	AUSTRALIA / SYDNEY	SAIL TRAINING / 6	A
L.A.DUNTON	1921 / W	FISHING SCHOONER / 37.8m			U.S.A. / MYSTIC	AFLOAT / 16	J
MASTER	1923 / W	STEAM TUG / 21.5m		91	CANADA / VANCOUVER	OPERATIONAL / 17	O
MEDWAY QUEEN	1924 / S	EXCURSION PADDLER / 54.8m		316	U.K. / ?	FLOATING CLUBHOUSE / 14	O,N
KINGSWEAR CASTLE	1924 / S	EXCURSION PADDLER / 32.9m		47	U.K. / MEDWAY	AFLOAT / 14	O,N,H
ALEXANDER HAMILTON	1924 / S	PADDLE FERRY / 103m		2367	U.S.A. / NEW YORK	AFLOAT	W
FORCEFUL	1925 / S	STEAM TUG / 36.9m		288	AUSTRALIA / BRISBANE	OPERATIONAL / 8	Q,A
KRUSENSTERN	1926 / S	4 MASTED BARQUE / 97.5m		3064	USSR / -	SAIL TRAINING / -	K,E
DELTA QUEEN	1926 / S	RIVER STERNWHEELER / 76.3m		1837	U.S.A. / CINCINNATI	COMMERCIAL / 21	O
JOHN OXLEY	1927 / S	PILOT STEAMER / 51.2m		544	AUSTRALIA / SYDNEY	AFLOAT / 9	Q,A
ST ROCH	1928 / W	MOTOR ARTIC SUPPLY SHIP / 31.7m			CANADA / VANCOUVER	DRY IN BUILDING / 27	G
PORTWEY	1928 / S	TWINSCREW STEAM TUG / 24.5m		94	U.K. / DARTMOUTH	OPERATIONAL / 27	H
STADT LUZERN	1928 / S	LAKE PADDLE STEAMER / 60.0m			SWITZERLAND / LUCERNE	COMMERCIAL / -	L

NAME	YEAR BUILT / MATERIAL	TYPE OF SHIP / LEN. (M) (DISPL) (TONNES)	GROSS (TONS)	COUNTRY / CITY	METHOD OF PRESERVATION / YRS PRESERVED	REF
LYDIA EVA	1930	STEAM TRAWLER		U.K.	OPERATIONAL	
	S	29.0m	138	LONDON	8	N,H
CHALLENGE	1931	STEAM TUG		U.K.	AFLOAT	
	S	30.5m	212	LONDON	6	H
HERO	1931	PADDLE TUG		U.K.	OPERATIONAL	
	S	33.5m	202	CHATHAM	11	H
ST. CANUTE	1931	STEAM TUG		U.K.	AFLOAT	
	S	26.2m	310	EXETER		H,Q
WATTLE	1933	STEAM TUG		AUSTRALIA	OPERATIONAL	
	S	24.4m	100	MELBOURNE	8	A
WILLIAM C.DALDY	1935	TWIN SCREWSTEAM TUG		NEW ZEALAND	AFLOAT	
	S	38.4m	346	AUCKLAND	1	Q,A
SOUTH STEYNE	1938	STEAM FERRY		AUSTRALIA	AFLOAT	
	S	67.1	1203	SYDNEY	4	Q,A
BELFAST	1939	HEAVY CRUISER		U.K.	AFLOAT	
	S	187m(11,735)		LONDON	8	G,N,C
U-505	1941	SUBMARINE		U.S.A.	DRY ON LAND	
	S			CHICAGO	25+	G
HAIDA	1942	DESTROYER		CANADA	AFLOAT	
	S	108.4m (2,788)		TORONTO	16	G,C
NORTH CAROLINA	1942	BATTLESHIP		U.S.A.	AFLOAT	
	S	222.2m(47,500)		WILMINGTON	18	G,C
JOHN W.BROWN	1942	LIBERTY SHIP		U.S.A.	AFLOAT	
	S	128.9m	7230	NEW YORK	O	
YORKTOWN	1943	AIRCRAFT CARRIER		U.S.A.	BEACHED	
	S	270.7m(42,000)		CHARLESTON	9	G,C
AULD REEKIE	1943	STEAM STORES LIGHTER		U.K.	OPERATIONAL	
	S	20.4m	97	-	11	H

NAME	YEAR BUILT MATERIAL	TYPE OF SHIP LEN. (M)	(DISPL) (TONNES)	GROSS (TONS)	COUNTRY CITY	METHOD OF PRESERVATION YRS PRESERVED	REF
CASTLEMAINE	1943	CORVETTE			AUSTRALIA	AFLOAT	
	S	56.7m	(1041)		MELBOURNE	8	A
CAVALIER	1944	DESTROYER			U.K.	AFLOAT	
	S	110.6m	(2560)		-	7	G,C
TAIOMA	1944	STEAM TUG			NEW ZEALAND	DRY ON LAND	
	S	34.4m		232	WELLINGTON	1	Q,A
FEARLESS	1945	STEAM TUG			AUSTRALIA	AFLOAT	
	S	34.6		249	ADELAIDE	6	A,Q
BRENT	1946	STEAM TUG			U.K.	OPERATIONAL	
	S	22.5		54	-	10	H
CERVIA	1946	STEAM TUG			U.K.	OPERATIONAL	
	S	34.4		233	CHATHAM	8	H
WAVERLEY	1947	SEAGOING PADDLER			U.K.	COMMERCIAL	
	S	51.5m		693	GLASGOW	6	Q
CHEYNES II	1947	WHALE CHASER			AUSTRALIA	OPERATIONAL	
	S	47.9m		440	HOBART	O	Q,A
ALLIANCE	1947	SUBMARINE			U.K.	DRY ON LAND	
	S	87.2m	(1620)		GOSPORT	O	V
YELTA	1949	STEAM TUG			AUSTRALIA	AFLOAT	
	S	31.5m		233	ADELAIDE	3	A,Q
MAID OF THE LOCH	1953	LAKE PADDLE STEAMER			U.K.	COMMERCIAL	
	S	63.4m		555	LOCH LOMOND	-	O
GYPSY MOTH IV	1966	KETCH			U.K.	DRY ON LAND	
	COLD VENEER	16.5m			GREENWICH	11	N

