A DECADE OF RADIO DEVELOPMENT - 1

Electronics technology has never remained static for long. Personal computers, home video recorders, compact disc players and satellite TV are some examples of considerable development in this last decade. In the 1920's and early 30's, there was a similar period of rapid evolution in domestic radio receivers.

In 1925, American radio manufacturing was expanding rapidly, to satisfy a huge demand for receivers for the booming new broadcasting industry. And despite the stock market crash and the following depression, a rapid rate of technical progress was maintained during the following decade.

By 1935, domestic receivers had evolved from dependence on battery powered triodes and with major problems in stable RF amplification, into high performance and reliable equipment that underwent little further basic development right to the end of the valve era. To get some idea of the extent of the changes in technology during this decade, in this and next month's column, we will compare a typical 1925 receiver with its 1935 counterpart from the same manufacturer.

Although during this period radio equipment was produced in many parts of the world, American developments were foremost — a result of the sheer size of their market, competition, purchasing power, the number of makers and economic influences. Because they were therefore 'state of the art', I have selected a pair of typical US-made receivers for comparison.

Despite our geographical remoteness and small populations, Australia and New Zealand receiver design was often in advance of Britain's and not far behind America's. For example, by 1933 the superheterodyne accounted for only 50% of British models, whereas here it had already become the standard. Philips did not produce a superheterodyne until 1934, the same year that AWA produced the first edition of the internationally published series of the *Radiotron Designer's Handbook.*

Pairs of 1925 and 1935 receivers from the one maker are not plentiful. Although literally hundreds of American firms joined the rush into radio manufacturing in the mid 1920's, the majority did not survive the crash and the depression. Similarly, few of the pioneer Australian companies were still making receivers in 1935. Furthermore, after 1930, tariffs restricted US imports into Australia and to a lesser extent into New Zealand.

One make that *was* available in both 1925 and 1935 was Stewart Warner. Like the better-known Atwater Kent organisation, before entering the radio business Stewart Warner was a well established maker of automobile accessories. In 1925, they produced their first radio, the model 300 TRF. This will be compared with their R-136 of 1935.

Over 1000 models

McMahon's *Radio Collector's Guide* lists 1173 identifiable American models for 1925. Three main classes of receiver were being produced, comprising 15 superheterodyne, 70 neutrodyne and an incredible 695 tuned-radio-frequency (TRF) models.

The remaining receivers were a miscellany ranging from crystal sets, through simple regenerative to reflexed receivers. Many were low performance or obsolete types that would not have sold in large numbers.

Of the three major types, most advanced was the expensive, and, for the time, very complex superheterodyne to which RCA had the monopoly for complete receivers.(They did, however, licence AWA to make an Australian version). The neutrodyne, usually with two neutralised tuned RF stages, was the industry's answer to the superhet. Neutralising stabilised and optimised gain from the triode valves used as RF amplifiers, but was avoided by most manufacturers as it was subject to Hazeltine Corporation royalties. Accordingly, the majority settled for the TRF receiver. This usually consisted of two RF amplifier stages, a grid-leak detector and two transformer-coupled audio amplifiers. As there was no ganging of the tuned circuits, the TRF, like the neutrodyne, generally had three tuning controls — which had to be adjusted more or less simultaneously.

The TRF was so simple that many makers did not bother to supply circuit diagrams. The chief variations were in the means of stabilisation of the triode RF stages to prevent oscillation, none being as efficient as neutralisation. One popular method was to connect resistors in series with the grids of the RF valves.

For their model 300, Stewart Warner used an earlier method that reduced the gain sufficiently to damp any tendency towards oscillation by positively biasing the control grids of the RF valves.

Fig.1: In 1925, domestic receivers had not become pieces of furniture. With its metal panel and lack of ornamentation, the Stewart Warner 300 was strictly functional in appearance.

