

THE INTRODUCTION OF COPPER SHEATHING
 INTO THE ROYAL NAVY, 1779-1786

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THE most important technical innovation to be implemented by the naval protagonists during the American War of Independence was the sheathing of ships' hulls with copper, and it was the British who developed this technique and held the initiative. During the century as a whole the design of faster and better ships lagged behind the French because of a lack of, and, indeed, a prejudice against a theoretical approach; the only new ideas that were likely to impress the Navy Board were those which were practical and proven, originating from someone with professional experience. The coppering of the fleet illustrated how, once the Navy Board Commissioners had been convinced, it was possible for a new technique to be adopted rapidly. The episode demonstrated, too, the professional attitudes of the civil administration towards untried methods and towards problems of which there was no full understanding. In spite of the mistakes which were made, the speed and eventual success of this undertaking were most impressive achievements.

The effect of the copper was to keep the ships relatively free of weed, and thus improve their sailing performance, while at the same time it afforded better protection for the timbers against the ravages of the worm than the existing sheathing. Of the first of these advantages there is ample evidence, and the development did much to offset the numerical disadvantage of the British fleet in this war. Kempenfelt's much-quoted dictum that twenty-five coppered ships of the line were enough to 'tease' the combined French and Spanish fleet in the Channel in 1779 served to illustrate the inefficiency of the enemy rather than the advantages of the new sheathing, but coppered ships quickly became a factor to be taken into strategic as well as tactical consideration. Individual reports to Lord Sandwich, First Lord of the Admiralty, were never less than enthusiastic. Lord Mulgrave wrote that his ship, 'answered beyond my hopes as her superiority in sailing is hardly credible'. This 'superiority' led to problems unless every ship in a squadron had been coppered; wooden ships were, according to Admiral Thomas Graves, 'unable to act with copper bottoms, for it is very difficult to keep a close line with them and they are unable to keep up upon a pursuit'.¹ In spite of these difficulties, copper proved

its worth in more than one action. Rodney attributed much of his success in capturing six Spanish ships of the line off Gibraltar in 1780 to the copper sheathing of his ships, and de Grasse excused his lack of success in the West Indies against Hood by his relative lack of manoeuvrability.²

The search for a sheathing which would keep the hull of a ship protected from the boring mollusc known as the *teredo navalis*, or more generally as the 'worm', had been continuing for years.³ The sheathing used up to this time was thin plank laid on a coating of tar and hair, but this covering was itself very susceptible to the worm. The importance of finding an efficient alternative increased as the worm was brought home from tropical waters, and lodged in wood and water in the Medway, particularly at Sheerness, and to a lesser extent at Portsmouth. First experiments with copper were made at the end of the Seven Years War, when the frigate *Alarm* was sheathed with the material and was sent on a two-year voyage to the West Indies. Although it was shown to be particularly successful in keeping the hull clean, the problem of corrosion by the galvanic action of the copper on the iron bolts which secured the main frame and the planking seemed insoluble, and this discouraged further developments.⁴

Although desultory experiments continued, little progress was made in the first years of Sandwich's administration; but by 1775 the Navy Board began to show renewed interest. There is no firm evidence to account for this new enthusiasm; a minor factor may have been the inability of the timber contractors to supply enough sheathing board. It is more probable that the arrival of the *Hawke* sloop, coppered, from India after a five-year cruise gave some impetus, for it showed that protection against corrosion was possible. The results were seen by Sandwich himself at Sheerness: those bolt heads which had been covered with lead were 'still sound and whole', although those which were not were 'almost eat in two by the effects of the copper'.⁵ In the next two years a number of small ships were sent off on voyages with copper bottoms with 'compositions' to protect the iron bolts from corrosion, and by the end of 1776 one 32-gun ship, one 24, four 20's and a sloop had been coppered. Methods had been developed which were to form the basis of those which were adopted throughout the war. The *Pegasus* sloop and the *Ariadne* (20), for example, were ordered to be coppered once they had been proved to be 'tight'. The bottom was then painted with a mixture of white lead and linseed oil, on which the copper plates were to be fixed with nails made of an alloy which included copper; this came to be known as 'mixed' or 'compound' metal. The same material was used to make the braces and pintles. The false keel was to be fixed to the main keel with copper staples with a thin sheet of lead between them.⁶

