Prof. Bondi. Does the possibility of two energy producing regions introduce difficulties?

Mr. Hoyle. No, the difficulties arise from the effects of gravitational, rather than from nuclear processes.

Dr. Atkinson. How much does the total helium content increase in the region between your two discontinuous solutions?

Mr. Hoyle. Not very much. The helium gives a large liberation of energy and the temperature rises rapidly. This accelerates the reaction and could lead to an unstable core.

Dr. Atkinson. Can you predict the occurrence of supernovae?

Mr. Hoyle. We require better techniques for calculating what happens when the core is fired to give a precise answer, but I would be very doubtful if supernovae had anything to do with this stage of evolution.

The President then thanked Mr. Hoyle and all those who had contributed to the discussion and adjourned the meeting until 1958 July 10 at the University College of North Staffordshire, Keele.

THE GREENWICH TIME BALL

By P. S. Laurie
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The institution of a Time Ball at the Royal Observatory, Greenwich, by John Pond in 1833 was a notable step in time distribution. Intended primarily for seamen and chronometer-makers, whose close contact with the Royal Observatory dated from 1821 when Pond undertook the superintendence of the trials of chronometers offered for Government purchase, the Time Ball provided the first authoritative time signal in the world.

Erected on the north-eastern turret of Wren's original building, the apparatus was constructed by Messrs. Maudslay and Field for the cost of about £180. The ball itself, some 5 feet in diameter, consisted of a wooden framework covered with leather. It was raised to the top of its 15-foot vane-surmounted mast by means of a winch situated in a small lobby near the external door of the Octagon Room. When the ball reached the top of the mast, it was held by a catch connected with a simple hand-operated trigger-mechanism. The time of release was taken from one of Graham's astronomical month clocks, regulated to Mean Solar Time, standing in the lobby.

The assistant responsible for the daily duty raised the ball half-way up the mast at 5 minutes to 1 o'clock as a preliminary warning. At two minutes to the hour he wound the ball up to the mast top. A slate, on which was written the error of the Ball Clock, hung nearby, and at precisely one o'clock the trigger was tripped, the beginning of the drop indicating the hour. At first a system of weights and pulleys took up the weight of the ball, but as this proved unsatisfactory a cast-iron cylinder and piston were fitted to slow down the rate of fall.

Two years after the erection of the Time Ball, G. B. Airy succeeded Pond as Astronomer Royal and immediately set about minimising the errors in the time signal, as shown by the following:—"1836. January 20. General Order. Comparison of Chronometers. Some time before 1 o'clock every day the comparison watch is to be carried round by one of the Transit assistants, setting it by the Transit Clock and Ball Clock, and bringing it back to the Transit Clock and comparing it with the Transit Clock". Later, a second assistant, watch in hand, independently recorded the time of drop, enabling Airy to report to the Board of Visitors—"I am thus in a condition to exhibit the absolute error in the time of its drop; it is usually a very small fraction of a second in time".

The simplicity of the mechanism resulted in few failures to drop the ball, although occasionally in severe weather, snow or hard frost, piled up on top of the ball as it slid up the mast, would freeze the moving parts to the mast. The expectant public was then on rare occasions treated to the sight of the unfortunate assistant in charge (or, probably, more expendable material, such as a supernumerary computer) attempting to scale the mast. The drop was, if possible, repeated at 2 o'clock. The only other circumstance preventing the drop was high wind; at the discretion of the duty assistant the ball was not raised. Any such failure was personally reported by Airy to Admiral Beaufort, the Hydrographer of the Navy.

Long-range observation of the Time Ball no doubt helped the Clerkenwell chronometer-makers, but sections of the public still seem to have remained in doubt as to the hour of drop, as many enquiries show. Reasons supporting the enquiries were sometimes given, such as:—"Mr. Henry Shaw bets Mr. Joseph Peters that the Ball which drops at the Royal Observatory at Greenwich to denote the time of Day, drops nearer the Hour of 12 o'clock in the Day than 1 o'clock, and Mr. Peters bets that the said Ball drops nearer the Hour of 1 o'clock than 12 o'clock daily. Both all the year round. This Bet is to be for the sum of Five Guineas, which said amount is to be spent at the "Victoria" (opposite Astley's), Westminster Bridge Road".

In 1852, after three years planning and negotiation with the Admiralty, Airy linked the Royal Observatory with the new electric telegraph system, then in the hands of private companies and the railways. Airy purchased a new Mean Solar Standard clock by Shepherd which not only dropped the Greenwich Time Ball but distributed time to London, via the Electric Telegraph Co. and the South-Eastern Railway, and then by means of a complicated piece of machinery, known as a "chronopher", along the railway telegraphs of the country.

It might have been thought that this advance in time distribution, coupled with the new submarine cables to the Continent and later across the Atlantic, would have sounded the death-knell of the Time-Ball.

Far from this being so, requests for time balls operated from Greenwich flowed in. A duplicate was put up by the Electric Telegraph Co. on their offices in the Strand and, in a circular to chronometer-makers, Airy stated that "implicit reliance may be placed on the accuracy of the time given by the drop of the Ball. The time occupied by the transmission of the galvanic current from the Royal Observatory to the Strand is about 1/3000 part of a second. The time occupied by the unloosing of the machinery which supports the Ball is less than 1/5 part of a second". From 1855 Airy superintended the dropping of a Time Ball at Deal, erected by the Admiralty on the old semaphore tower, for giving time signals to the ships in the Downs. This was ultimately followed by duplicates at Devonport, Portsmouth and Portland.

The Time Ball's one major disaster occurred on 1855 December 6 when, during a gale, the whole mast was blown into the Courtyard. Repairs took some two months.

Civic authorities and individuals continued to petition Airy, amongst them Lt. Col. Hall, of the Ordnance Survey in Southampton, whose note was brief "*This* port should have a Time Ball and I would be glad to afford you any assistance I could in getting it up". In the 'fifties other observatories, such as Liverpool and Edinburgh, followed the lead given by Greenwich. A Scottish periodical expressed the opinion that "we have little doubt that our time signals will be not less accurate than the English ones". By 1863 the 1 o'clock time signal from Greenwich was adding to its laurels by firing guns at Newcastle and North Shields. This form of time distribution became fairly popular, some guns remaining in service until today.

Although now over a century since the introduction of electric time signals, the Greenwich Time Ball has remained a popular and useful feature. The daily dropping of the ball was carried out with few interruptions from 1833 until World War II when the Time Department was moved from Greenwich for safety. After the War the Service was resumed and remained under the control of the Astronomer Royal until 1957 April. Recently removed for repair, the Greenwich Time Ball will, when re-erected, continue to give its familiar signal, but it will then be operated by the National Maritime Museum and the link with the Royal Observatory finally severed.