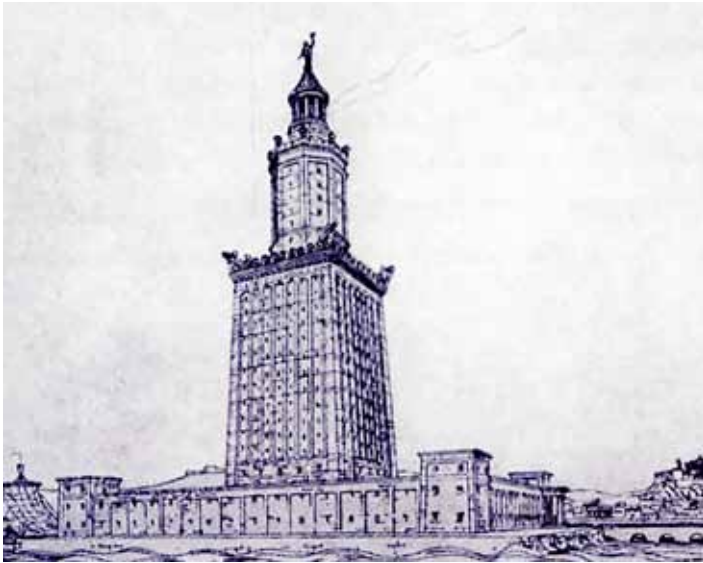


Australian Lighthouses

By Ian Arthur

The idea of writing an article on lighthouses for ASHET News originated in my reading a paper in the journal of the Society for the History of Technology, based in America. The paper by Michael Brian Schiffer is titled *The Electric Lighthouse in the Nineteenth Century: Aid to Navigation and Political Technology* and is published in the Volume 46 Number 2, April 2005 edition of the Society's journal *Technology and Culture*. The paper mentions that the second Macquarie Lighthouse in Australia, when it opened in 1883, had the most powerful electric light in the world.

This led me to read more about lighthouses in Australia, and this article is the result. It is timely, since the Australian Maritime Safety Authority (AMSA), responsible for providing aids to ocean and coastal navigation in Australia, celebrated its 100th anniversary in 2015, and 2018 will be the 200th anniversary of the opening of the first Australian lighthouse, the Macquarie Lighthouse on South Head in Sydney.



The Pharos of Alexandria



Roman Tower of Hercules in Spain, built during second century AD

The earliest lighthouses

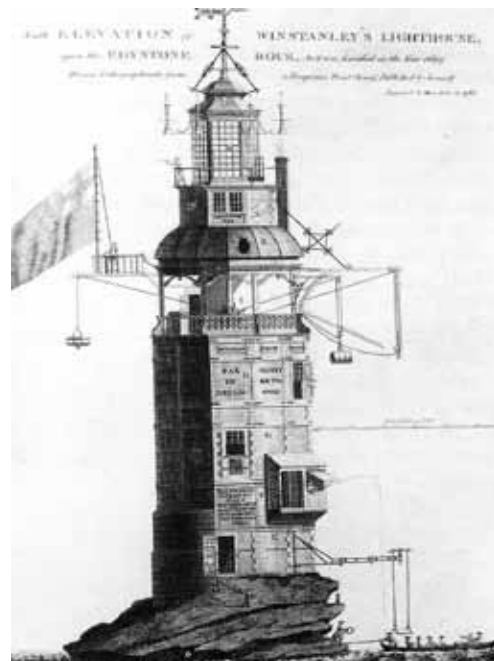
The first authenticated record of a lighthouse is that of the Pharos of Alexandria, one of the Seven Wonders of the ancient world. It was built around 280 BC on the island of Pharos at the entrance to the port of Alexandria. It was large even by modern standards, around 120 m high, built of stone faced with marble. At the top was a wood fired beacon that could be seen under good conditions 30 miles out to sea.

The Romans and the Phoenicians built many fire-beacons and a few lighthouses wherever they traded regularly, at locations reaching from the Eastern Mediterranean and the Black Sea to the Atlantic coast of Spain and to Britain. Most had a wood fire; after the first century AD a few had candles or oil lamps protected by glass.

