REINFORCING THE CAISSON

Evolution of Ships:

Development of Bombay Dockyard

'Naval architectue is an Egyptian art athe main lines of the history of shipbuilding for the whole world were laid down in Egypt toward the end of the 4th millennium B.C.', averred Elliot Smith in 1917 in his *Ships as Evidence.* His claim was buttressed by the fact that the earliest knowledge of boats, small craft and ships came from Egypt where, as farbackas 4,000 B.C., boats and other small craft were already far advanced from the primitive form which they had in all probability been derived - rafts in the form of bundles of reeds tied together with ropes made of hemp or other natural fibres and steered by oars or punt-poles.

For a few millennia rafts were used in all parts of the globe and as seagoing craft in modern or comparatively recent times they arebestknown in the form of the catamarans (Kattumaram, tied wood, in Tamil) of India and balsas *(balsa* is Spanish for the word 'raft') of South America. Wishing to test the theory with regard to the populating of Oceania millennia ago, i party of Norwegian scientists led by Thor Heyerdahl built a raft simitar to the ones used in South America in the ancient days and sailed from Peru to the islands east of Tatiti a little over three decades ago in a voyage lasting over three and a half months known as the Kon-Tiki expedition. The other vehicles on which man conveyed himself and his goods by water and some of which were still in use were dug-outs or hollowed tree trunks, canoes of bark and skin with an internal framework, canoes and boats formed from planks stitched together, vessels with planking nailed together and with a framework inserted and vessels built by attaching planks to a prefabricated framework.

The ships and galleys built by the Greeks, however, laid the foundation for the evolution of large ships for high-sea na viga tion and bluewater operations for Greek vessels were built using a technology entirely different from that of Egypt, having keel, stem, sternpost and internal framing with the planks attached edge to edge or overlapping downwards respec tively, similar to the carvel and clinker building techniques of modem times.

Very little is known today of the ships of the Cretans who dominated sea power in the eastern Mediterranean about 1500 B.C. or of the Phoenicians who took their place but it is known that both nations had begun to differentiate between the fighting vessel and the merchantman and between the rowing galley and the sailing ship, the more striking developments being the arrangement of oars in two banks at different levels and the fitting of a ram bow in galleys intended for use in war for ramming and damaging enemy ships, though some believe that the ram was an Egyptian invention.

At the time of the siege of Troy the galley, an oar-propelled fighting vessel, was generally a 50-oar boat with a single row of 25 oars on each side. Since the length of the galley could not be increased because of the strains of 'sagging' caused to the hull, some other method of generating greater propulsive power had to be found and this was done by arranging the oars in two staggered rows in galleys appropriately called biremes (bi - two, *remes-oat,* 700 B.C).Thenumberof rows of oars was later further increased in triremes which had as many as three rows of oars and the many-banked galleys (500 B.C.).

Well before the beginning of the Christian era the sail had appeared on the scene, initially being suspended from the mainmast rigged for the purpose and soon evolving into its multisail configuration. The steering gear, consisting of a large paddle-shaped rudder to begin with, was inherited fromEgypt and was initially fitted on the ship's side, then moved to the starboard quarter and finally to the stern.

The invention of gunpowder during the 14th century brought about further changes in ship design and soon after the middle of the century there begana process which caused the sailing man-of-war to become more and more distinct from the merchantman.

Over the centuries the number of masts and consequently the number of sails increased and by the end of the 15th century the largest ship had as many as four masts and eight sails. The 16th century saw the appearance of the caravel, a small lateen-rigged vessel with three masts, equipped with a battering ram, a wide transom on which the aftercastle was based and **the** planking was so attached to the hull frame as to give a flat finish to **the** surface (caravel-building). Then came the galleon with a much longer **hull** with the ram lengthened to a long beak and a square-ended forecastle in place of the tringular forecastle of the earlier type. The frigate soon followed as a small member of the galley family as a small fast vessel with the length further increased and with the top hamper - necessary but cumbersome equipment on board - considerably reduced.

By the second half of the 17th century it had been realised that ships armed solely on the broadside should fight in line-ahead formation in a prearranged order and that was the origin of the term 'ship of the line' or 'line-of-battle ship', the latter being later abbreviated to 'battle-ship'.

It was at the beginning of the 18th century that the steering wheel made its appearance and brought about an extremely important change. From the middle of the 16th century to the end of the 17th, the tiller which operated the ship's rudder had been worked by the 'whipstaff, a vertical lever passing through a pivot in the deck to move the tiller laterally, and thus was a device that was far less efficient than the wheel, first introduced in 1705, with its ropes leading to the end of the tiller.

By the middle of the 18th century the number of guns fitted on board started rising rapidly. The frigates built during 1750s and 1760s had 28,32 or 36 guns, but the number soon grew to 56 and more until the *Victory,* built in 1765, bristled with 100 guns.

The 19th century saw the introduction of the clipper, a ship with an increased length and raking bow and masts, which was capable of greater speeds and was largely employed in transoceanic trade. The American clipper *Lightning* of 1854 is believed to have made the best day's run ever recorded by a sailing ship, 436 miles, but the two ships that consistently made the fastest passages across the Atlantic in all conditions were the two British tea clippers, the *Thermopylae* and *Cutty Sark* of 1868.

This period saw the beginning of the use of iron to strengthen the keel and the mainframe which obviated the 'sagging' of heavily-loade d long mainframes and enabled the yards to build larger ships leading to the use of wooden planking on iron frames. Another significant change was the replacement of hemp with wire for standard rigging.

Paddle steamers had made their first appearance in the British fleet in 1822 and with the adoption of the crew-propeller in the 1840s, it became possible to combine steam propulsion with the complete broadside arma-ment of the sailing ships. By 1850 construction of purely sailing ships had been discontinued and all ships began to be equipped with steam propulsion to supplement or alternate propulsion by sail. Masts and sails were etained for a long time but gradually the two systems of propulsion exchanged roles and the man-of-war, instead of being a sailing ship with an auxiliary engine, becamea steamship withauxiliary sail. The opening of the Suez Canal in 1869 also dealt a heavy blow to sailing ships since, besides shortening the route to the East, the Canal reduced the distance between coaling stations and so allowed the steamers to reduce the size of their coal-holds and thus increase their cargo capacity.

'Composite' construction, i.e., the combined use of wood and iron soon made way for all iron and then steel construction and screw-propellers began replacing paddle-wheels around the globe. In 1853 the Peninsular and Oriental (P&O) Line built the iron-hull screw steamer *Himalaya,* the biggest vessel of her type in the world at that time, with a gross tonnage of 3,438, dimensions of 340 feet in length, 46.2 feet in width and 34.9 feet in depth of hold and her engine capable of giving her a sustained speed of 13.9 knots. The first twin-screw steamer, the 400-ton *Flora,* was built on the Thames in 1862.