However, the problem of corroded bolts was still not solved, and the Admiralty decided to make an experiment with bolts made primarily with copper, but with a mixture of zinc and iron added. These had been developed by James Keir in uneasy partnership with Matthew Boulton. Several small ships were ordered to have all fittings below the loaded waterline made of copper. The Navy Board had doubts about this measure at the start, for it thought that the relatively soft material would not allow the bolts to be driven home with sufficient firmness; nor, once fitted, would they be strong enough. The Admiralty therefore agreed to limit the use of these bolts to those ships building in the royal yards, and, in spite of further developments and trials, these bolts eventually proved to be unsatisfactory.⁷

The next year, 1778, saw a large number of small ships being coppered, but the administration hesitated before issuing any general orders for applying the process to all ships. No solution to the corrosion of iron bolts had yet appeared, and copper bolts were trusted only for ships of fifth and sixth rates. However, those ships already coppered had been seen in action and had impressed the sea officers; pressure therefore increased on Sandwich to copper more ships. According to Sir Charles Middleton twenty-five years later, it was at this point that he, as Comptroller of the Navy, overcame Sandwich's reluctance to commit himself to coppering ships of the line, and that a visit to the King, with the Comptroller's encouragement, finally persuaded the First Lord to issue orders to copper every ship in the fleet. Middleton's reminiscences were prone to inaccuracy; in fact, in September 1778 the Admiralty asked the Navy Board if it was advisable to copper the ships of the line, and it received a very cautious reply, recommending instead two 50-gun ships, and asking for more time until the copper on the frigates was sufficiently tested.⁸

However, three months later a similar request for advice found the Navy Board with a more confident assessment of the chances of extending the process to ships of the line. The reason for this change of opinion was an apparently successful protection for iron bolts provided by the application of thick paper between the copper plates and the hull, which was to create a watertight barrier between the copper and the iron bolts. This had been tried out on a 44-gun ship (probably the *Jupiter*), and the result made Middleton confident that this method would be the answer to the problem of corrosion.⁹ In May the Admiralty issued a general order to copper all ships below 32 guns, and in July the same was to apply to all ships below 44 guns. At the same time selected line of battleships were to be coppered, the first of which (the *Invincible* (74) and the *Russell* (74)) were ordered in February 1779. From this point, the Navy Board

issued a long series of orders in a constant search for improvement, for the idea of trying to protect the bolts by a barrier was to prove more than difficult to carry out. Whether or not he knew it, Middleton was taking a risk, for he based his advice on experiments which were neither thorough, nor, as events were to prove, did he leave sufficient time for a true result to emerge; as J. R. Harris has noted, 'should anything go wrong with a technical process adopted at this headlong pace, the results could be disastrous'.¹⁰

Nevertheless, the methods evolved by trial and error before and during hostilities prevented the worst effects of corrosion from being felt until after the war. The insides of the copper plates were given three coats of white lead mixed with linseed oil. This mixture, the Board announced with confidence in its first Standing Order on the subject, 'from repeated experiments . . . prevents the verdigrease from gathering and injuring the iron but is of great use in preserving the copper itself'.¹¹ However, a year later the Board gave a contractor named Dawson a monopoly of supplying the yards with his composition, which was held to be more effective. The bottom of the ship was to be 'dubbed as smooth as possible', and painted with tar. Between these two barriers the paper was placed, which itself was dipped in oil of tar and Dawson's composition. The paper was a constant problem, and there were many changes in methods and materials during the war. 'Strong brown paper' was changed for cartridge paper, and again for prepared paper supplied by Dawson; sometimes the hull of the ship was to be completely covered by paper, sometimes there was paper only underneath the edges of the plates, and sometimes there was a combination of these two methods. Once the paper was thoroughly penetrated by the composition, the technique was for it to be applied while still wet, so that it adhered to both the hull and the plates.

Minor problems were solved as the war progressed. It was found that the copper plates by the bow were damaged when the anchor was weighed, and this was partially solved by rounding off the ends of the anchor stocks and substituting thicker plates on the bows. Eventually, all the plates were made thicker, and ships were fitted with 28 and 32 oz. (to the foot square) plates, instead of the thinner plates which the Board had hoped would suffice. Several difficulties were met in providing efficient nails for the copper plates; countersunk nails came to replace nails 'of the common sort' and were found to be 'superior in every way'. Copper on the keels of the larger ships was found to be more easily damaged when heaving them in and out of dock, and eventually the old expedient of 'filling' (or studding) the false keel full of copper nails was found to be a more efficient protection than sheet copper.