The decline of commerce during the Dark Ages following the collapse of the Roman Empire around 400 AD halted lighthouse construction. Construction of beacons and lighthouses revived, along with trade, around 1100 AD, and by 1600 AD, led by Italy and France, at least 30 major beacons were established. The influence of the Hanseatic League helped to establish at least 15 lights on the Scandinavian and German coasts.

The modern age of lighthouses

The first modern British lighthouse was a timber structure built by Henry Winstanley on the Eddystone Reef, off Plymouth, and first lit in 1698. It lasted only until 1703 when it was completely swept away in a storm, along with Winstanley himself who was visiting at the time and was



First Eddystone Lighthouse, in England

drowned. A second timber tower on the site was built in 1708 and was destroyed by fire in 1755. John Smeaton built a substantial stone tower in 1759 using interlocking blocks of masonry and a hyperbolic curved profile that was copied by many other lighthouse builders. The rock under Smeaton's tower was being undermined by wave action and the tower was replaced by a new one on an adjacent site. The upper part of Smeaton's tower was dismantled and rebuilt on Plymouth Hoe where it still stands.

By 1820 there were an estimated 250 lighthouses in the world, most of them in Europe.



Argand light

Providing the light

Early lighthouses had smoky open fires, fuelled by wood and later, coal. In 1782 Aimé Argand, a Swiss scientist, invented a smokeless oil lamp especially designed for lighthouses. It used a circular wick inside a glass chimney resulting in an even flow of air to the flame, ensuring that it burned steadily without smoke. It rapidly gained acceptance for lighthouses for which it was made with up to ten concentric wicks. The Argand lamp became the most common one for lighthouses for the next 100 years, and many Argand lamps are still in use. The fuel was originally fish oil, usually whale oil, which was superseded by vegetable oil and around 1880 by mineral oil, typically kerosene.

In 1901 Arthur Kitson invented a lamp that burnt kerosene vapourised under pressure and mixed with air. It was used to heat an incandescent mantle, producing around six times the light of oil wick lamps.

Gustav Dalén of Sweden developed a number of improvements in technology for lighthouses between 1900 and 1910. They included the use of acetylene gas dissolved in acetone, making it safe for storage and use. It was burnt either as an open flame or with a mantle. His other improvements included an automatic mantle exchanger and a daylight switch that turned the lamp off during the day. These innovations permitted lighthouses to be operated unattended, a tremendous advantage for lighthouses in remote locations.

The electric arc light was a discovery made by several physicists in the first years of the nineteenth century. A carbon arc was produced by connecting carbon rods to each of the two poles of a battery, bringing them together and then separating them by a short distance so that the arc formed and emitted a brilliant white light. A practical problem was that arc lamps imposed a heavy drain on batteries, the only practical source of electric current at the time. Michael Faraday's discovery of electromagnetic induction in 1831 led to the invention during the 1850s of powerful

electrical generators that could provide power for arc lights in applications such as lighthouses. Frederick Holmes conducted a trial of a system incorporating an arc light and a steam driven electrical generator at the South Foreland lighthouse near Dover in 1858. Over the next few years a number of lighthouses, including one in Australia, the second Macquarie Lighthouse, were equipped with arc lights, which were far more powerful than any other light source available. In 1881 the British government had plans to install 60 arc lights, but never installed more than a handful, even though it built over 200 lighthouses in the period 1887-97. Arc light installations proved expensive to build and maintain, and all have been replaced with other sources of light.

Providing a bright light

There was a need for bright lights, that could be seen from ships 20 to 30 miles out to sea, and which would be visible in bad weather. The first effort at providing a bright light was placing the lamp at the focus of a parabolic reflector so that it produced a strong narrow beam. Reflectors were made from copper plated with silver. They were less than satisfactory because they became tarnished and affected by smoke. An alternative form of parabolic mirror that proved more successful was made from small pieces of mirror glass set in a plaster cast.

To provide a light that could be seen from all directions, the mirror needed to be mounted on a rotating platform, producing a flashing light. The first rotating beam lighthouse was installed at Carlsten, Sweden, in 1781.