APPENDIX D

'WARATAH'

PRELIMINARY SURVEY

1976

BILL HAWKINS, FRANK BELL.

S.T.WARATAH.

Report of Cursory Hull Survey carried out 23-3-75, Blackwattle Bay.

HULL EXTERNAL:

While circumstances did not allow for other than a visual survey from the Dockside, indications are that the topsides area is in reasonably sound condition.

The wind & water & underwater areas were fouled to a degree which precluded any meaningful assessment.

Indications seen at some internal Compartments, eg. the forward Accommodation Space, show signs of Hull penetration by external pitting.

No worthwhile opinion can be given until Ship is Docked &, preferably, sand blasted.

HULL INTERNAL:

Isolated areas of severe deterioration seen at this inspection included & were most pronounced at;

1) Port & Stb Coal Bunkers where wide areas of shell plating & framing are perilously thin.

2) Boiler Room Bilge area where the C.V.K. is excessively wasted.

3) Cross Bunker area, where the Bulkhead plating is wasted thin in places.

4) Engine Room where sections of framing is corroded away.

In addition, underdeck tie plates, beams & stringer plating were found to be in poor condition over wide areas.

SUPERSTRUCTURE:

Generally sound; some isolated repairs required.

BULWARKS: Poor throughout.

RECOMMENDATIONS:

To return the Vessel to a maintainable condition will entail a great deal of work & considerable expense, though it is considered that reclamation is practical.

The following programme is recommended:-

1) As a matter of urgency, (because of known potential leaks below waterline) Dock or Slip the Vessel, sandblast underwater area & build up excessively deep pits by welding.

2) Whilst Docked or on Slip, ultrasonicly test thickness of selected areas of shell plating to enable planning of future repairs.

3) Renew defective areas of shell plating & framing at a further Slipping or Docking, when available finance will cover tendered costs.

4) Remove wood decking throughout, renew underdeck plating & framing as found necessary & renew wood decking. (If acceptable from an aesthetic point of view, it may be cheaper to plate in the decks but this would take away the uniqueness of the Ship).

5) Renew the Bulwarks & renew many Items of Weather Deck & 'Tween Deck fittings.

NOTE: Approx. estimated cost $200,000 - $300,000.

Yours faithfully,

Bill Hawkins
Frank Bell

APPENDIX E

'WARATAH'

PRELIMINARY SURVEY

1976

FRANK BELL, H. GERARD.

Lloyd's Register of Shipping
P & O Building, 2 Castlereagh Street,
Sydney, N.S.W. 2000
G.P.O. Box 4231
Sydney, N.S.W. 2001
Telephone (02) 221-1277 Telex AA26164 Cables Miramar, Sydney

The President,
Sydney Cove Waterfront Museum Ltd.,
P.O. Box 514,
NORTH SYDNEY, N.S.W. 2060.

Please address further communications to The Surveyors, and quote

Our Ref HG/FBL/eg

Your Ref -

Date 15th August, 1975.

Dear Sir,

Steam Tug "WARATAH"
(Built about 1902)

Following your recent request, the undersigned, assisted by Mr.F.B. Last, carried out a preliminary general examination of the above ship on the 13th instant whilst she was lying afloat in Blackwattle Bay, Sydney.

This examination was made with a view to advising the Museum Authority as to the general condition of the hull and machinery to assist in deciding the future possibilities for the vessel as part of a permanent exhibition in Sydney.

The ship was stated to have been built in Sydney at about the turn of the century but it is not known whether the hull and machinery were fabricated in Australia or overseas.

It is desired to emphasise that as the ship was not completely cleaned, and opened up as necessary for a detailed survey, this letter cannot be regarded as an accurate specification of repairs to restore the vessel to an operational condition. However, the following comments are offered with a view to assisting the Museum Authorities to formulate their future plans for the ship:-

A HULL

Shell Plating: Generally in fair condition but holed in several places in the vicinity of the topside wood belting and "wind and Water" area. The condition of the riveting also gives grounds for concern particularly in the vicinity of end laps below ceiling level in holds, coal bunker and below the floor plates in stokehold.

Frames, Floors, beams and beamknees: signs of severe wastage in coal bunkers, stokehold and below boiler front.

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Deck Plating and Wood Deck. Wood deck planking, fastenings and caulking generally in poor condition and representative sections should be lifted to permit closer, detailed examination of atringer and tie plates. Sections of cement in the waterway adjacent to the bulwarks, also to be removed for examination of the stringer plate.