Turbine engines,as opposed to steamenginesusingreciprocatingma-chinery,runby the impact of high-pressure steam on wheels,as invented by Sir Charles Parsons, were used at sea for the first time when an experimental ship, *Turbinia,* was fitted with turbine engines with a shaft horse power of 2,000 in 1894. It was interesting to note that during a review of the Royal Naval Fleet at Cowes in the same year the ship caused a great sensation by dashing out among the assembled ships at what was then the astounding speed of 34.5 knots.

In 1903 the first ship to be built w ith an internal combustion engine which exploded a charge with a hot incandescent bulb or an electric spark, the Caspian steamer *Wartdal,* was completed. The engine dro /e a generator which in turn ran a motor coupled to the screw-propeller. Ru dcf Diesel had taken out a patent in 1892 for an engine in which the charge was exploded by raising its temperature by sudden compression and thus was born the diesel engine. One of the earliest ships to be fitted with diesel engines was the motor ships *Selandia* whic h was completed in 1911 and ran until 1942. Diesel-electric propulsion wherein the screw-propeller is driven by a motor energised by a generator which in turn is driven by a bank of diesel engines was soon accepted as the most effective mode of propulsion ships. The German navy was one of the first to adopt it in a submarine salvage vessel *Vulcan* in 1907.

The development of ships from the earlier decades of this century to the end of the 1980s, graduation into nuclear and other modes of propulsion, evolution of various types of surface vessels, submarines, surface-effect ships, hydrofoil ships, etc., are of too recent vintage to merit repetition here.

Ships of the Indian Peninsula

As ragards the Indian peninsula, ships are known to have been built in this subcontinent ever since the dawn of civilisation over five millennia ago. The earliest evidence of the existence of ships and boats is a rectangular seal unearthed at Mohenjodaro in the Indus Valley dating back to at least 3,000 B.C. The sharply upturned prow and stern of the vessel portrayed on the seal are distinctive features also found in the representations of boats peculiar to other ancient civilisations such as the early Minoan seals, the pre-dynastic pottery of Egypt and the cylinder seals of Sumer which directly suggest the existence of intimate maritime intercourse between the Indus Valley and these countries at that time.

While Mohenjodaro had developed on a site on the right bank of the Indus, some 250 miles from its mouth, its twin city, Harappa,had come into being at a site on the left bank of the Ravi, now in Pakistan. Around 2,000 B.C. i.e., about a millennium after the advent of the high-prow vessels, some Harappans sailed in ships and boats down the Indus to the sea and then coasted south to Kathiawar to settle down there and widen the extent of Harappan culture. During this period Kachchh was an island as the Rann surroundingit was deeper and still navigable. A dry-dock pertaining to this period and measuring 710 feet in length, 124 and 116feet in width at the two ends and 11 feet in depth built around 2,350 B.C. has recently been excavated at Lothal in Gujarat. The dock is equipped with a gate and appears to have been used as a wet basin and a boa t pen. The dock also had provision for regulating the inflow and outflow of water at high and low tides by using suitably designed spill channels and for refloating ships by using sliding gates and an arrangement for operating watertight caissons.

It was during the Vedic period from 2,000 B.C. to 600 B.C. that references were made in contemporary literature to the description of boats and ships, construction of river craft and seagoing vessels, nautical terms and ocean voyages. The remarkable work of Kautilya, the *Arthashastra,* which was compiled during the period from 321 B.C. to 300 B.C. refers to the existence of a naval department run by a *Navadhyakska* (superintendent of ships), navigation of the lakes, rivers and oceans, providing shelter to tempest-tossed ships in harbours and construction and repairs to ships in Maurya India. During the pre-Mauryan era, as recorded in Pali literature, especially the Rajavalliya, there was considerable maritimeactivity such as the banishment of Prince Vijaya of

Bengal by king Simhavahu to Simhala (Sri Lanka) and his voyage with his 700 followers on board his flagship. Another document of this period, the *Mahawanso,* describes the 12-day passage of Vijaya's bride in a very large ship carrying 18 officers of state, *75* menials, a number of slaves and 700 other women. The *Jatakas* have descriptions of Indian-built ships and ocean voyages. It is also recorded that during Alexander the Great's invasion of India in the 4th century B.C., boats and ships - some of them 30-oared - were built for his navy in Punjab.

Towards the end of the Gupta era in the 5th century A.D., ship -building techniques had reached a high level of sophistication which has been documented in detail by King Bhoja Narapati in his *Yukti Kalpataru.* According to another contemporary document, *Vriksha-Ayurveda,* our ancient shipbuilders had acquired thorough knowledge of shipbuilding ma terials and the properties and types of timber used for building ships; for instance, soft and light timber which would be joined to any other type was knownastheBrahminc!ass,lightand hard timber which couldnotbejoined to the other types was the Kshatriya class, soft and heavy timber was the Vaishya class and the hard and heavy timber was the Shudra class. The mixed class with a blend of these properties was known as the Dwija ti class. Bhoja's treatise also warns shipbuilders against the use of iron as it would expose ships to the influenceof submarine magnetic rocks. Instead it recom mends securing the ships' planks to each other with ropes which provided the necessary resilience to the buffeting caused by rough seas, caulking, i.e., stuffing the joints with oakum to render them waterproof, applying a paste of quicklime and oil on the planks to protect them from seawater and double-planking to improve the buoyancy and safety of the hull. Besides, the *Yukti Kalpataru* mentions ships and boats of various types with single, double, triple or quadruple masts, multiple sails, oars and rudders with the superstructure on the prows, *Agramandira,* or in the middle, *Madhyaman-dira,* or covering the entire deck, *Sarvamandira.*

Evidence from our ancient literature indicates the fact that by about 200 B.C. the size of ships built in India had increased considerably, a number of bulkheads were used to strengthen the hull which was built with Malabar teak which had proved itself as far superior to oak seaworthiness, impermeability to water and resistance to ma rine organisms. The discovery of the 'trade winds' or the monsoon air current blowing across the Indian Ocean by Hippalus in 45 A.D. ushered in the era of sailing ships and signified the gradual obsolescence of the multi-oared galleys though the oars were retained for use in no or low wind conditions and for manoeuvring the ships inside harbours. The earliest sails seen in our waters were lateen or triangu lar sails on long yards at an angle of 45 degree to the mast and were made of thick cloth or light canvas. These were later replaced by square and rectangular sails, the ships carrying a large number of these sails in square-rig configuration and were built with more than one deck.

A very large number of travellers and writers who have adorned history's hall of fame such as Herodotus of the pre-Mauryan era (5th century B.C.), Megasthenes and Strabo of the Mauryan era (321-184 *B.C.),*Pliny *(77* A.D.), Ptolemy (140 A.D.), Fa-Hien (415 A.D.), Hiuen-Tsang (646 A.D.), Marco Polo (1208 A.D.), Ibn Batutah (1377 A.D.), Abdur Razzaq (1442 A.D.), Nicolo Conti (1444 A.D.), Varthema (1503-1508 A.D.) and Thomas Bowrey (1670 A.D.), have corroborated the available evidence of these ships being able to sail virtually as fast as the wind and their ability to ride the sea well and to withstand heavy seas during cyclones.