In 1821 Augustin Fresnel of France invented a way of using the refracting properties of glass, now known as the Fresnel or dioptric lens. On a lens panel he surrounded a central bull's-eye lens with a series of concentric glass prismatic rings. The panel collected light emitted by the lamp over a wide horizontal angle and also the light that would otherwise escape to the sky or to the sea, concentrating it into a narrow, horizontal pencil beam. With a number of lens panels rotating around the lamp, he was then able in 1824 to produce several revolving beams from a single light source, an improvement over the mirror that produces only a single beam. The Fresnel lens system was installed in most large lighthouses throughout the world. A large Fresnel lens system could weigh as much as five tonnes. These systems were mostly mounted on a turntable floated in a circular trough containing mercury.

Prior to Fresnel's invention the best mirror systems could produce a light of about 20,000 candela with an Argand burner. The Fresnel lens system increased this to 80,000 candela, roughly equivalent to a modern



Fresnel lens at Cape Otway Lighthouse

automobile headlamp. With a pressure oil burner or an arc lamp intensities of over 1,000,000 candela could be achieved.

Electric filament lamps for lighthouses came into use around 1920, and are in common use today. However there are many lighthouses that still use oil or acetylene lamps.

Australia's first lighthouse

Governor Arthur Phillip established a signal station on South Head, Sydney Harbour, in 1790, and in 1794 a beacon was installed with an iron basket initially burning wood and after 1797, coal.

In 1816 Governor Lachlan Macquarie, the first military governor (the first four governors were Royal Navy men) moved to build a lighthouse on South Head. Its design, by convict Francis Greenway, was similar to that of lighthouses being built in Britain at the time, a substantial sandstone tower 26 m high. The lights, imported from Britain, were a set of oil lamps set in parabolic reflectors mounted on a structure that revolved with a clockwork mechanism. The light was visible 22 miles out to sea. It commenced operation in 1818.



Old and new Macquarie Lighthouses in 1883

Greenway warned that the sandstone used in the tower would soon deteriorate, which it did, with stones falling off within five years. The tower was reinforced with iron bands, but building of a replacement was not commenced until 1881.

The new light, designed by the Colonial Architect James Barnet, first operated in 1883. It was housed in a tower adjacent to the first lighthouse and was of similar size and style. The lighting equipment, with arc lights and an optical system with Fresnel lenses supplied by Chance Brothers of Birmingham, was of the latest design and could deliver light at a level of 6 million candela, making it the most powerful light in the world at the time. Power was provided by two steam driven generators on the site. The arc light was expensive to run and it was used only during bad weather; at other times the light was provided by a gas burner. In 1912 the lighting system was replaced by a vapourised kerosene incandescent mantle system. This in turn was replaced in 1933 by an electrical filament lamp

system connected to mains power and a new optical system smaller than the original. This has since been replaced by the current system using a single 1,000 kw quartz halogen lamp connected to mains power with a diesel engine and generator backup. The equipment was automated in 1976 and the keepers were withdrawn in 1989. This second lighthouse is still in regular use. The first lighthouse has been demolished.

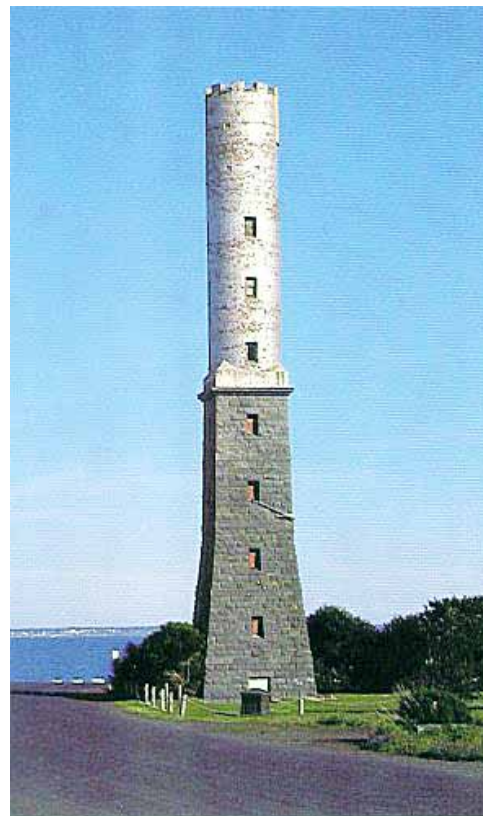
Other early Australian lighthouses

After the first Macquarie Lighthouse the next lighthouses built by the NSW colonial government were in what is now Victoria. The first Williamstown Lighthouse, a timber tower on Gellibrand's Point at the entrance to the Yarra River, was built in 1840. It was replaced by new light in a bluestone tower in 1849, and this in turn was replaced by a lightship in 1859. A time ball was installed in the tower and operated until 1926. In 1934 the bluestone tower was extended in brick by 10 m and again became a lighthouse. It was taken out of service in 1987 and the brick extension was removed from the tower, leaving the original blue stone tower in which a replica time ball was installed to commemorate its history.