Peak Tanks, examined internally.
Forepeak: The general structure and cement wash coating appears reasonably good in the lower section, but the shell plating is holed in the upper section, port side, in the vicinity of the wood belting (sponson).
Afterpeak: The general structure and cement wash coating appears reasonably good throughout.

Transverse Watertight Bulkheads. Bulkhead between stokehold and forward hold completely wasted and holed in centre section - to be renewed as necessary.

Hatch coamings and covers: Generally in poor condition; to be repaired and the closing appliances overhauled. Bunker hatch coaming and covers beyond repair and to be replaced.

Bulwarks and Bulwark Stays wasted, indented and stays buckled or broken practically throughout - to be cropped and part renewed or faired throughout.

Deckhouses & Casings Generally in fair condition but lower boundary bars to be dealt with as necessary after deck boundary planking removed for examination of these areas.

Steering Gear: Engine, chains, rods and quadrant to be dismantled and completely overhauled, particular attention being given to the deck sheaves and lead blocks with their fastenings to the decks and casings. Auxiliary steering gear to be placed in working order.

Sternframe and Rudder to be thoroughly cleaned whilst vessel in dry dock. The rudder to be lifted and rudder stock, pintles and gudgeons dealt with as necessary.

Mast and Rigging to be completely overhauled, particularly attachments of shrouds to structure. Deck wedges to be removed to enable mast to be examined at deck level.

Windlass and Anchoring Arrangements.
The windlass and anchoring arrangements appear unusual and together with the anchor chain, which appears small for the anchor at present fitted, need to be overhauled and examined.

............./3

3/............

B MACHINERY

The boiler was partly opened up, but not clean enough for a detailed examination, however it appeared to be generally in good condition. Before raising steam, it should be thoroughly cleaned internally and together with the mountings, feed pumps and piping, opened out for close examination.

The main engine (compound) could only be examined externally and appeared reasonably good, but it also should be opened up for examination of the cylinders, pistons, rods, valves and chests, crank, thrust, intermediate and tailshafts.

The main engine driven pumps were partly opened up and obviously in need of some repair. The same applies to the condenser.

The remaining pumps and pumping arrangements were not opened up at this time and it was noted that the piping generally was showing signs of wastage. It was also noted that there had been a number of alterations made in the piping systems and these would require checking out as to their conformance with recognised pumping arrangements, particularly in relation to the bilge pumping system, which should be tested under working conditions.

In view of the long period out of dry dock, the sea injections may be fouled with marine growth and should be cleared.

The fire extinguishing arrangements, including the pump, fire main, hydrants, hoses, nozzles and portable exinguishers to be overhauled. It is also recommended that a Shore Connection be provided.

The electrical installation is rather minimal and has been subject to numerous alterations. Probably the simplest method to deal with this would be to re-wire the ship and also include a suitable shore connection.

GENERAL REMARKS

No attempt has been made to assess a cost for essential repairs at this time. We would, however, emphasise that from the safety aspect certain repairs are considered minimal before the ship is again placed in service.

An extract of the Society's Rules covering the Survey of Old Ships is enclosed for your guidance in deciding a future course of action regarding this ship.

............../4

4/.............

It was stated that the ship had not been drydocked for about 8 years. It is therefore strongly recommended that the ship be docked at the earliest opportunity for a full examination of all vital underwater parts and before the ship is again placed in commission.

We would again express our appreciation of the help given on the occasion of this examination by Messrs W.J. Lovell and W. Hardiman.

Yours faithfully,

H. Gerrard.

(H. GERRARD)
Senior Principal Surveyor.

APPENDIX F

DOCK GATE CALCULATIONS

DOCK GATE CALCULATIONS.

See Figures 8, 9 and 10.

ASSUMPTIONS:

HEAD AT HIGH WATER	6.4 m
DENSITY OF SALT WATER	1.025 tonnes m^{-3}
YIELD STRESS (AS 1204 GRADE 250)	250 MPa

PRIMARY STRUCTURE

i) Vertical Beams (Figure F1).

Assume simple support on both ends

using case 3Da (Blodgett, 1976, p. 8.1-8)

$$M_{max} = 386 \text{ KNm}$$

$$\sigma = \frac{My}{I} \qquad \text{(Hall, 1974, p. 53)}$$

where,

I for 610UB x 125

$= 986 \times 10^6 \text{ mm}^4$ (BHP, 1978, pp. 28-29)