There were also administrative problems to be solved with the distribution of materials to the yards, and the Navy Board tackled this with vigour and success. Most of the copper came from the newly-discovered resources in North Wales which were being exploited by Thomas Williams. The Board used only one contractor, William Forbes, who was the London agent for Williams. Stocks were gradually built up, and the establishment for each yard was eventually set in May 1780 at forty tons of copper plate, thirty of which were to be lacquered with white lead.¹² The supply of paper from London was soon found to be inadequate reaching Portsmouth in a damp and rotted condition, and a local manufacturer was found who supplied a cheaper and better product. Regulations for the disposal of old copper and the accounts and returns were well organized. There were shortages in early 1780, when the decision to go ahead without restraint was having its effect, and inadequate supplies, especially at Portsmouth, led to delays. However, by the end of the year these difficulties were at an end.

The supply and manufacture of the braces and pintles, made of mixed metal by William Forbes at Deptford, continued to be a problem. Since it was impossible to standardize the exact shape of each ship's hull, a mould of each brace and pintle had to be made at the yard, which was then sent to Deptford. This task presented considerable technical difficulties, and Forbes complained of bad workmanship. A particular difficulty was that the moulds had to be made slightly smaller to allow for 'moulding in sand', which left the metal slightly larger than the moulds. The yard then hoped to have the manufactured pieces back before the ship was out of dock. Delays were perhaps inevitable, especially at Plymouth, but there were remarkably few, possibly because the pieces were transported by land, which was very expensive, but quicker and more reliable.

By the end of Sandwich's administration, satisfaction with copper and the method of sheathing was universal. The effort had been prodigious, and the First Lord mentioned the coppering of the fleet as being one of his great achievements in the defence of his administration in January 1782. Eighty-two capital ships, fourteen of 50 guns, 115 frigates and 102 sloops and cutters had been coppered to that time. In 1780 alone no less than forty-six ships of the line had been fitted with the new sheathing.¹³ The early optimism of the Comptroller had not yet been disappointed. Although his claim that coppering the fleet would more than double their effective numbers was subject to his usual exaggeration,¹⁴ there had been a real increase in efficiency at sea. More important, it lightened the burden of refitting on the yards. Not long before he left office, Sandwich wrote to Hood saying, 'Copper bottoms need fear nothing'.¹⁵

However, at the end of 1782, doubts about the effectiveness of the protection of iron bolts from the corrosive effects of the copper were raised very forcibly. The chief reason was the violent storm of September 1782 off the Banks of Newfoundland, when the captured French ships, the *Ville de Paris* (110) and the *Glorieux* (74), and the British *Ramillies* (74) and *Centaur* (74) all foundered with the loss of over 3,500 lives.¹⁶ It was thought that the chief cause of the tragedy was corroded bolts. In addition, confidence had been shaken by reports from the West Indies that the copper's effectiveness against the worm was not all that had been claimed for it. The Admiralty was undoubtedly thinking of abandoning copper altogether, and was more than irritated when it found that the Navy Board had ordered the ships to be laid up in Ordinary at the end of the war with copper on their bottoms.

The reaction of the Navy Board to the questioning of its methods was obstinate and high-handed, and it obviously regarded any doubts as a slight upon its professional competence. In a strongly-worded letter of 5 March 1783 the Commissioners dismissed any suggestion that the methods used to protect the bolts were anything less than satisfactory. The coppering of the fleet was, 'self-evident certainty of its security', and, they continued: 'The effects of lacquered copper on prepared paper has been so well ascertained, and its superiority and security beyond any other kind of sheathing', although they added, lamely, that if there was any evidence of corroded bolts, then the bolts were corroded before the copper was put on. They defended their failure to consult the senior board about putting the ships in Ordinary on Copper as being not worthy of discussion, and the only measure of doubt that they allowed was that they considered that, if possible, coppered ships should be inspected before they went off on long voyages, 'not that we apprehend any danger from omitting it'.¹⁷ Yet the evidence that they presented was unimpressive, for although they claimed that all reports from the yards on the sheathing had come to them, and had been 'fully digested', it is clear that the reports throughout the war had not been concerned with copper bolts, but only with the external appearance of the copper. A report on the *Unicorn* (20) of October 1779 seems to have been the last to mention corroded bolts. Subsequent reports mentioned only weed and the braces and pintles.