These ships displayed the motifs of their owners or monarchs on the sides of their sterns or on the transoms, theirhigh prows and sterns enabling them to carry their anchors well clear of the water-line, ensuring better visibility and preventing shipping of sea water in rough weather. Ships of this type were built all over the peninsula, especially at Kozhikode, Cochin, Kaveripattinam,Masulipatnam, Calcutta and other major inland ports and intrepots and were in use during the reign of the Mauryas, Andhras, Pallavas, Chalukyas, Kalingas, Palas, Cholas, Cheras and the Pandyas. These ships were larger than contemporary European vessels but not as largeas ships built in the FarEast as they wererequired to be used for trading purposes with ports in the Persian gulf and the Red Sea and had to often pick up their merchandise from India's minor ports and estuaries.

Considerable improvement took place during this period in ship design and lay-out and techniques of seamanship and navigation. Directional control, originally achieved with steering oars, was made more effective withside rudders and helms secured to the transom operated with the help of adequately sized tillers. Multitiered wooden planks fitted athwartship improved the hull's transverse strength and provided additional decks and compartments foraccommodation and stowage of merchandise. Improved technology was developed for preventing leakage and damage to the hull structure.

In the 11th century, the advent of the Muslim period, whichheld sway for nearly 700 years, saw the gradual supersession of the sailing vessels of the earlier centuries. The Arabs set up shipbuilding yards on the Indian coast and the yards at Surat; on the Malabar coast and the Maldive Island and earned considerable recognition for the high quality of vessels built by them. The Mughals had fleets of ships for their Imperial *Nowwara* (flotilla) and merchant fleet built at Dhaka, Hooghly, Balasore, Jessore, Lahore, Srinagar and many other sea and river ports.

Thearrival of the Portuguese in 1498 usheredintheera of gunships and fireships leading to some changes in ship design. The Zamorin of Kozhikode was the first to effectively emulate the Portuguese example and soon some of thenative rulers followed suit.The Portuguess built ships at Goa,Bassein and Damanand the local shipbuilders, who fabricated teak ships with bolts and nails and not ropes as was the practice earlier, adopted some of the better features of Portuguese shipbuilding technology. The Malabar coast had spawned a wide variety of ships of various sizes and shapes for centuries and a contemporary of the Portuguese-type ships was the *Batil* which was equipped with two masts with its hull being 50 to 60 feet long, 16 to 18 feet wide and 8 to 10 feet deep. The Portuguese built several ships at Goa and Daman using local technicians and artisans using indigenous ma terial but adopting a combina tion of the best fea tures of Indian, Arab and Portuguese shipbuilding technology. Tn many ways these ships resembled the *San Gabriel,* Vasco da Gama's flagship, which had brought him to Kozhikode from Mozambique in Africa.

There is also enough evidence to establish the fact that the technology of building ships especially designed for war at sea existed in this peninsula from well before the advent of the Europeans and that some of these ships were equipped with catapults and incendiary throwers. As far back as 1377 A.D. the ruler of Honavar on the Konkan coast carried out a massive naval operation by attacking a small port in Goa with a fleet of 52 war vessels.

A notable feature of this assault was the use of two landing era ft, probably the first time in India's maritime and naval history, which beached themselves on their sterns and as the stern doors were opened, cavalry soldiers charged forward on horseback to launch a blistering attack on the port's defences in support of the infantry which had already jumped ashore and gone into action.

Another type of ship with long endurance was the *BaghaJah* which roamed the seas around India, especially the Arabian Sea, from before the invasion of India by Alexander the Grea t to the end of the 19th century - one of the oldest and most successful ship designs that existed for over two millennia. These ships had a broad beam of about 25 feet, a length of 74 feet, **a** depth of 11.5 feet, drew about 150 tons and had a long life. One of the *Baghalah-type* ships, the *Daria Daulat,* was built by the British at Bombay in 1750 with two guns mounted on her stern and was in commission till 1837 - a period of 87 years!

The 17th century saw the revival of shipbuilding in the Maratha ship building yards at Vijaynagar, Suvarnadurg and Kolaba and a large number of two highly seaworthy and versatile classes of vessels, the *Ghurab* and the *Gallivat,* were built. These vessels were seaworthy, sturdy and versatile in their operational abilities and hence were also used by the Mughals for battles against the Marathas and the British.

Soon after the arrival of the British squadron of ships at Surat on September 5,1612, several British factors arrived there and set up factories and **a** shipyard for repairing and building ships for the British, Moghuls and Sidis. The first British ship to be 'careened' (turned to its side for cleaning, caulking and repairs) at Surat was the *Primrose.* As stated in a letter written to the Surat Council in 1626, the ships had to be sheathed by 'country carpenters, she being only a new ship only spoiled with the worme, soe that to make her fitt for any service she must be new plancked from the keels upwards (sic)/

Several ships, especially brigantines, were thereafter built and repaired at Surat for well over a hundred years. These ships were known for their durability, strength, seaworthiness and their imperviousness to sea-water-borne worms that attack timber and bore holes in it. The shipbuilders at Sura t mainly comprised Pa rsis who proved to be not only capable ship designers, builders and gunsmiths but excellent shipwrights as well.

Because of its strategic position, considerably wide range of tides, proximity to a large anchorage na turally protected from the sea and an ade quate number of landing places and shore sites for the repair, construction and launching of ships and craft and construction of cranes for handling stores and equipment, safety of egress and ingress into theanchorage by day and night and suitability for defence against sea-borne attacks, the advantage of building a dockyard at Bombay Island with the attendant benefits of a fine natural harbour, were soon recognised by the British.

Development of Maintenance Facilities, Expansion and Modernisation of Naval Dockyard Bombay

A skele tal dockyard was initially set up at Bombay in 1693-94 but was equipped with minimal facilities followed in 1735 with the construction of marine storehouses, quarters, officers, carpenter's sheds and a smithy. In 1736 the first of the famous line of Wadia master-builders to come to Bombay fromSurat, a youngParsi foremancarpenter named LowjiNusser-wanji, was brought to Bombay with his team of ten skilled carpenters, five of them from his own family, and a number of technicians and was entrusted with the modernisation of the existing dockyard.

Around the turn of the 17th/18th century the shipbuilding industry ir England was faced with an acute shortage of oak timber as the oak forests in South England had been severely depleted by the extensive felling of oak trees formaintainingtheimpregnability of the English Fleet by constructing more and more warships of all sizes. And hence, despite bitter opposition from British shipbuilders and workmen, it was decided to develop the existing facilities at Bombay into a fully equipped dockyard for the construction as well as refitting of ships and craft using local technicians and workmen and the indigenous Malabar teak which by this time had proved itself as excellent shipbuilding timber.

The first major dry-dock for the Bombay Dockyard was the Upper Old Bombay Dock - 209 feet long, *47* feet broad and 15 feet deep. This Dock was built in 1750 at a cost of Rs 12,000 followed soon by the Middle Old Bombay Dock -183 feet long, 51 feet broad and 20 feet deep - completed in 1762. A third dry-dock, the Lower Old Bombay Dock - 256 feet long, 51 feet broad and 20 feet deep -was completed in 1765. These docks proved to be a highly valuable acquisition to the Dockyard and attracted shipping from various parts of the continent to seek repairs. For docking purposes Bombay's considerable rise and fall of tide was found especially suitable.