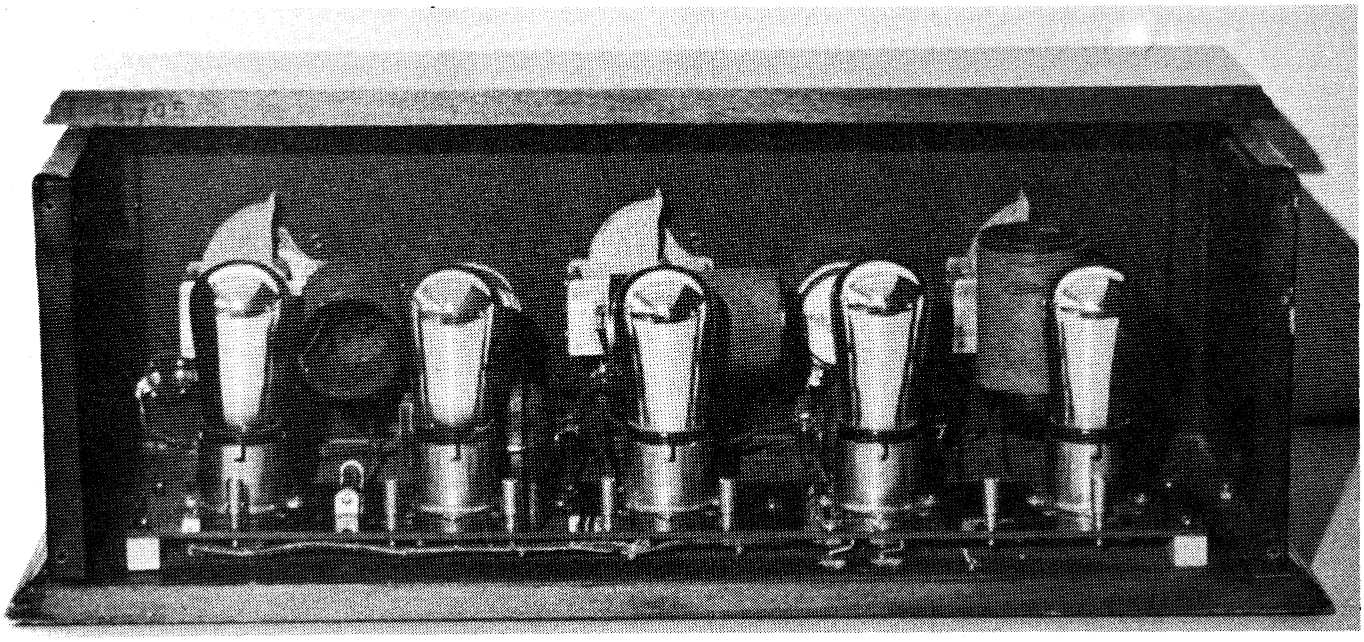


Fig.2: The rear of the Stewart Warner 300 with the wooden back and its attached lid removed. Directly under the lid, the all-important UV201A valves were readily accessible. From the right, they are 1st RF, output, 2nd RF, 1st audio and detector.

Many 1925 receivers had wooden cabinets and polished black front panels. For the 300, Stewart Warner chose a wrap-around brown crackle painted steel panel instead, but retained the mandatory hinged wooden lid and base.

Few components

Inside, the few components are laid out symmetrically on a baseboard. To minimise coupling, the large tuning coils, wound with green silk-covered wire, are mounted so as to be mutually at right angles. Between them are two audio transformers. An engraved strip of bakelite at the rear carries the five UV201A valve sockets, minor components and terminals.

There are only two fixed capacitors, both mica, and one fixed resistor — a 1 megohm grid leak. Two wirewound potentiometers and an on/off switch, complete the parts list.

The circuit in detail

Stewart Warner's model 300 is about as simple as a five valve radio can be. There are three variable capacitors, each carrying its associated tuning coil. The aerial terminal is connected to a tapping on the first coil — an efficient coupling method, but aerial capacitance affects the tuning capacitor setting, preventing ganging. Two RF amplifier stages follow, their anodes being fed through flat wound primary windings positioned inside the coil formers.

The 250pF grid capacitor for the detector is made of sheets of mica and tinfoil clamped between two pieces of fibre. There are two clips for the 'plug in' grid leak resistor, which may be anywhere between 0.5 and 5.0 megohms. Early grid leak resistors were made much like automotive fuses, with brass caps at each end of a glass tube protecting a carbonised element. The detector anode RF bypass capacitor is similar to the grid capacitor.

Following the detector is the audio amplifier, consisting of two identical transformer-coupled stages. With a transformer turns ratio of 1:3, each stage has a gain of about 25. In 1925, fidelity was not an issue, and like the associated horn loudspeakers, the small simple audio transformers have a very restricted response. More serious is the lack of power output. Even with optimum bias, a 201A with an anode supply of 90V is rated at providing only 15 milliwatts.