The professional board was, however, forced to make an investigation, and reports and opinions collected over the next few months were damning. A week after the letter of 5 March the Board forwarded the opinions of the Resident Commissioners on whether it would be safe to send ships to sea which had been coppered for some time. Their views were expressed by Commissioner Martin of Portsmouth: 'I still conceive that we are not

sufficiently acquainted with the effects of coppering to run the hazard of the greater part of our line of battleships being materially injured by it.' The Board had no patience with such hesitation, and told the Admiralty, that, 'on their opinion we lay no great stress'.¹⁸ In the next few months, however, the Board was forced to change its tune, and a thorough inspection of the *Edgar* (74), *Fortitude* (74), and *Alexander* (74), witnessed by some of the Commissioners themselves, showed irrefutably that the iron bolts of all three ships were in a dangerous condition. By July the Board asked the Admiralty whether it would be best to stop coppering all ships except those which were ordered on service, at least until the detailed reports which had been ordered from the dockyard officers had been prepared and digested, to which the Admiralty agreed.¹⁹

Although the Navy Board did not present their full report to the Admiralty until November, it must have been convinced of the dangers in August, for it wrote in an order to the yards that, 'there is no possibility of guarding the iron against the influence of the salt water'. Nevertheless, the Commissioners were convinced to the last that any corrosion which was the result of water penetrating the copper and paper was due to bad workmanship, and that a fundamental improvement in technique was not needed. Apart from the fact that the protection was very fragile, and the copper sheathing was easily torn off, this assumption was partially correct, for the effectiveness of the protection varied from ship to ship. Laforey, for instance, wrote to Middleton in 1781 from Antigua informing him that the *Russell* (74), one of the first ships of the line to be covered, had had none of her iron work injured by the sheathing.²⁰ Yet the fleet had to be coppered quickly; the result of this was that the quality of workmanship tended to be sacrificed to speed. Protection would be complete, reported the Deptford officers in 1783, if the,

bolts be well drawn and well driven, and their heads when spread in driving, trimmed with a cold chisel, and driven a quarter inch within the surface of the plank, and that be filled up with paste, and covered with tarred canvas, before the bottom is payed with composition; and if the coppered sheets be well lacquered, and time be given to harden the lacquer, and the bottom well payed with composition, no bad effect can arise from the copper. ²¹

This was intricate and time-consuming work, and the yards were under heavy pressure to get ships out of dock. Too many things were dependent upon time and upon adequate supervision. One particular pitfall was that the holes punched in the copper plates for the nails could come directly over the head of a bolt, and easily let the water in. There were difficulties in lacquering the copper sheets in sufficient time before the lacquer hardened, while the expectations of the Board in the adhesive qualities of the composition in which the paper was soaked were disappointed. Perhaps

most important of all, there was the difficulty of ensuring that the caulking behind the copper plates was of the highest order, for the maintenance of the timber and caulking behind copper sheathing was rendered more difficult.

The other major weakness was the lack of protection which the copper provided against the worm. The Master Shipwright at Jamaica wrote in early 1782 that, 'great injury' had been done by the worm to the *Sandwich* (90), and in the next year he reported that most of the fleet under Hood, and several of Rowley's division, would, 'not be able to stay here longer than six months before they prove leaky'.²² Hood reported to Middleton at the same time that the *Barfleur* (80) had had her stern post and rudder eaten by the worm, 'in a manner not to be conceived . . . I dread what may happen to many of the king's ships, if we have not peace to occasion their being called home to have their bottoms inspected'.²³ The worm had penetrated where the copper sheathing had been torn away, but the most constant weakness was that the yards had not been specifically ordered to put copper and paper behind the braces and pintles. This again was a difficult and time-consuming task, and, in spite of the earlier warnings, the order remedying this weakness was not issued to the yards until May 1783 – too late to be of any use during the war. The lesson was not appreciated in time; copper sheathing, like the links of a chain, had to be completely effective to be effective at all.

In spite of these difficulties, the Navy Board found strong support from the yard officers in the report of November 1783 for the retention of copper, and any idea that the Admiralty may have entertained for keeping the ships in Ordinary without sheathing at all was considered highly impractical. 'In three years at this port', wrote the Sheerness officers in their report, 'the worm would make a single bottom unfit to receive copper on an emergency'. Fortunately, the disquiet over the copper had stimulated the development of a new type of bolt. Keir's compound metal bolt, which had been under development since 1779, was finally rejected in December 1783 in favour of a copper and zinc bolt hardened by mechanical means. This bolt had been developed independently by William Forbes, and also by two men, Westwood and Collins, under the direction of Thomas Williams. It was made by a process which had been developed in the iron industry in which iron bars were drawn through grooved rollers.²⁴ This method finally provided a satisfactory bolt, and the officers replied in the affirmative to the Board's question, 'whether in order to remove every objection that can arise from ignorance or prejudice against copper sheathing . . . it may not be the most prudent and economical in the end to use compound metal bolts'.