It was in 1807 that the constructionof the Upper Duncan Dock - 286 feet long, 63 feet broad and 23 feet deep - was completed. Within a year thereafter the construction of the first ship built at Bombay for the Royal Navy, the 74-gun *Minden* was commissioned. She was also'the first ship to be constructed to the Upper Duncan Dock. As regards the high quality of construction of ships built at the Bombay Dockyard, it would suffice to quote from a letter the first commanding officer of the *Minden* wrote to the builder, 'The report made by the Surveyors of the Navy will note one fault; for they were not only satisfied but much gratified by the inspection. Ihave heard many of the officers declare that no ship so highly furnished .. .has been launched from any of His Majesty's Dockyards or from any other yard in England during the last fifty years'.

Ships continued to be built at the dockyard, earlier for the Royal Indian Marine and later for the Royal Indian Navy, until the fourth decade of the 20th century with the dry-docks being modified for the purpose from time to time. During its entire history the Dockyard distinguished itself by not only building ships better than any built in Europe but also excelled in providing maintenance facilities to a wide variety of ships and craft from a number of countries.

A description of the Bombay Dockyard in 1775 say:

Here is a dockyard, large and well contrived with all kinds of naval stores deposited in proper warehouses,|ogether with great quantities of timber and planks for repairing and building ships, and forges for making of anchors as well as every kind of smaller smith's work. It boasts such a dry-dock as, perhaps, is not to be seen in any part of Europe, either for size or convenient situation. It has three divisions and three pairs of strong gates, as to be capable of receiving and repairing three ships of the line at the same or at separate times; as the outermost ship can warp out, and another be admitted in her place every springtide without any interruption of the work doing to the second or innermost ships; or both outermost and the second ship can go out, and two others be received in their places without hindrance to the workmen employed on the third or innermost ship. Near the dock is a convenient place to grace several ships at once, which is done as well and with as great expedition, as in any dock in England. Near the dockyard is a rope-walk which, for length, situation and convenience equals any in England, that in the King's Yard, at Portsmouth, only excepted, and like that, it has a covering to shelter the workmen from the inclemency of the weather in all seasons.

Here are made cables and all sorts of lesser cordage, both for the Royal Navy, the Company's Marine, and the merchant ships, which trade to these ports of India. Besides cordage made of hemp, cables, hawsers, and all kinds of smaller ropes, are made of the external fibres of the coconut, which they have in such abundance in India, as to make a great article of trade among the natives of this place, and those along the coast between Bombay and Cape Comorin. The yarn made of the fibres is mostly manufactured in the towns and villages on, or near, the sea-coast of Malabar; many vessels belonging to the natives are laden entirely with this yarn which they always find a quick sale for at Bombay and Surat let the quantity be ever so great, as it is the only cordage made use of amongst the small trading vessels of the country; large ships use much of it made into cables,hawsers,and smaller ropes; it is called Kyah.

Ships built at Bombay are not only as strong, but as handsome, and are as well finished as ships built at any part of Europe; the timber and plank of which they are built, so far exceeds any in Europe for durability, that it is usual for ships to last fifty or sixty years, as a proof of which I am informed that the ship called the *Bombay* grab, of twenty four guns (the second in size belonging to the Company's Marine) has been built more than sixty years, and is now a good and strong ship. This timber and plank are peculiar to India only; what grows to the south, on the coast of Malabar, is, however, very good, and great quantities of it are brought to Bombay; it is called teak and will last in a hot climate longer than any wood whatever.

Seven generationsof Wadia Master-builders constructed 352 large and small ship-of-the-line, coastal vessels and harbour craft during the course of the 18th and 19th centuries and a high standard of workmanship, often assessed as superior to that of English shipbuilders, was maintained throughout. The durability of Malabar teak, the imperviousness of the Indian caulkingmix, the superior technique of planking, keel andhull construction and the higher standard of craftmanship and skill of Indian technicians earned the admiration of even the most experienced shipbuilders of Europe.

The 74-gun 1809-ton, *Cornwallis,* the first Bombay-built ship to be acquired by the Royal Navy from the then Indian Navy, was launched in 1813, fired the first broadside and took part in the Anglo-American war in 1826, participated in the Baltic campaignagainst Russia after conversion to steam in 1855, provided an extension to the jetty at Sheerness in England and was finally scrapped in 1895, full 82 years after her commissioning. Her hulk near the jetty has survived to this day.

A large number of ships were built in the Bombay Dockyard for the East India Company, for the Royal Navy and for some local rulers. Some of the outstanding ships built on Bombay were:

Malabar: 74 guns, 1715 tons, built by Jamshedjee Bomanjee, launched in 1818.

Ganges: 84 guns, 2289 tons, built by Jamshedjee Bomanjee, launched in 1821.

Asia: 84 guns, 2286 tons, built by Nowrojee Jamshedjee launched in 1824.

Rose-water was used in 1811 for naming the *Shahalhim* as to have done so with wine would have been against the principles of the Imam of Muscat for whom she was built. Of the *Asia,* which was Admiral Cordington's flagshipattheBattleofNavarino, Admiral Sir PultneyMalcome wrote,Tell my old friend Nowrojee what a glorious part the *Asia* sustained in the Battle of Na varino and how proud I am of his success as a builder/ Earlier, the first Lieutenant 'Second command' of the *Salsette,* a frigate had written to Jamshedjee Nowrojee, 'Your professional abilities were the happy means of preserving us from what appeared to the human eye to be unavoidable destruction; that ship, with five other small vessels-of-war and twelve valuable merchantmen under convoy, being beset by the ice in the Baltic Sea in the winter of 1808-1809, she alone escaped shipwreck.'

Perhaps as remarkable as the career of any other ship was that of the *Swallow* built by Maneckjee Nowrojee in 1777.

> "She was firs t employed as a Company's packet;' wrote a chronicler and made several trips between India and England; was then taken into the Bombay Marine,and, after a short time, returned to the packet service in whichshecontinuedforrnany years. About theyear 1800, the *Swallow* not being required as a packet, was sold to the Danes, fitted in London, and went to Copenhagen, whence she is supposed to have proceeded to the West Indies; but, while there, was seized by a British man-of war-for a breach of treaty and condemne d as a prize. She was cut out from her anchorage by a sloop-of-war after a severe action, in which the British ship lost a number of her crew. She was then pur chased into the King's service, became the 'silly' sloop-of-war and was latterly commanded by Captain Sheriff; after serving some time in the West Indies, she was, on her passage home, dismasted, and received other damage in a violent gale of wind. On her return to England she was sold out of the King's service and bought by some merchants in London; made three voyages to Bombay, her parent port, as a free trader, and was lost on the James Mary shoal in the Hooghly, on the 16th June, 1823.

It was estimated by the Controller of the Dockyard in 1834 that an 84 gun ship could be built at Bombay at a cost of over £20,000 less than in England and said that 'it is universally admitted that a Bombay teak-built ship is 50 per cent superior to vessels built in England.'

