Vintage Radio

by PETER LANKSHEAR

National's legendary 'HRO'

Arguably the best known communications receiver of all time is the instantly recognisable National HRO. Technically very advanced at the time of its introduction, it combined mechanical and electrical excellence and remained in production with minimal changes for 30 years. Its concepts influenced communication receiver design right to the end of the valve era.

First some background to the advent of the HRO. In the January 1990 column, we showed how in 1929, the Pilot 'Super Wasp' was a major advance shortwave receiver design.

With such success, it was not long before the Super Wasp had competition. Within a year, the National Company of Malden, Massachusetts - in consultation with Robert Kruse, the Super Wasp's designer - had introduced the SW5 'Thrill Box' regenerative TRF shortwave receiver. With ganged tuning, and very smooth regeneration controls for a tetrode detector, the SW5 was a definite, but somewhat expensive advance on the Pilot receiver.

National, under the leadership of James Millen, a gifted mechanical engineer, had already established itself with its Browning Drake receivers as a maker of superlative components, an important factor in the success of the SW5. America's fledgling commercial aviation authority was setting up a communications network and chose the SW5 for its ground stations, an endorsement of the quality of National equipment.

Although by 1932 the superheterodyne dominated American domestic radio, there were still serious doubts as to its worth for shortwave work. However in April of that year, Hammarlund, National's competitor in quality products, released their 'Comet Pro' for communications work.

Covering from 1500kHz to 20MHz with plug in coils and with a beat frequency oscillator, the Comet Pro proved that a superhet communications receiver could be a viable proposition. Despite being without a radio frequency amplifier stage preceeding the mixer, and initially also without automatic gain control, the $88 Comet nevertheless confirmed the operational superiority of the superhet over the less selective regenerative TRFs.

Meanwhile, aviation radio was changing from CW (Morse) to radio telephone, and for this the SW5 was proving to be inadequate. At the request of the US Department of Commerce, National developed the Airport Ground Service (AGS) superheterodyne. Not only did this have an RF stage and AGC, but it featured a crystal IF filter, which had first appeared in 1930 in the English 'Stenode' superhet and publicised in America by the the amateur magazine *QST*, to provide remarkable selectivity.

The 'AGS' used three plug-in coils for each band, and covered a frequency range of 1500kHz to 20MHz. This receiver was a winner, but only the affluent could afford the cost of more than $200.

To cater for hams, in February 1933, National provided what was essentially a cut down AGS. Named the 'FB7', it had no RF stage or power supply, the BFO and crystal filter were optional, and the basic cost without valves was a much more affordable $33.

Late in 1933, with the knowledge already gained, National started work on a revolutionary new 'state of the art' receiver later to be known as the 'HRO'.

Split development

The distribution of the teamwork was unusual, but effective. Mechanical design work was the responsibility of a group located at National's headquarters in Massachusetts, while electrical research was undertaken by a laboratory in California. After specifications had been agreed to, each team concentrated on its own objectives without interference from the other, which otherwise may have compromised results.

The prime requisites for communications receivers, especially those with mechanical tuning, are solid construction and precision tuning drives, and no firm was better qualified to make these than National. Electrical design requires a mastery of circuit theory and a practical knowledge of operating, both qualifications of the Californian team.

The specifications were stringent. The

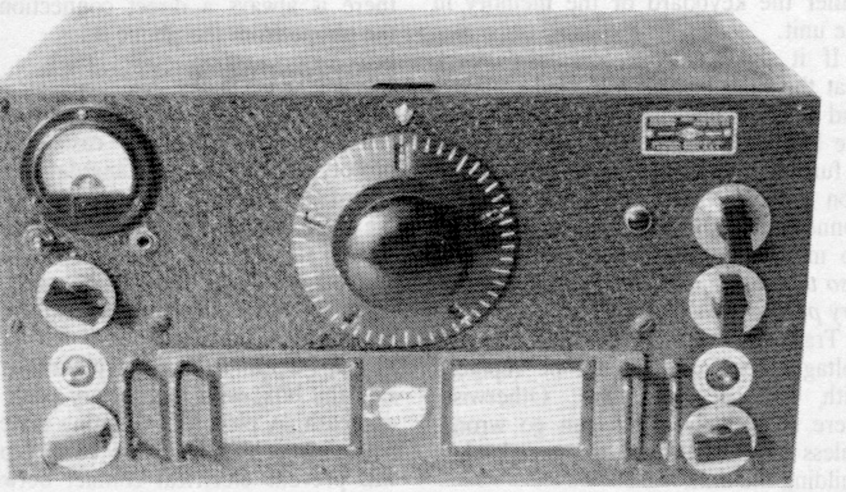

Fig.1: The unique 'PW' dial and plug-in coil boxes make the National HRO instantly recognisable. This wartime version is very similar to the original model of 1934.

proven IF transformers and Lamb crystal filter from the AGS were used without change. Trimmers and padders had air dielectrics. Typical of the quality of components, coil formers were moulded from powdered mica bonded in a bakelising process and grooved.