The report of November 1783 effectively stopped any controversy between the two boards, and a further survey in 1786 on the *Goliath* (74) and *Crown* (74) confirmed that even on recently coppered ships iron bolts had corroded dangerously.²⁵ The final order to change all ships to the new bolts came in August 1786 when the Admiralty ordered all guardships to be copper fastened, 'as fast as the docks can be spared'. However, the public debate still continued. In the Commons, Captain MacBride directed a question at Middleton, asking,

if it was intended to persevere in the absurd system of suffering the ships to remain in their coppered bottoms during the whole of the peace? . . . The consequence would be, that the instant ships which had long lain by were sent to sea, their bottoms would drop out, and thousands of brave seamen would perish in the ocean.²⁶

This history of the introduction of copper sheathing illustrates the strengths and weaknesses of the civil administration of the navy during this period. Once the innovation had been accepted, vigorous measures saw that difficult administrative problems were solved. Here, Middleton's role cannot be sufficiently emphasized. At the same time, technical reports on corrosion were neglected once the measure had been adopted. Prolific resources, which the French were unable to match, enabled the supplies of copper to the yards to be built up quickly. The coppering of the fleet was a formidable achievement, and, although the copper of some ships of the line had to be repaired during the war, less maintenance was needed and consequently the burden of the dockyards was lightened. Yet it must be said that the measure was hastily and overconfidently adopted, and that the time and development devoted to the measure was as inadequate as the obstinacy of the Navy Board after the war. The attitudes of the seventeenth century, as observed by John Ehrman, were still maintained: 'this type of scientific investigation was more often the extension of traditional practice to theory than the application of theory to practice, and often significant of the development of organization around a problem rather than of an attack upon the problem itself'.²⁷ It needed an energetic capitalist, who foresaw a large market for his product disappearing, to provide a bolt which was as hard as iron yet free from corrosion.

It was largely due to Middleton's obstinacy that the Navy Board's innovation of 1779 became the orthodoxy of 1783. While the Board accepted that the braces and pintles and the nails securing the copper needed to be made of an alloy, it was reluctant to accept that costly bolts of the same material would be needed. It was not until a satisfactory process and material were developed that ships were sufficiently safe; MacBride's fears might well have been realized had the fleet remained with iron bolts protected only by paper. 'England's technological victory'²⁸

may have had its effect at sea during the war, but the real technological victory was not won until after the war had been fought. Moreover, the phrase 'copper-bottomed' may have taken on a very different meaning.