The Shortland Bluff Lighthouse was built in 1843 near the entrance to Port Phillip Bay, but deteriorated quickly and was replaced by the present one, in unpainted bluestone, in 1862. It is still in operation, now lit by electricity and unmanned.

The Cape Otway Lighthouse at the entrance to Bass Strait, was built in 1848. It was decommissioned in 1994, and was at the time the longest continuously operating lighthouse on the Australian mainland. It was replaced by a small solar powered light housed in a GRP (glass reinforced plastic) cabinet nearby.

A beacon with a coal fire to guide ships to the port of Newcastle was built in 1804 on Signal Hill at the mouth of the Hunter River. This was replaced in 1858 by a lighthouse on nearby Nobbys Head, a rock island now joined to the mainland. The lighthouse is a stone tower 35 m high on the rock base that has been reduced to 25 m above sea level. The original light was an oil lamp and optical system delivering 20,000 candela and had a range 16 miles out to sea. The lighthouse was automated and de-manned in 1935 and is now fitted with a 1,000 watt electric lamp.



1849 bluestone Williamstown Lighthouse, with 1934 brick extension



Shortland Bluff Lighthouse



Cape Otway Lighthouse at the entrance to Bass Strait in Western Victoria

Early lighthouses in Tasmania

Once Van Diemen's Land became constitutionally separated from New South Wales, in 1825, the Lieutenant-Governor George Arthur moved quickly to establish lighthouses. The first, completed in 1833, was at Iron Pot, a rocky islet in the Derwent Estuary. In 1920 the light was converted to acetylene, automated, and the keepers were withdrawn. It was converted to solar power in 1977.

The second lighthouse in Van Diemen's Land, completed the same year, was at Low Head, designed by Colonial Architect John Lee Archer and fitted with locally made lights and reflectors. The original lighthouse was replaced by the present one in 1888. Tasmania's third lighthouse, at Cape Bruny, was built in 1838. The original tower still stands, but the light is now provided by an electric light housed in a GRP cabinet of standard design installed in 1996.



Tasmania's first lighthouse, Iron Pot, 1833



Cape Bruny Lighthouse, 1838

Australian lighthouses in Australia's colonial period

In 1844 a tower to serve as a lighthouse was built by convict labour at the entrance to Raine Passage in the Great Barrier Reef in North Queensland, but its light was never installed. Queensland's first light was built on a wooden frame in 1947 on Cleveland Point near Townsville. It was replaced with a 9 m hexagonal weatherboard tower in 1864. The light was relocated in 1976 to a 12 m tower made from prefabricated concrete columns in which it still operates.

Work was commenced on Western Australia's first lighthouse in 1841 on Rottnest Island near the entrance to the Swan River and completed in 1849. Western Australia's second lighthouse was on Breaksea Island at the entrance to King George Sound. The Sound provided a better anchor-



Currie Harbour Lighthouse, on King Island, built in 1880, was prefabricated from cast iron and wrought iron sections in Britain and assembled on site. The light was extinguished in 1989 but relit in 1995 following a public protest.



Green Cape Lighthouse in southern NSW was designed by government architect James Barnet, and built in 1883, was the first concrete lighthouse in Australia. It is no longer in use, replaced in 1998 by a steel lattice tower close by.

age than Fremantle and had become an important port close to the shipping routes to the Cape of Good Hope and the Suez Canal. The British government undertook to erect two lighthouses if the colonial government would cover the running costs. The main tower was constructed from cast-iron plates shipped from England. The light was unsatisfactory and new optics were shipped from England in 1895, but were not installed until a new tower was completed in 1901.