To give the greatest possible signal to noise ratio and protection from images, two RF stages were specified - at that time virtually unheard of in a superhet.

Band switching was too inefficient to be considered. Instead, in a unique system, the coils for each band, along with their padders and trimmers were mounted in rectangular boxes and assembled in sets of four on front plates to provide plug-in units. Contact studs on the boxes mated with fingers under the tuning capacitor, providing very short connecting leads.

These coil assemblies were plugged into the front panel, requiring the tuning capacitor to be mounted longitudinally, parallel to the panel. Consequently, a right angled drive was necessary, incorporating what was to become the famous 'PW' drive.

National trademark

If ever a component became an instantly recognisable company trademark, it was the unique National PW dial, an integral part of the PW assembly. As the dial rotated, the calibrations appeared through slots in its face.

Essential specifications were calibration accuracy, mechanical bandspreading and no backlash. A gearbox with a 20:1 heavily spring loaded worm drive was coupled to the epicyclic geared dial drive, having a readout capability of one part in 500 and an effective scale length of 12 feet! Most importantly, dial settings were repeatable.

The whole assembly was massively constructed. The 3/8" rotor shaft had bronze end bearings, insulated to reduce noise and alignment was maintained by four radial bearings. Stators were insulated with the promising new 'Steatite' ceramic. Each rotor section was insulated to improve stability by isolating earth returns.

The whole rigid assembly of tuning capacitor, gearbox and dial was an independent unit. Consequently, any racking or warping of the chassis had no effect on tuning.

The position of the tuning coils at the bottom of the chassis minimised, but did not completely eliminate drift from heating. Further efforts to reduce drift included making oscillator trimmers with a combination of aluminium plates, brass spacers and steel studs.