It was on board the Bombay Dockyard-built Royal Navy ship, *Minden,* the first ship-of-the-line built of teak outside the UK to the order of the Admiralty, while she was shelling the town of Charleston, West Virginia during the Anglo-American War that the American national anthem, the Star-Spangled Banner, is said to have been composed by Francis Key. Another Bombay-built *ship, Asia,* was the flagship of the British Naval Fleet at the sea battle of Navarino in 1827. The *Punjab,* later renamed the *Tweed,* once made the London-to-Melboume passage in a record time of 83 days of sailing which remains unbe aten to this day.

Trincomake, which was rena med Her Majesty's Training Ship *Foudroy-ant* after she was decommissioned from the Royal Navy, was launched at Bombay as far back as 1817 but is still afloat at Portsmouth Harbour and is servingas a training vessel-theoldest naval ship afloat and inactiveservice in the world. Writes Charles Allen in anarticleon the evolution of shipbuild ing in India:

> Anchored in the roadsteads of the British Navy's dockya rd at Portsmouth, a battered, ancient hulk swings with the tide. Compared with Nelson's flagship, *Victory,* gleaming with spit and polish and fresh paint in her dry-dock close by, she seems a pathetic sight, with her masts cut short and her gun-ports battened down. Yet the history of Her Majesty's Training Ship *Foudroyant* is just as remarkable in its own way as that of its more famous sister-ship-of-the-Hne not, because of the men who sailed in her but for those who built her.
>
> *Victory* and *Foudroyant* are the last survivors of the days when Britain's Navy really did rule the seas, but *Foudroyant* has the distinc tion of being the oldest vessel in the world that is still afloat and in active service, which these days is serving as training ship for youngsters who come aboard for a few days to learn what it was like to live and work in an old man-o'-war. One reason why she has remained afloat for well over a century and a half is that unlike the *Victory* made from the 'Hea rtsof Oak' that Englishseamen were so proud of, theFou-*droyant* is built of Malabar teak, cut from the forest of Western India. *Foudroyant,* in fact, is not a British ship at all but an Indian one, built for the Royal Navy in Naval Dockyard, Bombay in 1817.

The shipwrights who designed and constructed the *Foudroyant* along with fifteen other sailing ships for the Royal Navy and a great many more for the Indian Navy- were all members of an extraordinary family who for nearly who hundred years dominated the dockyard of Bombay, and helped to turn what was a quiet backwater into the busiest seaport in Asia.

> In 1839 a steam sloop of 705 tons and 230 horse-power, armed with 5 guns, was launched at Bombay, followed in 1840 by a steam frigate of 946 tons and 220 horse-power, armed with six 8-inch guns, and in 1842 another steam frigate came from the hands of the Parsi builders of the Dockyard Ships which were built in Bombay and the engines supplied from Britain. Lowe, the naval historian says of them, "These steamers and sailing ships constructed at Bombay were the most serviceable of any in the possession of the Company, and such as were not lost by the accident of the sea, were in perfect condition at the time of the abolition of the Service, while those steamers built or purchased in England were generally signal failures/
>
> In 1863, when the Indian Navy was abolished out of its 20 war vessels, all but three had been built in Bombay and ten of them were steam-powered frigates, sloops or gunboats. The most powerful were the *Punjab* of 1800 tons and 700 horse-power, and the *Assaye* of the same tonnage and 650 horse-power.

Nowrojee Jamshedjee Wadia, who was the head of the firm under whose superintendence so many of the ships of the Indian Navy had been constructed, died on November 2,1860 at the age of 85. As a mark of respect to him, Commodore Wellesly closed the Dockyard on the day of his death and the flags of the vessels in harbour were half-masted. With his passing, began to pass too the glory of Bombay as a shipbuilding centre. Also, iron ships would soon take the place of wooden ones and it was to be sometime before India could again become a great shipbuilding country. The last ship built by the Wadias was the *Navigator,* which was launched in 1881.

At the time of the Industrial Revolution there had been significant change in the technology of ship construction with the introduction of iron in place of wood and steam propulsion in place of sails. Since the British shipbuilders hadrefused to transfer this technology to the Indians and since industrialisation in India had lagged way behind the European nations, it had signalled the beginning of the virtual extinction of the shipbuilding industry in India. Though the Bombay Dockyard had succeeded in building its first steamship, the *Hugh Lindsay,* as early as 1830, it had failed to sustain the effort of updating the technology of building ironclads and thus was relegated to the status of a maintenance and repair yard.

The two World Wars, especially the Second, were watersheds in the evolution of the Bombay Dockyard and from 1914 to 1918 and later from 1939 to 1945 it carried out major refits to a large number of ships and craft that were either severely damaged during operations at sea or needed urgent maintenance. In fact, every campaign during the last two centuries and more, from China to Ethiopia, from Egypt to the Cape of Good Hope, received material support in a large measure from this Dockyard but the importance given to it during World War II was never exceeded in the past. With Hong Kong and Singapore lost to the Japanese, it became the only dockyard available to the Allies east of Suez in thenorthern hemisphere and had to consequently handle a wide variety of ships and craft involved in the operations in all theatres of war from the Coral Sea to the Mediterranean.

When World War II broke out in September 1939 the Dockyard was lacking both men and equipment for the immense tasks of the conflict, but it eventually rose to the occasion and by the time Hitler marched into Poland, it had started working 'at full belt' to make the RIN ships and requisitioned vessels ready for war. Within the first 10 days of the commencement of the War, 17 vessels were got ready withmany, many more to fellow during the course of the next six years.

During these six years the strength of workers in the Bombay Dockyard increased ten times, its productive area was increased by fifty per cent, a hundred and seventy thousand square feet of covered area wasconstructed, five acres of non-productive buildings were demolished to make room for new stores and workshops, the number of ships handled at a time increased from two or three to thirty- the dry-docks were extended to take in larger vessels, berths were deepened to accommodate larger fleet units, the number of trades was considerably increased from tailors to tinsmiths and from optical experts to millwrights and refits were cut to a third or a quarter of the time they took before the commencement of the War, thus rendering the dockyard comparable to the Chatham Dockyard.

The tasks handled by the Dockyard included repairing a destroyer with seventy feet of its stemmissing,refittinga frigate requiringanewstem, conversion of four P&O liners into armed merchant cruisers, fitting out passenger ships as troop transport, hospital ships and mule ships, converting coastal craft into local naval de fence vessels, refitting whaling ships as minesweepers and installing guns and weapon control systems on a large number of 'defensively armed merchant ships.'

The first major action-damage repairs were carried out on the cruiser *Cape Town* after she had been torpedoed off Massawa; in January 1942 the destroyer *Kimberley,* whose stem was blown off by a German submarine in the Mediterranean, was towed to Bombay where the Dockyard built a new stern on her and realigned the nine -ton main gear wheel; another Royal

Navy ship, the *Isis,* was brought to Bombay after she had been extensively damaged, refitted and sent to Singapore where she suffered fresh damage during a Japanese bombing raid and was once again brought to Bombay for major refit before she sailed out for operations in the eastern theatre yet again.