Around 130 Australian lighthouses were originally built in the nineteenth century. Many of the early ones were later rebuilt, but the majority are still in service, with updated equipment.

Most of the colonial lighthouses in Australia were of what was then the conventional design, tapered circular stone towers, painted so that they were readily visible by daylight. Eight of Queensland's colonial lighthouses were timber framed, with corrugated iron or weatherboard cladding. A few colonial lighthouses were clad in cast iron panels imported from Britain.

Four lighthouses, Wonga Shoal light near Adelaide, the Moreton Pile Light at the mouth of the Brisbane River, the Gellibrand Light at the entrance to the Yarra River in Melbourne and the South Channel Pile Light in Port Phillip Bay, Victoria, were constructed on piles set in the sea bed.



Troubridge Island Lighthouse in St. Vincent's Gulf, was the second lighthouse to be built in South Australia, in 1856. It was the first to be built of cylindrical cast iron segments imported from England and assembled on site.



Booby Island Lighthouse, on an island in Torres Strait off the Queensland coast, was built in 1890. It is one of several Queensland lighthouses to be built with a timber frame and galvanised iron panels.



Gellibrand Light at the mouth of the Yarra River in Melbourne, on fire following collision with the 7,000 tonne Melbourne Trader in 1976.

Three of the four were demolished by ships colliding with them. The one that survived, The South Channel Pile Light, operated for 91 years until 1965 when it was turned off for a trial period and never turned on again. In 1998 Parks Victoria removed it to Melbourne, restored it and mounted it on new piles around 3 km from its original site. It is no longer lit. The end of the Gellibrand Light was spectacular. On a foggy morning while its fog horn was not operating it was hit by the 7,000 tonne *Melbourne Trader*. It was decided to demolish the wreckage by setting fire to it. Its replacement is a simple steel pile with a solar panel.

The twentieth century

Up to the time of Federation in 1901 the individual colonies had managed the construction and operation of lighthouses under the supervision of the British government through the Colonial Office and the Board of Trade. The British government's formal involvement ended with Federation, but it was not until 1915 that the Commonwealth Lighthouse Service was established under director Joshua Ramsbotham, an English engineer who had been working for the Western Australian government on a proposed graving dock. The Commonwealth took over on 1 July 1915 104 manned lighthouse stations and 18 automatic lights, along with buoys, beacons and obelisks. Staff and other resources were gradually transferred from the states. The current arrangements, based on a 1934 agreement between the Prime Minister and state Premiers, are that the Commonwealth through the Australian Maritime Safety Authority (AMSA) is responsible for the provision of aids to navigation necessary for ocean and coastal navigation, while the states, ports and territories provide aids necessary



The unmanned Fitzroy Island Lighthouse near Cairns in Queensland, built of tiled concrete in 1973, replaces the original manned light built in 1943.



The first 'headlamp' type light in an Australian lighthouse was this one designed and manufactured in Australia in 1962 and installed in the lighthouse at Marino Rocks in South Australia.



South Brook Island Lighthouse is a steel framed structure off the Queensland coast near Cairns. It was built in 1921 and there are several others like it.

for the safe entry and navigation of ports and those required by fishing vessels and pleasure craft.

In the early twentieth century some important technical developments were taking place. The innovations made by Gustav Dalén in the period 1900-1910 that made it possible for lighthouses to operate unmanned were being progressively implemented in Australia, both in new lighthouses and in de-manning existing ones. Dalén's innovations included the use of acetylene dissolved in acetone as a fuel that could be stored safely and burnt as an open flame or mixed with air in an incandescent mantle. Dalén also developed sun-valves that turned the light on and off, and systems for automatically changing mantles or electric lamps when this was required.