$y = 310$ mm

$$\sigma = \frac{386 \times 10^6 \times 305}{986 \times 10^6}$$

$= 119 \text{ Newtons/mm}^2$

$= 119$ MPa

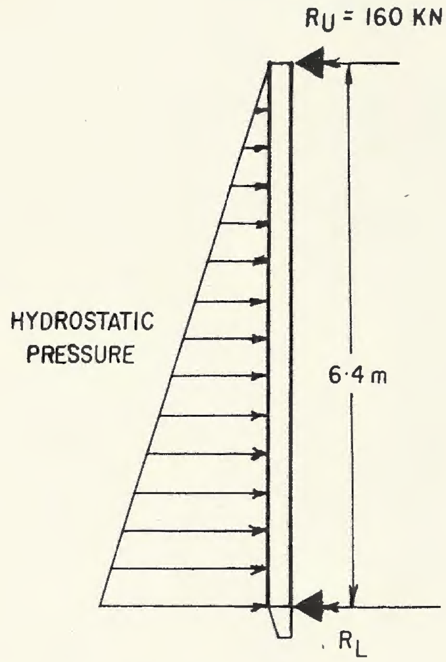

FIG F1
VERTICAL BEAM DIAGRAM

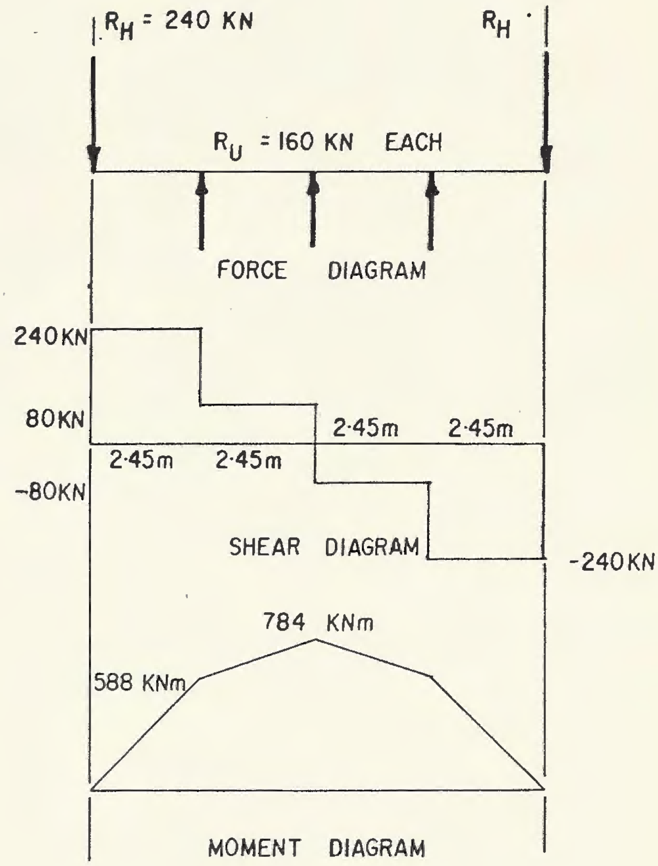

FIG F2
HORIZONTAL BEAM

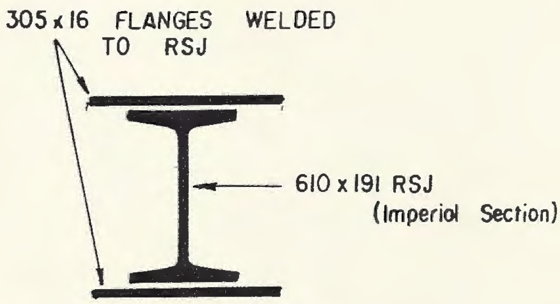

FIG F3
SECTION THROUGH HORIZONTAL BEAM

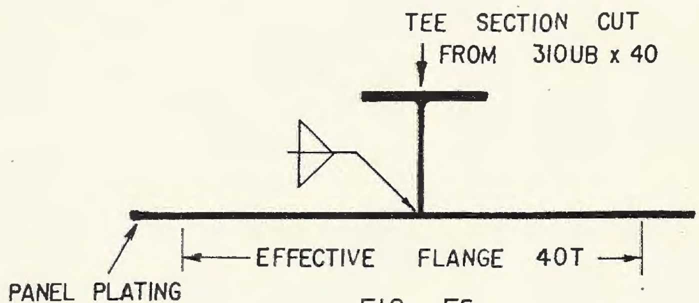

FIG F5
SECTION THROUGH SECONDARY STIFFENNING

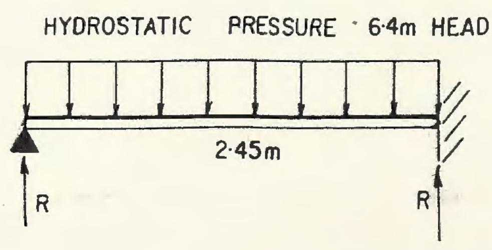

FIG F4
SECONDARY STIFFENING DIAGRAM

Stress Factor $= \dfrac{250}{119}$

$= 2.1$

ii. Horizontal Beam (Figures F2 and F3)

Assume span of 9.8m simple support at each end. Reaction of each vertical beam against the horizontal beam:

$R_u = \dfrac{Phm}{6} = 160$ KN (Blodgett, 1976, p. 8.1-8)

From Figure F2

$M_{max} = 784$ KNm

Moment of inertia of horizontal beam (See Figure F3).

Original section made from Imperial size 24 inch x 7.5 inch x 95 lb R.S.J. with a 12 inch x 5/8 inch doubling plate welded onto the outside of each R.S.J flange.

I for 24" x 7.5" x 95 RSJ $= 2533"^4$ (BHP, 1952, p. 88)

$$I_{total} = 2533 + 2\left[(1/12 \times (5/8)^3 \times 12) + (12 \times 5/8)(12.625)^2\right]$$

$$= 4924"^4$$

$$= 2049 \times 10^6 \text{ mm}^4$$

$$y = 321 \text{ mm}$$

$$\sigma = \frac{My}{I}$$

$$= \frac{784 \times 10^6 \times 325}{2049 \times 10^6}$$

$$= 124 \text{ MPa}$$

$$\text{Stress Factor} = \frac{250}{124}$$

$$= 2.0$$

SECONDARY STRUCTURE

PANEL STIFFENERS see Figures F4 and F5.