These six years saw the Engineering Department trebling its capacity, the Gun mounting Depot coming into being, a massive naval stores com plex being set up, a number of workshops catering to diverse maintenance disciplines beginning to function and a large number of vessels being made battleworthy within the shortest possible time. To quote Captain W.R. Sh-ewring of the RIN, 'In six years of concentrated effort, the historic Naval Dockyard at Bombay has made a distinguished contribution to Victory, worthily maintaining its 200 years tradition/

There was a brief lull thereafter in the activities of the Dockyard which were confined to refitting of ships but construction of ships had been permanently discontinued. By the time of Independence, however, three major shipyards had been set up in the country - Hindustan Shipyard, Vishakhapat-nam, Garden Reach Workshops, Calcutta and Mazagon Dock, Bombay and some privately owned yards had started building fishing trawle rs, barges, powered boats and small craft but construction of warships was yet to be revived.

The first major task assigned to the Bombay Dockyard after Independence was renderinga thi rd of the undivided fleet andassocia ted assets of the British Royal Indian Navy earmarked for transfer to Pakistan seaworthy and capable of making the passage to Pakistan's major naval bases on its western and eastern sea-fronts, Karachi and Chittagong. All officers and ratings of the undivided RIN opting for Pakistan had to be transferred to these ships which were refitted, fuelled, victualled and stored and their operational efficiency maximised before their departure for Pakistan as Karachi and Chittagong were equipped with only minor repair facilities at that time. A third of the machinery and equipment allotted to the Pakistan Navy was also shipped to Pakistan. The personnel of the Dockyard rose to the occasion and the ships that would constitute the Pak fleet on August 15, 1947 - two sloops including the undivided RIN's flagship, *Godavari,* two frigates, four mainsweepers, two trawlers, two motor minesweepers and four harbour defence motor launches - sixteen vessels in all - were got ready and sailed out of Bombay Harbour by August 15,1947. These ships thereafter struck the RIN ensign and the Union Jack and hoisted the Royal Pak Naval ensign and the Pakistani national flag at sea and set course for the Pakistani ports.

Following the departure of the Pakistani fleet and its personnel, the Indian naval authorities undertook the task of restructuring the organisation of the Dockyard for meeting the requirements of Independent India's navy but it was soon embroiled into a state of hectic activity for preparing the Indian Navy's fleet for its first naval operation after Independence -bottling up the coastal waters of the state of Junagadh in Kathiawar which had illegally acceded to Pakistan. Three sloops, three minesweepers, three landing ships and one motor launch were refitted and made operational at short notice for the operation against the belligerent Nawab of Junagadh and his rebel force in October, 1947. The tasks of landing the Army on the Kathiawar Coast, sanitizing the area off the recalcitrant 'native state' and occupying its shore areas, which were of considerable tactical importance, was successfully carried out.

In order to revamp the Dockyard's organisational tree, which had clung to the archaic Royal Naval dockyard structure for several decades, and to optimise its material efficiency, a special committee had been set up immediately after Independence and had recommended theadoptionof the principles of the industrial system of management for the purpose. This would in turn facilitate the introduction of the latest scientific techniques of controlling refitting and maintenance operations and at the same time carefully preparing a phased plan for the expansion of the Dockyard to meet its future technological requirements. It was emphasised that with the introducion of the industrial system of management it would be possible to plan the Dockyard's activities in detail, ensure better coordination and progress at managerial and workshop levels, improve economy and progress and ensure effective control in the handling of material, labour and equipment.

The recommendations of the committee were accepted and, within a year of Independence, a new organisation based on managerial concepts came into being with the Dockyard being headed by a Captain Superintendent under whom was placed an Industrial Manager heading five technical departments: Engineering, EIectrical,Construction,Maintenance and Gun-Mounting. Anewly set up Planning Section was charged with planning and sequencing the docking of ships and repairs on a scientific basis, effecting greater economy in the utilisation of materials and manpower and improving and co-ordinating the operations of all technical and non-technical services. A number of cranes and cradles with hoisting gear imported from the UK were installedat suitable locations to facilitate the handlingof heavy equipment A large quantity of stores and spares worth a few crore rupees, which had been lying unused in the various departments of the Dockyard since the end of World War II, was withdrawn and placed under the Dockyard's stores officer and an efficient centralised system of spares storage, retrievaland issue was introduced with thecreationofaSpare Parts Distribution Centre. A beginning was also made in indigenising the suppl of stores and spares.

With theacquisitionof the Navy's first cruiser, *Delhi,* in 1948, one of the dry-docks of the Dockyard, the DuncanDock,had to undergo a minormodi-fication to accommodate the 555-foot hull of this 'David' who had slain 'Goliath' in the Battle of the River Plate and a number of tugs and ferry craft had to be requisitioned to manoeuvre the cruiser through the caisson into the Duncan Dock, an operation undertaken by the Dockyard staff for the first time.

With the acquisition of the three R class destroyers, *Rajput, Rana,* and *Ranjii,* in 1949, one store ship, *Dharini,* in 1952, the three Hunt class destroyers, *Godavari, Gomati* and *Ganga,* in 1953, one Tanker, *Shakti,* in 1954 and six minesweepers, *Bassein, Bimlipatnam, Kakinada Cannanore, Karwar* and *Cuddal-ore,* in 1956, the maintenance facilities had to be considerably extended and modernised to cope with the post-World War II generation of propulsion machinery, weapons and weapon control systems, electromagnetic and underwater sensors, data transmission systems and damage control techniques.

When the first atomic reactor, Apsara, was being set up at Trombay during the early 1950s, the Atomic Research Centre was faced with a major engineering task which bad not so far been undertaken in this country that of fashioning a very large base-plate weighing a few tons for the fuel element rods of the reactor with great accuracy at short notice as Prime Minister Jawaharlal Nehru was to inaugurate the reactor within a few weeks. The Dockyard technicians accepted the challenge, worked round the clock and completed the task within a few days and the plate fabricated met all the requirements of structural strength, composition and 'tolerance', Le., permissible variation in weight and dimension. Another instance of the high level of the Dockyard's expertise was that two ships, *Cauvery,* and *Konkan,* which underwent extended major refit at the Dockyard, exceeded the speeds attained by them during the builders' sea trials over 15 years earlier in England and that the propellers of *Delhi,* which had suffered damage during operations, were changed by the Dockyard within the record time of six hours.

In order to improve industrial relations and channelise the specialist skills of the workers, a Works Committee was formed with the Industrial Manager as the Chairman and the heads of various departments and representatives of the workers union as members. The first task undertaken by the Committee was the classification of workers into different trades and skills and the reorganisation of thehierarchical structure of the departments and shops on the basis of the latest managerial concepts.