Chief among the heat reduction fea-

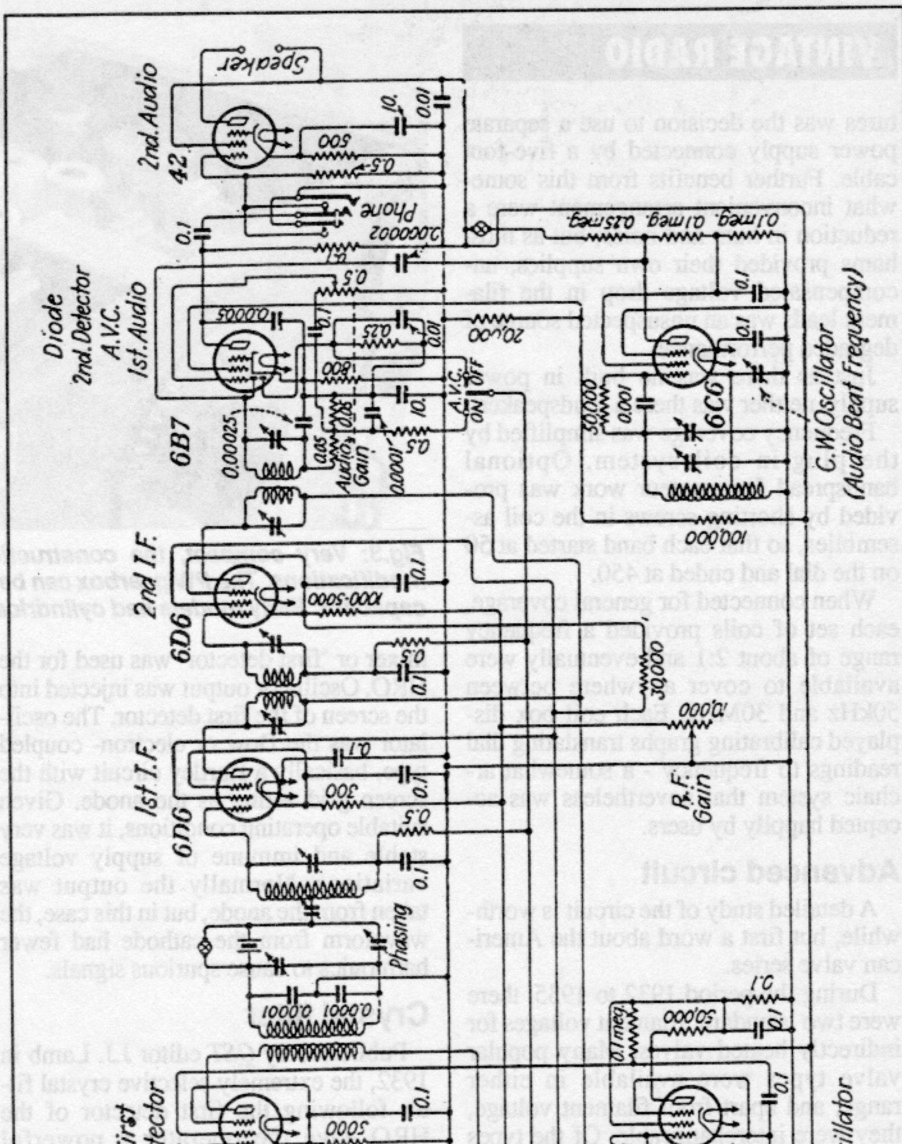

Fig.2: A classic example of sound design, there were no shortcuts or skimping of components; but neither were there any unnecessary frills. Originally 2.5 volt valves were recommended for mains operation.

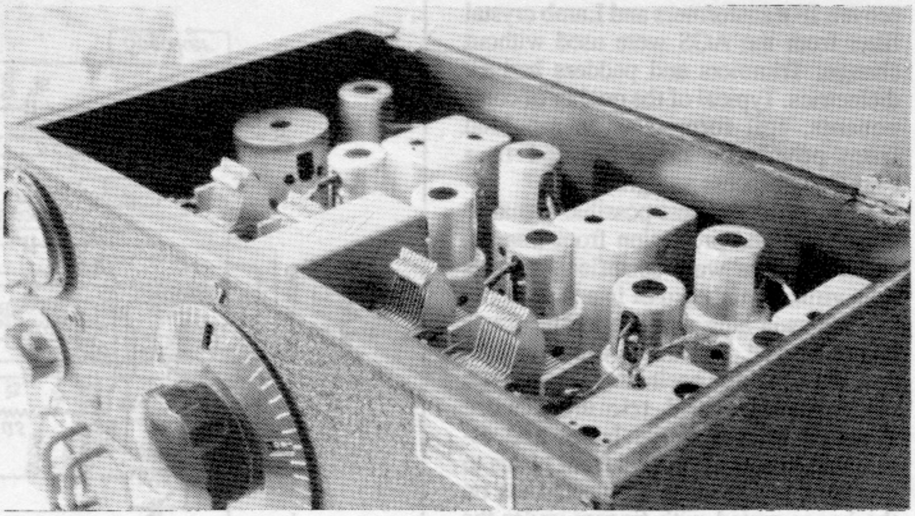

Fig.3: *Very compact, the construction of the HRO left little room for later modifications. The PW gearbox can be seen between the two halves of the tuning capacitor. Early models had cylindrical IF tuning capacitors.*

tures was the decision to use a separate power supply connected by a five-foot cable. Further benefits from this somewhat inconvenient arrangement were a reduction in hum and noise; but as most hams provided their own supplies, uncompensated voltage drop in the filament leads was an unsuspected source of degraded performance.

Just as there was no built in power supply, neither was there a loudspeaker.

Frequency coverage was simplified by the plug-in coil system. Optional bandspread for amateur work was provided by shorting screws in the coil assemblies, so that each band started at 50 on the dial and ended at 450.

When connected for general coverage, each set of coils provided a frequency range of about 2:1 and eventually were available to cover anywhere between 50kHz and 30MHz. Each coil box displayed calibrating graphs translating dial readings to frequency - a somewhat archaic system that nevertheless was accepted happily by users.

Advanced circuit

A detailed study of the circuit is worthwhile, but first a word about the American valve series.

During the period 1932 to 1935, there were two 'standard' filament voltages for indirectly heated valves. Many popular valve types were available in either range, and apart from filament voltage, they were interchangeable. Of the types used in the HRO, the 2A5 was identical electrically to the 42, the 58 to the 6D6, the 57 to the 6C6 and the 2B7 to the 6B7.

Initially, National specified the 2.5 volt series for mains operation of the HRO. Although their much higher current exacerbated the filament voltage drop problem, they were quieter, particularly around 15MHz where the early 6D6 valves produced modulation hum. Later this fault was cured and the 6.3 volt valves became standard for all types of service.

The two RF amplifiers were similar, and typical of good conservative design practice. For AM phone reception, automatic gain control (AGC) was applied to both stages. Variable cathode bias control was used for the second RF stage and the two IF amplifiers when receiving CW. Band spreading was obtained by transferring switching screws from internal coil terminals 2 to terminals 1.