Assume worst case between dockside and vertical beam at bottom of gate (neglect sloped walls). See Figure F4. In this case, one edge can be assumed clamped, the other simply supported.

The span is 2.45 m, spacing 762 mm. Stiffeners are made from a 310UB x 40 Section cut in half welded to 16 mm plate of the panel itself (See Figure F5). The effective width of flange has been assumed as 40 t.

Moment of inertia of combined section (dimensions obtained from BHP, 1978, pp. 30-31.)

$$I = 38.3 \times 10^6\ mm^4$$

$$y = 133.5\ mm$$

Using case 5B (Blodgett, 1976, p. 8.1-18)

$$M_{max} = \frac{wL^2}{8}$$

$$w = 1.025 \times 6.4 \times .762 = 48.98\ KNm^{-1}$$

$$L = 2.75\ m$$

$$M_{max} = 36.75\ KNm$$

$$\sigma = \frac{My}{I}$$

$$= \frac{36.75 \times 10^6 \times 133.5}{38.3 \times 10^6}$$

$$= 128\ MPa$$

$$\text{Stress Factor} = \frac{250}{128}$$

$$= 1.95$$

TERTIARY STRUCTURE

PANEL PLATING

Maximum size of unstiffened panels

5.17m x .762 m   ASPECT RATIO = 6.8

Assume simple support for plates under uniform lateral pressure.

$$\text{Stress} = K \frac{P}{2} \frac{(b)^2}{(t)^2} \quad \text{(Hughes, 1976, Figure 8.7)}$$

K = a constant = 1.45 (From Figure 8.7)

b = .762

t = thickness

Calculating t to give a load factor of 2 for a yield stress of 250 MPa

DEPTH (M)	PRESSURE HEAD (KPa)	CALCULATED THICKNESS (mm)
1	10.0	5.8
2	20.1	8.2
3	30.1	10.0
4	20.2	11.6
5	50.2	13.0
6	60.3	14.2
6.4	64.3	14.7

The thicknesses above are the minimum for a load factor of 2. These thicknesses were altered in the actual gate design to be preferred thicknesses.

SHORES FOR HORIZONTAL BEAM

See Figure 6.

- Analyse for buckling of 200 UC x 59.5 shores
- Assume no initial deflection of horizontal beam before contacting shores.

For 200 UC x 59.5 -

$I = 20.4 \times 10^6 \text{ mm}^4$ (BHP, 1978, p. 30)

$E = 207 \text{ GPa}$

Critical Force $P_{cr} = \frac{\pi^2 EI}{L^2}$ (Hall, 1973, p.307)

$$= \frac{\pi^2 \times 207 \times 10^9 \times 20.4 \times 10^6}{(5.71 \times 10^3)^2}$$

$$= 1278 \text{ KN}$$

Combined critical load from both shores normal to the gate panels,

$$2(P_{cr}) \times \cos 53^\circ = 1538 \text{ KN}$$

Equivalent force necessary at midspan of horizontal beam to counteract moments from the three vertical beams.

$$M_{max} = \frac{PL}{4} \qquad \text{(Blodgett, 1976, 8.1-5)}$$

$$P = \frac{4\ M_{max}}{L}$$

where M_{max} = 784 KNm

L = 9.14 m

$$P = \frac{4 \times 784}{9.14}$$

$$= 343.1\text{KN}$$

$$\therefore \quad \text{Load factor} = \frac{1538}{343.1}$$

$$= 4.4$$

The load factor of the combined horizontal beam and shores would depend upon the free deflection of the beam before contacting the shores as well as the effectiveness of the shore end supports. Because the dock had never been designed to take these shores, it is doubtful that the shores could be loaded up to critical load without the end supports failing at a lower value. For this reason, the Load Factor has only been taken as 4 for the complete structure.

LOAD FACTORS

The load factors accepted for the dock gate design were determined from the experiences of a number of persons who were consulted. Later, a reference was discovered

(Harvey-Evans, 1975, pp. 258-59) which provided a method of calculating adequate load factors. These are compared with the actual load factors in the table below:

COMPONENT	STRESS FACTOR(YIELD)		LOAD FACTOR (COLLAPSE	
HORIZONTAL BEAM AND SHORES	ACTUAL	CALCU.	ACTUAL	CALCU.
	YIELD MEANS COLLAPSE		4.0	4.0
VERTICAL BEAMS	2.1	1.45		2.3
PANEL STIFFENING	1.95	1.9		1.9
PLATING	2.0	1.95		1.95

APPENDIX G

BLACKWATTLE BAY DRY DOCK: MUD SURVEY

1977.

The Andrew Diving Company

11 Kessell Ave. Homebush

Ph: 767486

Sydney Waterfront Museum,
213 Miller Street,
North Sydney, N.S.W. 2060

14th February, 1977

Attention: Captain J. Lovell

Subject: Survey - Proposed Western Dry Dock

Dear Sir,

We have pleasure in being able to help you with your latest project. Lt. Cdr. Willcox RANR asked us to do this survey owing to lack of training ti around this date.