REFERENCES

- 1 Naval Record Society, *The Private Papers of John, Earl of Sandwich*, (ed.) G. R. Barnes and J. H. Owen (1932-38), III, 34, 2 July 1779; IV, 174, 4 July 1781. See also other letters, IV, 49, 17 August 1781, Darby; IV, 57, 3 September 1781, Mulgrave; IV, 82, 13 January 1782, Kempenfelt; also N.R.S., *Letters and Papers of Charles, Lord Barham*, (ed.) J. K. Laughton (1907-11), I, 62-3, 24 June 1780, Young to Middleton.
- 2 See Piers Mackesy, *The War for America* (London, 1964), p. 322. N.R.S., *Sandwich Papers*, IV, 286.
- 3 See John Ehrman, *The Navy in the War of William III*, (Cambridge, 1953), p. 17; J. R. Harris, 'Copper and Shipping in the Eighteenth Century', *Economic History Review*, XIX, 1966, pp. 551-2; Maurer Maurer, 'Copper Bottoms for the Royal Navy', *Military Affairs*, XIV, 1950, pp. 57-61; G. Rees, 'Copper Sheathing, An Example of Technological Diffusion in the English Merchant Fleet', *Journal of Transport History*, I, 1971, pp. 85-6.
- 4 See the memorial from Captain Brereton to Pitt (Public Record Office, 30/8/116, fos. 114-16 undated) claiming that it was he who originally thought of the idea. One or two ships were coppered in the 1760s; see National Maritime Museum, ADM B/174, Navy Board Letters to the Admiralty, 6, 8 March 1764; B/178, 3 October 1766; B/181, 15, 29 July 1768. Also A. L. Cross, 'On Coppering Ships' Bottoms', *American Historical Review*, 1927-28, pp. 79-81.
- 5 P.R.O., ADM 7/662, fos. 21-2 Minutes of Sandwich's Visitation of 1775.
- 6 P.R.O., ADM 95/95, Navy Board warrants to the Yards, 10 December 1776. Braces and pintles were the hinges by which the rudder was fixed to the hull; they were first made of the mixed metal in June 1776.
- 7 N.M.M., ADM A/2711, Admiralty Orders to the Navy Board, 8 January 1777; ADM B/193, 11, 16 January 1777. See Harris, p. 556, for details of Keir's bolts.
- 8 N.R.S., *Barham Papers*, III, 16, April 1803; 29, May 1804; N.M.M., ADM A/2731, 19 September 1778; ADM B/197, 29 September 1778.
- 9 N.M.M., ADM A/2735, 16 January 1779; B/197, 27 January; B/198, 23 February 1779. The use of tarred paper was not new, for it had been used under wooden sheathing for some time; but, according to Middleton, its use in connection with coppering had been suggested to the Board by Roger Fisher, a Liverpool shipbuilder and naval contractor. It is interesting to note that nearly 150 merchant ships were coppered between 1777 and 1780, many from Liverpool; see Rees, p. 86.
- 10 Harris, p. 554. Between 1779 and 1783 the Board issued eighty-two standing orders to the dockyards directly concerned with copper sheathing.
- 11 Most of the following technical discussion of coppering is based upon the Standing Orders (P.R.O., ADM 106/2508).
- 12 By 1815 the *Victory* needed 3,640 plates weighing over eleven tons; see Burney's *New Universal Dictionary of the Marine* ... (London, 1815), p. 452. For additional figures of the quantities involved see Commissioner Martin's notebook (British Museum, Add. MSS.41363, fo. 37).
- 13 P.R.O., Abstract of Progresses, vol. 5, part 1.
- 14 N.R.S., *Sandwich Papers*, III, 175, undated, Middleton to Sandwich.
- 15 *ibid*, IV, 201, 9 November 1781.
- 16 See Harris, p. 554; also K. Breen, 'The Foundering of H.M.S. *Ramillies*', *The Mariner's Mirror*, 56, 1970, p. 192.

17 N.M.M., ADM BP/4, 4 February, 5 March 1783. The Board's reaction to a suggestion for improvement by Samuel Bentham in 1781 was similar; the sheathing was, 'so secure and superior to that proposed by him that we cannot advise any alteration' (P.R.O., ADM 106/2209, 28 April 1781).

18. N.M.M., ADM BP/4, 11 March 1783.

19 N.M.M., POR/D/23, Portsmouth Yard Officers' Reports, 14 April 1783; P.R.O., ADM 174/19, Plymouth Commissioner's Letters to the Navy Board, 1 May 1783; N.M.M., ADM A/2789, 3 July 1783.

20 N.R.S., *Barham Papers*, II, 126, 28 November 1781.

21 N.M.M., ADM BP/4, 5 November 1783.

22 P.R.O., ADM 106/3472, Deptford Yard letter book, 5 April 1782.

23 N.R.S., *Barham Papers*, I, 253-54, 28 February 1783.

24 For a full explanation see Harris, pp. 555-560. The extra cost of the bolts was considerable. The Board estimated that they would cost £2,272 10s for a 100-gun ship, and £1,559 for a 74, more than iron bolts. Martin noted later that the *Canada* (74) used 17 tons at £135 a ton, which came to £2,295 (N.M.M., ADM BP/4, 5 November 1783; B.M., Add. MSS 41363, fo. 40).

25 N.M.M., ADM BP/6b, 13 July 1786. Of the sixty-three iron bolts sampled from the *Crown* (64, built at Blackwall in 1782), thirty-nine were only a little corroded, but twenty-four were, 'much corroded at the head', and 'many drove slack'.

26 *Parliamentary Register*, XIX, 1786, pp. 250-251. MacBride had long held ideas on sheathing; see P.R.O., ADM 95/95, 1 March 1779. Well-informed criticism of coppering continued until 1786; see, *Strictures upon Naval Departments, with a recommendation to abolish the Coppering of the Ships in the State of Ordinary*, by a sailor (London, 1785). Rees (p. 87) notes that it was not until this year that there was a 'steady extension' of the technique in the merchant fleet.

27 Ehrman, p. 17.

28 Mackesy, p. 285.