Although the pentagrid converter became available during the development period, the superior combination of a separate oscillator and biased pentode mixer or 'first detector' was used for the HRO. Oscillator output was injected into the screen of the first detector. The oscillator was the Dow or electron- coupled type, basically a Hartley circuit with the screen grid acting as the anode. Given suitable operating conditions, it was very stable and immune of supply voltage variations. Normally the output was taken from the anode, but in this case, the waveform from the cathode had fewer harmonics to cause spurious signals.

Crystal filter

Publicised by *QST* editor J.J. Lamb in 1932, the extremely selective crystal filter following the first detector of the HRO gave the operator a powerful means of rejecting unwanted signals and remained standard equipment on any real communications receiver for the next forty years. The HRO filter was claimed to be capable of a bandwidth of only 20Hz.

A specialised version of tuning indicator, the 'S' meter was part of a bridge circuit in the anodes of the two IF valves. The two 500kHz IF amplifiers were conventional, using extremely well made transformers with air dielectric trimmers and provided much of the overall gain.

For CW reception, another (6C6) electron-coupled oscillator acted as the beat frequency oscillator (BFO). Next was the double- diode-pentode valve (6B7) performing several tasks. One diode acted as second detector, BFO injection point, and the AGC voltage source. During manual operation, the second diode clamped the inactive AGC line.

Plenty of audio amplification was provided by the resistance- coupled pentode section of the diode-pentode, feeding either the output stage or headphones. Finally, a standard output pentode (42) was provided to drive a loudspeaker. To avoid damage to the output valve, it was important to leave a speaker connected at all times.

The classic concept of the HRO, with its two RF stages, an oscillator/mixer followed by a crystal filter and two IF stages, BFO, detector and audio amplifier was so successful that it became almost a *defacto* standard for generations of high performance single-conversion communication receivers.

The HRO at work

First release of the HRO was during November 1934. It exceeded the aviation industry's specifications, and for the affluent who could afford the list price of \$233 (less 40% discount for hams) it was the ultimate experience. One unusual aviation application was operating without tuning dials in remote fixed tuned receiver installations.

Meanwhile, other manufacturers were not idle and before long many manufacturers including Hammarlund, Hallicrafters, Patterson, RME, and RCA were in competition. Their receivers all had band switching and direct reading dials. Nevertheless, the qualities of the HRO were such that it needed only a few minor modifications to retain its popularity. A further boost came in 1938 when Howard Hughes installed HRO receivers for his flight around the world.

World events then conspired to guarantee immortality for the HRO. In 1939 at the outbreak of war, Britain desperately needed communications receivers and all available HRO's were rounded up. The Admiralty found them to their liking and ordered a shipment from America. When America herself was put on a war footing, the HRO was in great demand by the armed forces and large numbers were made. Many of the HRO receivers to be found today, including the model pictured, were made at this time.

Even after 1946, the HRO remained a popular receiver. Naturally, modifications were made over the years, but right until it was finally withdrawn in the mid 1960's, the HRO with its magnificent PW dial was instantly recognisable.

Many imitations

If imitation is flattery then the HRO had plenty of admirers, for during World War II it was copied in a remarkable number of instances. Both the Germans and Japanese are reported to have made recognisable versions, but there are examples nearer home. Australia's Kingsley produced the 'AR7', and AWA the 'AMR-100'. Physically, these were HRO receivers, with equivalent specifications - although there were differences in valve types and circuits.

Less well known is that New Zealand too made HRO replicas. Collier and Beale produced some excellent models, using high mutual conductance TV valves in the front end. I well remember using a rack mounted set of three, arranged for triple diversity reception. When connected to three widely spaced aerials and tuned to the BBC's Pacific Service, the results were most impressive at the time.

AWA made an unusual receiver that looked like an HRO but wasn't! Using the traditional panel layout, PW dial and plug in coil boxes, it was a radio station monitoring and rebroadcast receiver, with only a single RF stage and very broad selectivity.

Collecting the HRO

The HRO is considered by many to be the most collectable communications receiver. Most common are the wartime models. However, be warned. Many of these receivers were understandably snapped up by amateurs. Hams, traditionally, are strivers for the ultimate and HRO's are quite likely to be found in much-modified condition. Provided that no mutilation has taken place, restoration is possible, but extra holes and missing components can tax even the most skillful restorer.

Finally how did the HRO get its odd name? Legend has it that the factory staff were under considerable pressure to push the development along. As the administration hadn't caught up sufficiently to issue a job code, the staff invented their own, writing on their time sheets 'H.O.R.', standing for Hell Of a Rush. The term HOR stuck, until someone felt that HRO sounded more circumspect.