Our original method of survey was to use a 1 metre long probe to pierce t mud and show us the depth. This would have allowed us to move under "Waratah" and set up a grid survey using known co-ordinates. Unfortunate after initial trials, the mud proved too deep. We then set about using a large length of rod to probe the mud using two divers.

The results can be seen illustrated over the page. The mud level varies from 47" in the centre, to 98" at the mouth. The level is higher on the sides than in the centre and supported in place by undergrowth. The readi up in the blind end (38") is in fact correct and would suggest there is a step in the floor. There is also evidence of the staircase going to the bottom in three levels.

The mud itself is very thin and "silty" like "thickened black ink", and w brought to the surface, gave off sulphur fumes. There appears to be ple of binding for the mud, particularly near the outside edges where mollusc shells have been buried for some years. Large amounts of debris includin drums and pipe are also on the bottom.

Rough calculations show approximately 22,000 cu. ft. or 800 cu. yds. of mud in the dock, with various obstructions.

In conclusion, the task to clear this dock would be a large one, probably larger than initially anticipated. We feel it needs a dredging type operation. It would be almost impossible to do it on a "do-it-yourself" basis. The first worry would be removing the mud at the entrance to facilitate replacing the gates.

If there is anything we could do to be of further assistance, please do n hesitate to call upon us.

Yours sincerely,

Colin Stewart

Colin Stewart
TECHNICAL DIRECTOR

APPENDIX H

DOCKING ARRANGEMENTS.

DOCKING ARRANGEMENTS

i KEEL BLOCKS

Assume:

- Maximum allowable crushing pressure for cribbed blocks is 432 tonnes/m^2 and for free standing blocks 216 tonnes/m^2 (Rawson & Tupper, 1976, p. 286)

- Width of keel in contact 51 mm (See Figures 3 & 12).

- Crushing Caps 305 mm wide oregon.

- Displacement when docked 102 tonnes.

- Blocks freestanding

Total area of keel to be in contact with keel blocks so as to be within the maximum recommended crushing force

$$A_t = \frac{102}{216} = .47m^2$$

Area in contact with each cap

$$A_c = .051 \times .305 = .0156m^2$$

Number of blocks required $\frac{.47}{.0156} = 30$

30 blocks to be used, the first 28 spaced at 915 mm centres and the last two aft at 610 mm centres. See Figure 8.

ii SIDE SHORES

Requirements for the shores to be able to withstand an earthquake with accelerations of 0.2g.

Assume:

- Displacement in dock is 102 tonnes.
- Height of centre of gravity above keel 2.3m.
- Shores 2m long.
- Shores positioned 2.7m above keel.

Moment of forces to be resisted about the keel during an earthquake of 0.2g.

$$M = (102 \times 0.2 \times 9.8)\ 2.3$$
$$= 460 \text{ KN}$$

Assume a minimum of four shores per side in operation at any one time.

Force per shore (F_s)

$$F_s = \frac{460}{2.7 \times 4}$$

$$= 42.6 \text{ KN}$$

Recommended max, compressive working pressure for Oregon parallel to grain is 5.17 MPa (Bootle, 1971, p. 39, 198).

Because of the possible serious consequences of failure and the additional forces within each shore due to the fixing in position with wedges, a working pressure two thirds the above was used, i.e., 3.45 MPa.

Area of shore required to resist compression:

$$A_s = \frac{F_s}{P}$$

$$= \frac{42.6 \times 10^3}{3.45}$$

$$= 12347 \text{ mm}^2$$

SHORES TO BE 111mm x 111mm square each.

Check for buckling.

Assume Euler Buckling (Hall, 1973, p. 307)
Modulus of Elasticity for Oregon 13 GPa
(Bootle, 1971, p. 38)

$$P_{cr} = \pi^2 \frac{EI}{L^2}$$

where

$$I = \frac{1}{12} \times (111)^4$$

$$= 12.7 \times 10^6 \text{mm}^4$$

$$P_{cr} = \frac{\pi^2 \times 13 \times 10^9 \times 12.7 \times 10^6}{(2000)^2}$$

$$= 407 \times 10^9 \text{ N}$$

This is far above the 42.6×10^3 N calculated as F_s.

From the above; six shores per side to be used, (allowing two to be removed on each side during repairs), each a minimum of 111mm square section. (See Figures 8 and 12).

APPENDIX I

DOCKING CALCULATIONS

DOCKING CALCULATIONS.

i) INCLINING EXPERIMENT.

CARRIED OUT ON S.T. WARATAH JUNE 1977
(Yates, 1977).

STATE OF THE VESSEL:

'Waratah' was, at the time of inclining, partially dismantled in preparation for the docking and subsequent restoration. Her loading was similar to that when she was docked; all stores removed, fore peak tank full, bilges and aft peak tanks empty but not dry. All loose gear was secured.

CONDITIONS OF EXPERIMENT:

The 'Waratah' was inclined in the Blackwattle Bay Dry Dock. The day was calm and the winds light. The mooring lines were slackened during the experiment and no personnel were aboard other than those engaged in the experiment.

EQUIPMENT:

Total mass of inclining weights 2.4 tonnes

Two oil dampened pendulums were used

Fore Pendulum	$l = 4.51$ m
Aft Pendulum	$l = 4.28$ m

RESULTS:

Approximate draughts

Fwd	1.7m
Aft	2.3m
Midships	2.0m

Displacement on this draught 98.6 tonnes. (PWD, 1902, Lines Plan).