The two variable resistors provide interactive control of the receiver gain and stability. R1, called 'Battery Control' with a total resistance of 3 ohms, is connected in series with the negative filament lead, and is used to reduce the 6.0 volt battery supply to the rated 5.0 volts for the 201A valves.

The correct use of negative grid bias was not always fully understood in 1925, and a casual glance at the circuit gives an impression that the audio valves have none. In fact the voltage drop across the battery control does provide some bias, but only about 1V, which is less than RCA's recommended 4.5 volts for correct operation of a 201A at 90 volts HT.

Bias can be increased by reducing the filament voltage with the battery control, but the performance of the output valve is restricted even more. The Stewart Warner 300 is strictly low powered and low fidelity!

RF amp 'volume control'

'Volume Control' R2 is a 300-ohm potentiometer connected across the filament supply line, enabling the grid returns of the two RF valves to be varied continuously between the positive and negative leads. This effectively allows the grid bias to be varied from negative to positive. Valve operation is more or less normal with the wiper at the negative end of the control, but at the positive end, grid bias is cancelled and grid current flows, loading down the tuned circuits sufficiently to prevent oscillation.

The term 'volume control' is a misnomer, as it is more of a stability control. Significantly, positive grid operation was abandoned and grid bias batteries were used in the following year's models.

The third tuned circuit is connected to the grid-leak detector. Simple, sensitive and suited to transformer coupling, grid-leak detectors were used universally in early receivers. They effectively used the grid and cathode of the valve as a diode detector, with the resulting audio developed across the grid-leak resistor and then amplified by the valve in the normal way, as an audio amplifier.

Two transformer-coupled audio stages follow. They provide adequate gain, but as mentioned previously, the valves for these stages are under biased with inadequate power output even for a horn speaker. By later standards, audio transformer fidelity is poor, with little low frequency performance, and a restricted and peaked treble response.

The S-W 300 in use

Direct comparison of the operation of the 300 with that of a modern radio is difficult. In the early days, large outside aerials were standard, typically with 30 metres of wire suspended between 12-metre poles; but the situation today is very different. Signal strengths are now much higher, receivers are more sensitive, and internal ferrite aerials are generally adequate.

Connected to an aerial about 20 metres long and rising to 10 metres, a good earth system, a horn speaker and battery eliminator, the 300 was 'fired up'. First the 'Battery' control was set to give 5.0 volts at the filaments and then the 'Volume' control set at mid scale. A gentle tap on the detector valve produced a healthy 'pong' from the loudspeaker, showing that so far, all was well.

Tuning in a station ideally requires three hands! Unless all three tuned circuits are in fairly close alignment, these unganged receivers are quite 'dead'. An essential aid is a station log, giving individual settings for the dials. Unlike most of its contemporaries, the middle dial of the 300 has a wavelength scale in addition to the normal 0-100 scale, making station finding easier.

Initially, this dial was set to the wavelength of a local station and the aerial tuning dial turned to a similar position. Next the detector dial was slowly rotated until a faint signal was heard. All three dials were then adjusted for resonance.

With the first station logged, the settings for other stations became easier to find. At the lower frequencies, where RF gain is low, the 'Volume' control has little effect, but at the upper half of the tuning range, it is needed to prevent oscillation. Receiver gain is best controlled by detuning of one of the variable capacitors.

Selectivity is more than adequate to separate local stations, and below about 700kHz is comparable to that of a simple superhet. But it falls off at the upper end of the band. On the other hand, sensitivity becomes noticeably greater as the frequency is raised. When connected to a reasonable outside aerial, RF performance overall is much the same as that from a modern receiver using a small ferrite aerial.

With the restricted audio fidelity and power output, listening quickly becomes tiring. However, in 1925, radio in the home was a miracle, and receivers such as the Stewart Warner 300 brought much pleasure and opened new horizons for literally millions of listeners, who were unconcerned about any technical limitations. These could be dealt with later.

During the following decade they were in fact overcome, and in addition there was a tremendous number of new developments — many of which were incorporated in Stewart Warner's R-136, to be described next month.