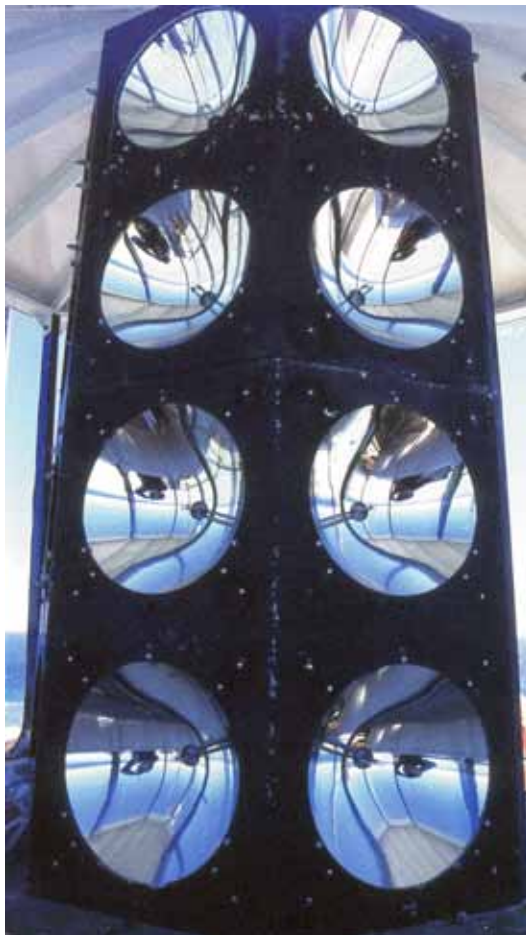
Some of the new Australian lighthouses were being built on steel lattice structures that were more economical than the traditional masonry towers.

A major concern for the Commonwealth was to improve navigation aids in Queensland, particularly the Inner Barrier Channel and Torres Strait. Preliminary studies were started in 1914. In 1922 Ramsbotham reported that the Commonwealth had provided twelve new lights on the Queensland Coast and in 1938 that despite the shortage of funds during the depression, it had constructed 27 unattended lights on the Australian eastern coast, most of them in Queensland and Torres Strait. By 1938 60 per cent of Australia's oil imports went through Torres Strait and nearly 3 million tonnes of shipping was passing through the northern entrance to the Barrier Reef route along the coast.

The Commonwealth's last new manned lighthouse was built in 1941 at Fitzroy Island near Cairns. It was replaced in 1973 by a 12 m high concrete tower and a lighting system using sealed beam electric lamps and is un-manned. It was deactivated in 1992 and at the same time an adjacent



Prefabricated glass reinforced plastic (GRP) cabinet with solar panels installed at North East Island, one of the Kent Group in Bass Strait in 1987. Similar ones have been installed since the mid-1960s in many other locations, in some cases replacing existing light-



Modern lamp array installed on Creal Reef Light on Hydrographer's Passage off the Queensland coast. Several other lighthouses are equipped with similar lamp arrays.

light at Little Fitzroy Island, which had been shut down, was reactivated.

After a period of restricted funding during World War II and the early post-war period, the level of activity in providing navigational aids increased. By 1963 the lighting of the eastern seaboard of Australia was considered adequate and lighthouses along the inner Barrier Reef channel were placed at an average of twenty miles.

Incandescent lamps had been improved greatly during World War II and as a result they were progressively replacing kerosene and acetylene lamps and at the same time providing much higher light levels. The last kerosene lamp in Australia was converted in 1985.

In June 1974 the Commonwealth had 333 navigational aids including 48 manned stations, 217 unattended lights and ten radio beacons. Two Decca navigational chains were established on the north-west Australian coast at Port Hedland and Dampier in 1970 and 1972 respectively. They provided an accurate positioning system over 300 miles of coastline and 250 miles out to sea and were the first radio and electronic aids to commercial sea navigation put into large scale use in Australia independently of lighthouses.

From 1965 glass reinforced plastic (GRP) panels were being used for constructing cabinets for unattended lights. These were typically slim cabinets up to 6 m high containing batteries and with a light mounted on top. Many of them are equipped with solar panels to charge the batteries.

The twenty first century

In 2016 there are around 130 active lighthouses on the Australia coast and more than that number offshore. None of them is still manned. The last manned lighthouse in Australia was the Maatsuyker Island Lighthouse in Tasmania, which is also the most southern lighthouse in Australia, established in 1891. It was deactivated in 1996 and allowed to decay. However its restoration as a heritage item is now under way with assistance from

the Tasmanian Parks and Wildlife Service.

In addition to the active lighthouses there are many inactive lighthouses that still survive, some of them having been moved to new locations and preserved as heritage items.