As regards training Dockyard workers in their numerous professions, a Mechanics' Institute had been set up as early as 1848 to train workers insteam propulsion of ships, which had just been introduced, but most of the workers had to be trained on an 'on-the-job' basis as no separate organisation for the composite training of workers in the various skills existed. And hence, in order to improve their performance, the lowest educational qualification for apprentices was raised to matriculation soon after Independence and a Dockyard Apprentice School set up within the Dockyard's premises in 1949 with 77 general apprentices who branched into various trades and professions after their basic training. Over the years this school has not only provided the necessary skilled manpower to the Dockyard but has also turned out a large number of professional tradesmen to meet the requirements of the industrial establishments.

Based on the strength of the Indian Navy of the late 1960s, as projected in the future plans drawn up at the

Naval Headquarters in 1948 which proposed the acquisition of a large number of aircraft carriers, cruisers, destroyers, frigates,tankers, minesweepers, hydrographic survey vessels, landing craft, store ships, submarines, submarine tenders, diving tenders, coastal craft, harbour craft, naval aircraft and helicopters, and in consultation with the British Admiralty, it was decided to suitably expand the Dockyard expeditiously and augment the facilities and services provided by it. Accordingly, Sir Alexander Gibb and Partners, consulting engineers of international repute, were contracted to prepare a suitable plan for creating, firstly, additional space within the Dockyard by reclamation, secondly, additional berthing facilities by constructing new wharves and, thirdly, additional dry-dockingfacilities for the repair of capital ships,i.e, cruisers and aircraft carriers, with the proviso that the expansion plan was to be implemented without affecting the normal functioning of the Dockyard.

In May 1950 the consultants finalised their report which provided for an increase in the existing land area of 39 acres to 120 acres by reclamation and by acquiring some portions of the Ballard Pier and the Royal Bombay Yacht Club, the construction of a 3,200-foot breakwater to form an artificial tidal basin and increasing the protected water area from 24 acres to 150 acres, constructionof new workshops, offices, stores and other buildings on the reclaimed and extended land area, construction of two 'graving' (dry) docks of suitable size for all classes of vessels to be acquired during the next two decades, and the extension of the total berthage within the area of the tidal basin by nearly four kilometres. After a few modifications regarding the location of the docks and the various buildings and workships, the consultant's recommendations were projected to the Government of India along with the proposal for a Rs 25.1-crore, five-stage, 12-year Naval Dockyard Expansion Scheme with Captain (later Vice Admiral) Daya Shankar, Chief of Material at Naval Headquarters, being the nodal functionary for obtaining Government approval and for the implementation of the project.

In 1952 the Government of India accorded its approval in principle for a modified two-stage project, the Rs 11.32-crore first stage comprising the extension of the Ballard Pier by 750 feet, reclamation of 27 acres of sea area, erection of three wharves on the reclaimed area providing 2,300 feet of wharfage and construction of a cruiser-graving dock on the reclaimed area. The Rsl459-crore second stage would extend the reclaimed area by another 40 acres on which would be constructed the outer deep-water basin with allied wharves to provide greater berthing facilities to be used for repairs and for operational reasons.

The Bombay Port Trust authorities and the Maharashtra Government did not, however, take very kindly to the Dockyard's proposed expansion scheme. The Port Trust felt that it would hamper the movement of passenger liners and freighters to and from the Ballard Pier and demanded a monetary compensation of Rs 1.4 crore while the Maharashtra Government's objection was based on the apprehension that it would mar an important tourist attraction - the panoramic view of the harbour from the Gateway of India. The controversy had delayed the launching of the project by over two years when Prime Minister Jawaharlal Nahru intervened, overruled the objections and decided in favour of the Dockyard's expansion. Work on the project entrusted to various contractors around the globe and overseen by Sir Alexander Gibbs and Partners could, therefore, commence only in 1955. Work on the project, however, came to a standstill once again in 1956 when differences over contractual obligations led to arbitration and further consequent delay in construction work.

In 1958 the late V.K. Krishna Menon, who was the Union Defence Min ister, vexed by the slow progress of the project, dissolved the Naval Dockyard Construction Committee, which had been overseeing the expansion of the Dockyard on behalf of the Government of India, and ordered the formation of a Naval Dockyard Expansion scheme with Commodore (later Admiral) S.M. Nanda as its first Director General. He was armed with adequate facilities, finance and authority to steer the project clear of the hazards it had so far been faced with. In 1960 Rear Admiral P.K. Mookerji of the Navy's Engineering Branch took over as the Director General and, during his long tenure of seven and a half years in this assignment, suc ceeded in completing several major projected works.

Construction of the cruiser-graving dock, equipped with three Pump-houses, two heavy-duty cranes and the attendant services, was well under way when it was de cided to acquire the Navy's first aircraft carrier, *Vikrant.* The dock was, therefore, suitably extended and its shore end modified to ac commodate the carrier's forecastle and its protruding gun sponsons.

After its completion, the cruiser-graving dock had the unique distinction of docking all three post-Independence flagships of the Indian Navy *Delhi, Mysore* and *Vikrant* In 1963 a large oil tanker, *SS Sarulla,* which had sprung a leak and had thus become a pollution hazard to Bombay Harbour, was isolated by being docked in the cruiser-graving dock, on a request received from the Bombay Port Trust, and necessary repairs carried out There were occasions when as many as four ships - submarines and frigates - were simultaneously docked in the cruiser-graving dock.

Along with the cruiser-graving dock, which was commissioned by Shri Krishna Menon, the barracks wharf, the destroyer wharf, the boat wharf and a patent slipway were completed and by 1962 the Ballard Pier was extended by 750 feet.

Construction of a south breakwater wharf, a rubble-mound breakwater and a protective retaining bund was commenced in 1958 after obtaining me clearance of the Bombay Port Trust. For this phase of the project, 24 large reinforced concrete caissons had to be laid on the prepared foundation, the tidal basin had to be deepened to 34 feet and nearly 40 acres of sea area had to be reclaimed by removing rocks, blasting charges underwater and filling up the cleared areas. The breakwater thus erected was capable of berthing the largest naval ships on the protected inner face in all weather conditions and on the outer face in fair weather. A novel fea ture of the south breakwater, owing to the cellular construction of the caissons, was the additional facility for the storage of fresh water and oil, provision of pressurised salt water and compressed air, location of electrical substations and a battery of cables and other equipment below the breakwater's upper exposed deck. This deck was left clear for the installation of cranes andother handlinggear, for (he movement of vehicles and for laying rails for the supply or removal of heavy machinery and weapons. The slipway was built for hauling up, drying out and repairing smaller craft such as patrol craft, minesweepers and local naval defence ve ssels without having to dry dock them.

The areas reclaimed around the cruiser-graving dock and the newly constructed wharves were utilised for the construction of workshops for the repair and maintenance of propulsion machinery, generators, weapons, weapon control systems, sensors, data transmission systems and naviga tional equipment installed on board the ships acquired after Independence as these were far more sophisticated and superior in their capabilities than similar equipment of World War II vintage.

Meanwhile the tidal structure and the pattern of the deposition of silt in the area contiguous to the Ballard Pier and south breakwater underwent a complete change owing to the erection of the concrete structure a few kilometres long and the reclama tion of a sizeable area.The dredging fleetof the Dockyard washenceexpanded and placed under the Commander of die Yard (acronym 'C of Y'), who controls all movement of ships in the Dockyard, for maintaining the required depth of sea water in the area.