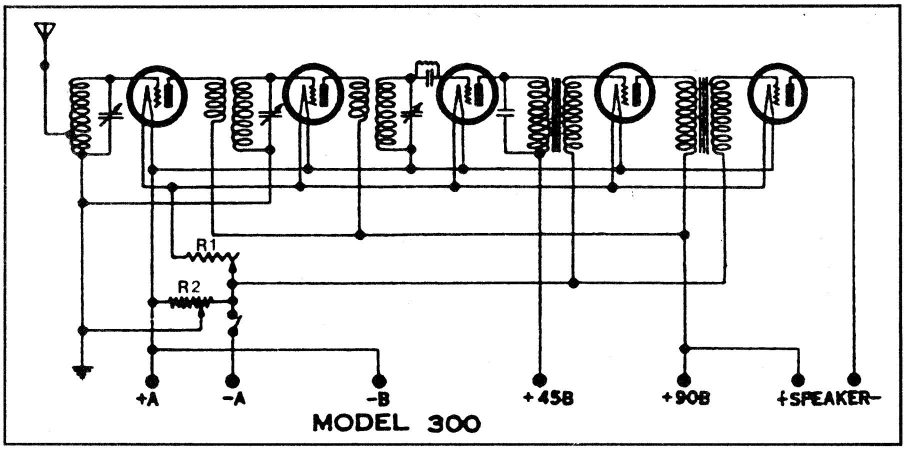


Fig.3: At this early stage, those manufacturers who did provide circuits rarely bothered to give component values. It's hard to imagine a simpler five valver.

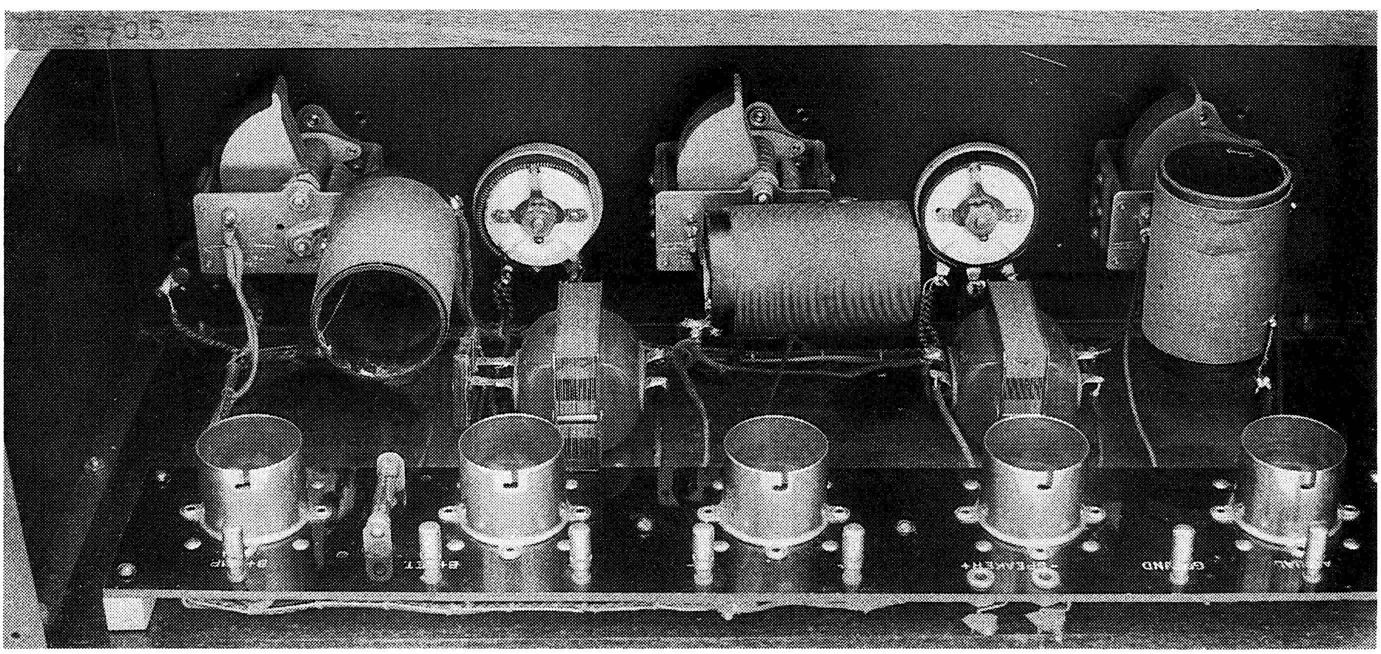


Fig.4: As this closeup shows, the construction was simple and not far removed from the 'breadboard' method popular with amateur builders of the time. TRF receivers used little if any shielding.