Total athwartships travel of inclining weights = 5.47m.

MOVEMENT	FORWARD DEVIATION (mm)	AFT DEVIATION (mm)
MIDSHIPS	0	0
STARBOARD	19	18
MIDSHIPS	0	1
PORT	-19	-17
MIDSHIPS	1	1

CALCULATIONS:

$$GM = \frac{wd}{W \tan \phi}$$ (Attwood, 1942, p. 121)

w = inclining weight = .24 tonnes.

W = displacement = 98.5 tonnes.

d = travel = $\frac{5.47}{2}$ = 2.74 m

ϕ is given as the angle of the pendulum from the vertical axis of the ship in the inclined condition.

$$\text{Tan}\,\phi = \frac{x}{l}$$

where

x = deviation

l = length of pendulum.

Average value of x fwd = .01875 m

Average value of x aft = .01725 m

$$\text{Tan}\,\phi \text{ forward} = \frac{.01875}{4.51} = 4.151 \times 10^{-3}$$

$$\text{aft} = \frac{.01725}{4.28} = 4.03 \times 10^{-3}$$

$$\text{Average tan}\,\phi = 4.094 \times 10^{-3}$$

$$GM = \frac{wd}{W\tan\phi}$$

$$= \frac{.24 \times 2.74}{98.5 \times 4.094 \times 10^{-3}}$$

$$= 1.63 \text{ m.}$$

NOTES:

- No correction for free surface was necessary because this was also present during docking.

- The value for displacement could be inaccurate because the original draught marks were no longer visable requiring less positive methods of determining draught to be used.

ii) CRUSHING FORCE ON AFTERMOST BLOCKS.

$$P = \frac{Mi}{L/2 - s}$$ (Barnaby, 1967, p. 93)

where,

M = moment to trim/cm

i = trim (cm)

L = Length on waterline

P = crushing force in tonnes

s = distance from AP to first keel block

M = 1.56 tonnes cm^{-1} (Goggin, 1977)

i = 60 cm

L = 30.5 m

s = 1.6 m

$$\therefore \quad P = \frac{1.56 \times 60}{30.5/2 - 1.6} = 6.86 \text{ tonnes}$$

The maximum crushing force of 7 tonnes on the aftermost blocks during docking is not excessive, particularly as it acts for only a short period.

iii) STABILITY DURING DOCKING.

During docking

$$\Delta GM = \frac{F}{W} \times KM_t \qquad \text{(Barnaby, 1967, p. 93)}$$

where, ΔGM is the change of GM during docking

F = Maximum crushing force = 6.86 tonnes

W = Displacement of vessel = 98.5 tonnes

KM_t = Height of transverse metacentre above keel

= 3.78 m (Goggin, 1977)

$$\Delta GM = \frac{6.86 \times 3.75}{98.5} = .25\text{m}$$

Minimum value of GM during docking

$$GM_{min} = GM_{initial} - \Delta GM$$

$$= 1.63 - .25$$

$$= 1.37 \text{ m}$$

This value is sufficient for docking.

APPENDIX J

UNDOCKING CALCULATIONS.

UNDOCKING CALCULATIONS

i) WEIGHTS AND CENTRES ESTIMATES.

COMPONENTS	MASS (tonnes)	LCG (m from AP)	PRODUCT	VCG (m above keel)	PRODUCT
Shell	22.67	14.31	324.4	1.91	43.30
Frames	6.77	14.02	94.9	2.02	13.38
Keel, Stem) Sternframe	2.29	12.52	28.7	1.02	2.34
Keelson	3.10	14.67	45.5	0.89	2.76
Stringers	2.63	15.21	40.0	2.15	5.65
Floors	1.21	15.47	18.7	0.85	1.03
Deck Beams	1.73	13.56	23.5	3.77	6.52
Deck Stringers	2.68	13.76	36.9	3.80	10.18
Tie & Deck Plates) Boundary Angles	2.24	16.09	36.0	3.77	8.44
Beam Knees	0.58	13.69	7.9	3.57	2.07
Bulkheads	3.32	12.79	42.5	2.41	8.00
Bunker casings Deep Beam, Baffles)	2.70	14.01	37.8	2.73	7.37
Bulwarks	4.64	13.32	61.8	4.32	20.04
Mchy Seatings	0.86	11.31	9.7	1.02	0.88
Cement	4.06	10.85	44.1	0.91	3.69
Deckhouses	8.52	13.69	116.5	5.24	44.64
Machinery	23.84	11.22	267.4	2.42	57.69
Deck	2.56	19.44	49.8	3.75	9.60
Miscellaneous	1.44	11.37	16.4	3.39	4.88
TOTALS	97.84		1302.5		252.76

$$\text{Estimated KG} = \frac{252.76}{97.84} = 2.58 \text{ m}$$

$$\text{Estimated LCG} = \frac{1302.5}{98.84} = 13.31 \text{ m Forward of A.P.}$$

ii) TRIM, STABILITY AFLOAT, AFT END CRUSHING FORCE, MINIMUM STABILITY DURING DOCKING.

Three cases analysed:

1. Unballasted
2. Ballasted with chain and water in Fore Peak
3. As in 2., but with additional ballast in forward accommodation bilges.

CONDITION 1

W = 97.84 tonnes

KG = 2.58 m

LCG = 13.31 m forward of A.P.