In order to improve the opera tional efficiency of the Dockyard, the National Productivity Council was invited in 1963 to examine its organisational structure and operating procedure. A team deputed by the Council, headed by a Ford Foundation specialist, conducted a detailed study of all aspects of the Dockyard's activities for a period of four months and pointed out the deficiencies in staffing, training, organisation and the planning and control of its maintenance and refitting operations.

As regards staffing, the main lacunae pointed out were quick rotation of technical officers, who mainly comprised officers in uniform, inadequate educational and professional training of technical personnel and low morale due to a poor wage structure and promotion prospects that had remained close to the low water mark since the cessation of hostilities in 1945. Training activities were considered infrequent and lacking in professionalism and needing reorientation on modern scientific lines and interaction with other similar technical establishments in India and abroad. The NPC team thus stressed the fact that the Dockyard was lacking in discharging several important functions of management, viz., process planning and estimating, production control, work study, da ta processing and a standard cost system- and recommended their inclusion in the organisational structure and operating procedure of the Dockyard. Accordingly, the organisational tree of the Dockyard was pruned, cross-cut and revamped and a production planning and control department was created in 1964 for improving the utilisation of human and material resources and productivity. A work study team was also created to systematically study and critically examine all activities of the Dockyard, recommend more efficient techniques of recording and evaluating defect and repair operations, and for reorienting the layout of workshops for improving their efficiency.

Constructionalso commenced of a Rs2.9-croresteamtesthouse for the repair of the shipboard steam-driven equipment such as turbo-generators, air compressors, pneumatic instrument controls and turbine-actuated blowers, pumps and ejectors. Work also began on setting up a modern weapons and control systems repair shop (WECORS), which was responsible for not only the maintenance of modern weapon and weapon control systems but also the calibration and overhaul of diverse electronic devices, weapon computers, sensors and video displays and their support facilities - electrical, electronic, mechnical and hydraulic. The Rs 5.8-crore first phase of the WECORS project was sanctioned in 1961 and a specially-equipped, air-conditioned, dust-free enclosure of 80,000 square feet floor area was erected by 1966 and inaugurated by the then Naval Chief, Vice Admiral (later Admiral) A.K.

Chatterji, The construction of WECORS lent concrete shape to the concept of integrated equipment repairs and fault diagnosis on a scientific basis.

The other improtant workshops set up were the diesel workshop for testing and repairing high-speed diesel engines and thus indigenising their maintenance, a steel fabrication shop for making steel castings for the replacement of damaged propellers, propeller shafts, junction boxes, crank pins, journals, casings, condensers and switchgear used onboard ships and yard craft and a quality control department to ensure reliability of shipboard equipment, machinery and weapons, to test raw material and spares for their suitability for use and to lay down specifications by the process of inspection, tests, documentation and scientific analysis of spares and components.

The Dockyard also undertook in-house maintenance and construction of its heavy-duty machinery equipment such a s hydraulic engines, boilers, caissons and dock gates. Arrangements were also made for the repair of cranes, davits, machine tools, motors, captive generators and hauling and other equipment by the dockyard staff. The functions of estimating, forecasting, procuring, provisioning, safekeeping, preserving, accounting and supplying a wide variety of stores and equipment by the Naval Store Organisation and the Spare Parts Distribution Centre were further streamlined on the basis of the modem concepts of logistics and material management with the assistance of the Administrative Staff College, Hyderabad and a special supply procedure evolved for handling spare parts of critical importance required for the refit of ships without upsetting the refit schedules of other ships urgently required for operations and exercises.

Since research and development in metallurgy and the chemical sciences has a direct bearing on quality control, Dr J.E. Keyston, the Chief Scientist of the Royal Naval Scientific Service, was requested in 1948-49 to prepare a report on this aspect of the Dockyards's activities. One of the recommendations made by him was the setting up of a Naval Chemical and Metallurgical Laboratory (NCML) within the Dockyard premises. Accordingly, an NCML came into being in 1953 with Dr G.E. Gate of the Royal Naval Scientific Service on loan service as the Scientific Adviser to the Indian Navy. The Laboratory was located in a 600-square-metre building within the precincts of the Dockyard and was suitably equipped to handle research in metallurgy, chemistry, biology, material corrosion and paints and to devise means to indigenise the production of naval stores.

The NCML made a significant contribution to the operational availability of ships by reducing the 'down-time' of weaponry and equipment throughits sustained effort to improve the quality of components. The main thrust of its activities, however, was on fighting the worst scourge at sea -corrosion. When the ship's hull was made of timber, it was protected from the sea organisms by covering it with a thin layer of copper whichhad to be periodically reinforced by 'recoppering' but when ironclads were introduced in the 19th century with an increasing variety of shipboard equipment made of metals, the main problems faced by the maintainers were rusting and fouling. In his artic le 'Saboteurs of Ships at Sea', Dr K.P. Buch, a senior Defence Scientist, says, Ironically,in the very watersitseeks to protect, the Navy faces its worst enemies - nay saboteurs - hidden in the sea! They are corrosion and marine fouling organisms, the latter directly contributing to enhance corrosion. What cancer is to the human body, corrosion is to the metallic structures immersed in sea water, whether they a re static or moving. Like cancer, corrosion can be localised or spread over large and isolated areas. If it is not detected in time and curative measures not initiated, corrosion can be fatal to the immersed structure. Corrosion affects the ships by attacking not only underwater hull and machinery components, but also every compartment, weapon systems and all fixtures and fittings on board.

The majorachievementsoftheNCML were thedevelopmentof heavy-duty paints containing synthetic chemicals, not affected by sea water in order to provide better protection to ships' hulls from corrosion and the introduction of 'galvanic anodes' designed in its laboratory for providing cathodic protection to the hull, i.e., passing a current to reverse the corrosive chemical reaction that has already taken place. The laboratory also developed sophisticated techniques of *in situ* welding and chemical cleaning of snips' machinery.

From Independence to the middle of the 1960s the Naval Dockyard, which had a distinguished record of service to the Royal Navy, Royal Indian Navy and the Indian Navy for well over two centuries, continued to reorient its operational philosophy towards meeting the increasing challenges of warship maintenance and their quicker turn-around. Since invention and sophistication of weapons, equipment, machinery, hulls, etc., is an ongoing process, spurred onby the ever-increasing pace of na valoperations, and the need for quicker reaction in attack and defence leading to even further automation of ships and weapon systems, the Naval Dockyard continued not only to handle the task of carrying out complex repairs of and providing logistic support to the Western Fleet more efficiently, but also to play the role of the lead yard of the Navy in warship maintenance and fitting out. And it continues to live up to the spirit of what Winston Churchill said on February 9,1941, 'We shall not fail or falter; we shall not weaken or tire. Neither the sudden shock of battlenor the long-drawn trails of vigilance and exertion will wear as down. Give us the tools and we will finish the job/