A DECADE OF RADIO DEVELOPMENT - 2

As we saw in the previous article, the primitive receivers of 1925, typified by the American made Stewart Warner 300, provided plenty of scope for development. This time we look at its lineal descendant, the 1935 model R-136 'Ferrodyne' chassis.

By the way, these American receivers have been selected because they were typical of their period, and Stewart Warner was one of the comparatively few manufacturers in business in 1925 who were able to survive the depression and thereby provide a continuity of models. I must emphasise that by 1935, locally made receivers compared very favourably with their US counterparts.

Continuous development

Each season there were such significant developments that often design details and cabinet fashion are sufficient to date receivers to the exact year of manufacture. Inevitably some ideas were abandoned after a brief trial, but by the mid 1930's, design had stabilised with features still to be found in receivers today.

Many historians regard 1930 as the transition year between the pioneering efforts and the 'modern' radio. By then, chassis construction, mains operation, and ganged tuning were standard, with increasing use of screen grid tetrodes and audio pentodes. Cabinets had become pieces of furniture, with integral moving coil speakers driven with adequate audio power.

Late in 1930, RCA relinquished its monopoly of the superheterodyne and within a year, other types were obsolete. Then followed variable-mu RF valves, RF pentodes, shortwave band switching, multi-function valves and much greater use of automatic gain control.

The golden years

There was a wide range of models available during the 1930's, ranging from elaborate 'top end of the market' receivers right through to budget priced rather 'low tech' models at the bottom end. Better grade broadcast receivers from this period can still hold their own alongside today's domestic radios.

By 1935, what may be called the standard superheterodyne had evolved. Thereafter, right to the end of the valve era, there were few major advances in domestic receiver technology. Of course there were still regular changes, but these were mostly in detail or cosmetic to meet the requirements of the marketing departments and simplification for economy. Design remained static during World War II and despite expectations to the contrary, few of the wartime developments in electronic technology had any significant influence on post war domestic AM receivers.

Later, smaller valves, which were not always as reliable as the older types, and better components became available, and in general receivers became simpler and cheaper, but not necessarily better. An example of a development that did nothing to improve valve receivers was the printed circuit. It is difficult to imagine solid state and integrated circuit technology without printed circuits, but boards in valve receivers were often carbonised from overheating by output valves and rectifiers, and cracks in the copper tracks were a problem.

But I digress. Let's compare Stewart Warner's R-136 receiver of 1935 with its predecessor of 1925.

First impressions

Seen side by side, it is difficult to believe that only 10 years separate the two receivers. The 300 is just a functional box with three large direct drive knobs, and covers only the medium wave broadcast band; but the cabinet of the R-136 has become a piece of furniture, featuring an elaborate 'Magic Dial' about 100mm in diameter. Frequency coverage is continuous in three bands, from 540kHz to 18.0MHz.

At this time, the term 'Magic' was in vogue, with receivers having 'magic eye' tuning indicators, 'magic brains' and in this case a magic dial. Stewart Warner had in fact used the description a couple of years earlier, to describe a dial in which the scales changed with band switching. In this case 'magic' refers to the scales being practically invisible unless the dial is lit!

The dial calibrations are accurate and colour coded for each band. Mechanically, the dial is an elaborate combination of gears and a planetary drive, with two concentric tuning knobs. In high ratio, 4.25 turns of the outer knob are required to rotate the tuning capacitor through 180°, whilst at the same time, a small single ended pointer rotates four times around a 360° logging scale. For fine tuning the planetary drive multiplies the gearing by a ratio of 5:1. Matching the bronze escutcheon, the main pointer