Electronic aids to navigation

The first three radio beacons for marine navigation in Australia were installed in Victorian lighthouses in 1938 and 1939. By this time radio beacons were in common use on land for aircraft navigation, and some of these beacons could be used by ships. Since then many more radio beacons have been fitted to lighthouses, beacons and buoys. They typically have a range of around 25 miles. Ships that can simultaneously see more than one beacon can use them to calculate their location.

A racon is a marine radio responder beacon with a typical range of 10–20 miles. It can receive a pulse from a radar-equipped vessel and respond to it with a pulse at a higher power, enabling the vessel to display the beacon's distance and bearing on its radar screen. In 2010 there were 45 racon equipped beacons in Australia operated by AMSA.

Omega was a world-wide electronic navigation system that became operational around 1971. It had nine long-range transmitters around the world, including one in Australia at Derriman, Victoria that is mounted on a 427 m high steel lattice tower, the tallest structure in the southern hemisphere. Ships equipped with Omega could determine their position with an accuracy of around four kilometres from the signals picked up from at least three Omega beacons. The system was shut down in 1997, superseded by the Global Positioning System (GPS).

Various positioning systems based on using satellite transmitters were developed during the 1960s. GPS in its present form was fully operational in 1964, owned by the US government. Initially the signal available for civilian use was intentionally downgraded, but this restriction was removed in 2000. Since then the system has been progressively improved and it now has world-wide coverage. Receivers that can provide information on position and time can be small, cheap and reliable and are installed in most computers and mobile phones. GPS is ideally suited to marine navigation and can display the position of a vessel conveniently on a map under all weather conditions. GPS currently has the capability to determine position to within two metres, more than adequate accuracy for maritime application.

Cospas-Sarsat is an international system for generating and detecting electronic distress signals for use on land, sea and air. It was introduced in 1982 and has since been expanded and refined. Distress signals are generated by 'beacons' carried by aircraft, ships and individuals. There is a world-wide network of transmitters and receivers including many carried by satellites. In Australia the system for shipping is managed by AMSA. Most vessels travelling more than two miles from land are required to carry a beacon for distress signals.

Lighthouses as heritage items

At present maritime nations such as Australia maintain their systems of visual aids to navigation even though their essential functions can be effectively performed by electronic systems such as GPS. With electronic positioning systems now universal and of proven reliability and convenience of use, it seems inevitable that lighthouses will become virtually obsolete over the next few years and will be progressively inactivated.

Every state in Australia has conveniently accessible museums specialising in lighthouses, with examples of the lights and optical systems. In addition there are many operating and inactive lighthouses that are open to visitors. It seems likely that a representative group of lighthouses and their equipment will be carefully preserved in every state, although many of the inaccessible lighthouses will be allowed to decay and eventually be demolished.

Sources and further reading

Encyclopaedia Britannica has a good article on the history and the technology of lighthouses. It is available on line at <https://www.britannica.com/topic/lighthouse>.

The best history of Australian lighthouses is the book by Gordon Reid:

Reid, Gordon, & Foote, Murray & Australia. Department of Transport and Communications, *From dusk till dawn: a history of Australian lighthouses*. Macmillan in association with the Department of Transport and Communications, South Melbourne, 1988.

The following books by John Ibbotson provide brief details and photographs of most of the existing Australian lighthouses. They include a chronological list of all Australian lighthouses up to 2000. They also have brief details of lighthouse museums and lighthouses that are open to the public:

Ibbotson, John, *Lighthouses of Australia : images from the end of an era* (1st ed., reprinted with corrections), 2004, Australian Lighthouse Traders, Surrey Hills, Vic.

Ibbotson, John, *Lighthouses of Australia: the offshore lights*, 2006, Australian Lighthouse Traders, Surrey Hills, Vic.

The website <http://www.lighthouses.org.au/lights/index.asp> of Lighthouses of Australia Inc., a non-profit organisation which aims to create a higher profile for Australian lighthouses, contains an index of Australian lighthouses past and present, with images and brief details for most of them. It also contains a list of publications and links to sources of information on lighthouses.

Wikipedia has a listing of Australian lighthouses at https://en.wikipedia.org/wiki/List_of_lighthouses_and_lightvessels_in_Australia and also has extensive information on individual lighthouses and related topics.

There is much other information on lighthouses readily available on the internet.