CONDITION 2

COMPONENT	MASS (tonnes)	LCG (m from AP)	PRODUCT	VCG (m from keel)	PRODUCT
FRESH WATER	7.6	28.57	217.13	3.57	27.13
CHAIN	2.0	28.27	48.06	1.83	8.11
SHIP	97.48	13.31	1302.5	2.58	252.76
TOTAL	107.44		1567.69		288.00

W = 107.44 tonnes

KG = 2.68 m

LCG = 14.59 m forward of A.P.

CONDITION 3

COMPONENT	MASS (tonnes)	LCG (m from AP)	PRODUCT	VCG (m above keel	PRODUCT
BALLAST	9.1	26.67	242.69	1.70	15.49
SHIP (As in COND. 2)	107.44	14.59	1567.69	2.68	288.00
TOTAL	116.54		1810.38		303.49

W = 116.54 tonnes

KG = 2.60 m

LCG = 15.53 m forward of AP

	CONDITION 1	CONDITION 2	CONDITION 3
L(m)	30.5	30.5	30.5
W(tonnes)	97.84	107.44	116.54
LCG (m fuel of A.P.)	13.31	14.59	15.53
KG (m)	2.58	2.68	2.60
Draught (m)*	1.98	2.07	2.15
MTC(tonnes m cm^{-1})*	1.63	1.61	1.71
LCB (m fwd of A.P.)	15.52	15.52	15.52
KM_t (m)*	3.81	3.81	3.83

* Goggin, 1977.

	CONDITION 1	CONDITION 2	CONDITION 3

TRIM

$$i = \frac{(LCB - LCG)\Delta}{MTC} + b$$

b = rate of keel to baseline at Designed water line.

= 72.5 cm

i(CM) =	213.8	134.6	71.8
	(excessive)	(excessive)	(acceptable)

AFT END CRUSHING FORCE

$$P = \frac{MTC \times i}{L/2 - K}$$

Where K is the distance between the aftermost keel block and the A.P. i.e. 1.6m

P (tonnes)=	23.96	15.88	9.00
	(excessive)	(excessive)	(acceptable)

	CONDITION 1	CONDITION 2	CONDITION 3
STABILITY AFLOAT			
$GM_t = KM_t - KG$			
$GM_t(m) =$	1.23	1.23	1.23
	(acceptable)	(acceptable)	(acceptable)
MINIMUM STABILITY WHILE DOCKING			
$\Delta GM = \frac{P}{W} KM_t$			
$\Delta GM(m) =$	.93	.56	.30
$GM_{min} = GM_t - \Delta GM$			
$GM_{min}(m) =$	.30	.57	.93
	(low)	(acceptable)	(acceptable)

NOTE: Weight estimates were biased to worst case. Trim and displacement were found to be less than the values above for Condition 3. Probably GM_t and GM_{min} values would have been larger when actually undocked.

APPENDIX K.

'S. T. WARATAH', LIST OF KNOWN MAJOR ALTERATIONS CARRIED OUT UP TO 1968.

'S. T. WARATAH', LIST OF KNOWN MAJOR ALTERATAIONS CARRIED OUT UP TO 1968.

i) The shower was moved from port side over stokehold to its present position (1903).

ii) The Galley was moved from starboard side over the stokehold to its present position (1903).

iii) Removal of forced draft fan and conversion to natural draft (1918).

iv) Replacement of her boiler with another boiler of slightly different dimensions which necessitated a number of modifications. The after bulkhead of the main bunker was moved one frame space further forward as was the front of the main deckhouse. The stokehold deckhead was also modified so that the steering engine could also be moved further forward (1956).

v) The funnel had been extended and then replaced in the 1950's by a welded funnel. This funnel was positioned one frame space forward of its original position to suit the replacement boiler.

vi) The vessel had undergone certain modifications to equip her as a bouy tender. The forward mooring post was removed and replaced with a lifting boom. The original windlass was replaced with a much larger winch and the original wooden mast was replaced with a steel mast and derrick. Scotch strakes were also welded to her plating forward to protect her hull from chafing while handling bouys (1950's).

vii) The main decks were altered. Sections of timber had been removed and replaced by a steel deck. Some of this steel deck had been covered in concrete while the rest had been left bare. The major areas were the deck forward of frame 52 and aft of frame 6.

viii)Extensive alterations to 'Waratah's' boat deck which included the original wooden decked, iron framed deck being replaced by an all steel deck of a different shape, the replacement of the engine-room skylight and the boat deck railings. The wheelhouse had also been replaced by a timber framed, masonite panelled house of a different shape.

ix) The original panelling in both forward and after accommodations had been stripped out, these being replaced by pipe berths.

x) A shelter for a sink and bench had been added outside the main deckhouse on the starboard side, forward.

xi) The access to the boat deck had been altered from a companion on either side of the deckhouse midships to one aft of the deckhouse.

xii) A number of alterations had been carried out to her machinery including the addition of a diesel generator, a deck fire pump, an injector and an ejector. Additional piping had also been fitted throughout the vessel.

xiii) The 'Waratah's' boats, boat dovits and cutting dovits had been removed.

xiv) The bulwarks had been extensively altered by the removal of the original timber rails, the fitting of a topgallant bulwark midships and the addition of a large number of unauthentic bulwark staunchions.