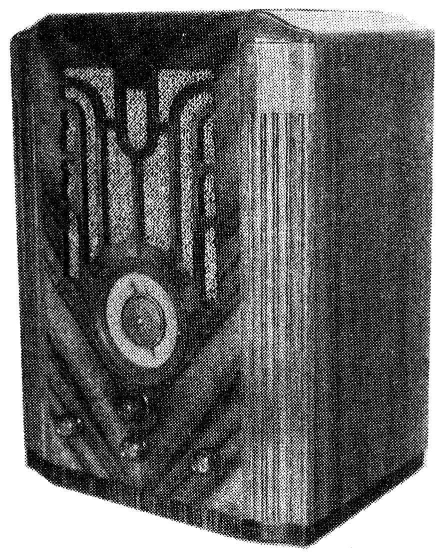
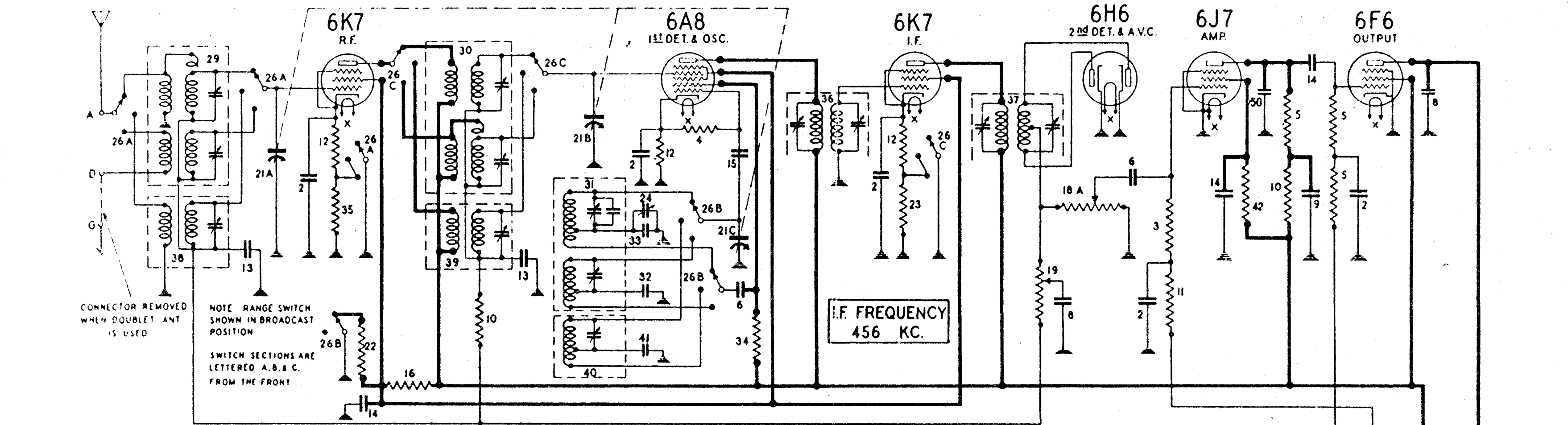
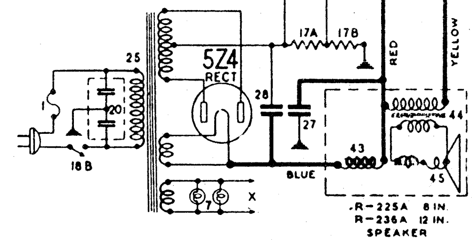
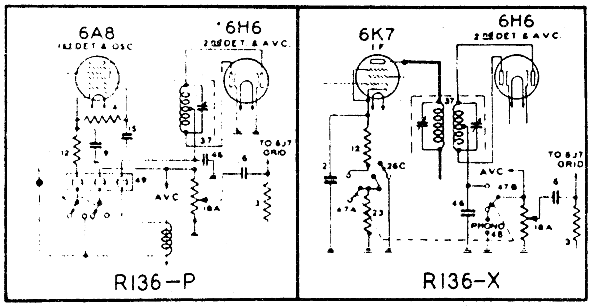


***Fig.1:** This mantel set was one of a number of Stewart Warner models using the R-136 chassis. Typical of 1935 fashion, its walnut veneered cabinet is finished in highly polished nitrocellulose lacquer with turned wooden knobs.*

STEWART-WARNER MODEL R-136 CHASSIS (RECEIVER MODELS 1361 to 1369)







PHONOGRAPH MODEL CIRCUITS

R-136 PARTS LIST

Diagram No.	Part No.	DESCRIPTION	List Price
1	38841	Fuse, 1 amp.	$0.10
2	81630	.1 mfd. 175 volt paper condenser	.30
3	83072	510,000 ohm 1/4 watt carbon resistor	.20
4	83080	51,000 ohm 1/4 watt carbon resistor	.20
5	83082	260,000 ohm 1/4 watt carbon resistor	.20
6	83219	.01 mfd. 600 volt paper condenser	.30
7	83278	Dial lamp 6.3 volt	.15
8	83706	.006 mfd. 600 volt paper condenser	.35
9	83974	.1 mfd. 200 volt paper condenser	.25
10	84198	110,000 ohm 1/4 watt carbon resistor	.30
11	84235	1.1 megohm 1/4 watt carbon resistor	.20
	84312	Output transformer (R-225-A 8" spkr.)	2.50
	84504	Diaphragm and shell assembly (R-225-A 8 inch speaker)	2.50
	84505	Field coil assembly (R-225-A 8" spkr.)	3.75
12	84888	300 ohm 1/2 watt wire wound resistor	.15
13	85053	.05 mfd. 100 volt paper condenser	.35
14	85059	.05 mfd. 300 volt paper condenser	.35
15	85061	.000051 mfd. mica condenser	.15
16	85063	15,000 ohm 2 watt carbon resistor	.25
17-A / 17-B	85067	275 ohm wire wound bias resistor / 25 ohm wire wound bias resistor } one unit	.50

R-136 PARTS LIST — CONT'D.

Diagram No.	Part No.	DESCRIPTION	List Price
18-A / 18-B	85073	250,000 ohm volume control / Line switch } one unit	$1.25
19	85074	500,000 ohm tone control	.85
20	85075	Dual .01 mfd. 750 volt A.C. paper cond.	1.00
21A to C	85084	3 Gang variable condenser	4.50
22	85116	25,000 ohm 1/2 watt carbon resistor	.15
23	85117	1,000 ohm 1/2 watt carbon resistor	.20
24	85285	Padding trimmer	.40
25	85428	Power trans. 115 V 60 cycle (136-A only) (See 85760 for other voltages and frequencies)	5.50
26A to C	85429	Three deck range switch	3.00
27	85430	16 mfd. 300 volt electrolytic condenser	1.25
28	85431	16 mfd. 400 volt electrolytic condenser	1.25
29	85432	Antenna coil and shield assembly (B & No. 3 S.W.)	2.75
30	85433	R. F. coil and shield assembly (B & No. 3 S.W.)	3.00
31	85434	Oscillator coil and shield assembly (B & No. 3 S.W.)	3.00
32	85440	.00351 mfd. mica condenser	.40
33	85441	.00042 mfd. mica condenser	.25
34	85442	21,000 ohm 1/2 watt carbon resistor	.20
35	85443	2,000 ohm 1/2 watt carbon resistor	.20
36	85452	1st I.F. transformer	2.50
37	85453	2nd I.F. transformer	2.50
38	85455	Antenna coil assembly (No. 2 S.W.)	1.50
39	85456	R.F. coil assembly (No. 2 S.W.)	1.50
40	85457	Oscillator coil assembly (No. 2 S.W.)	1.25
41	85467	.00137 mfd. mica condenser	.30
42	85472	1.6 megohm 1/4 watt carbon resistor	.15
43	85478	Field coil assembly (R-236-A spkr.) (See 84505 for R-225-A 8" spkr.)	5.00
44	85482	Output transformer (R-236-A 12" spkr.) (See 84312 on R-225-A 8" spkr.)	2.50
45	85592	Diaphragm and shell assembly (R-236-A 12" spkr.) (See 84504 for R-225-A 8 inch speaker)	3.50
50	84370	.00011 mfd. mica condenser	.15

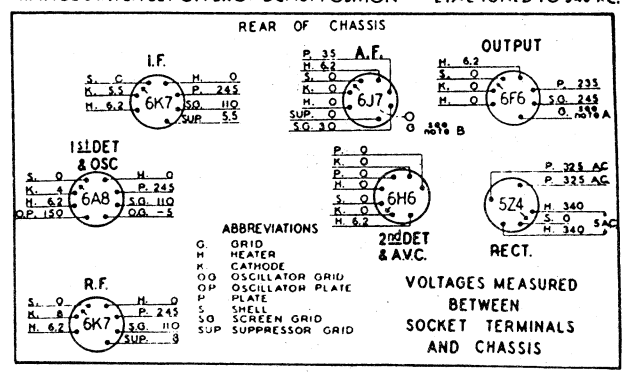
R-136P AND R-136X PARTS

Diagram No.	Part No.	DESCRIPTION	List Price
46	83539	.00026 mfd. mica cond. (136P & 136X)	$0.25
47A & B	84404	Phono toggle switch D.P.D.T. (136X)	1.10
48	84407	Phono terminal strip (136X)	.12
49	84112	3 lug terminal strip (136P)	.03
	85760	Power transformer 136X & 136-P only. (100 to 240 volts) (25 to 133 cycles)	8.50

Prices subject to change without notice

SOCKET VOLTAGES

LINE VOLTAGE 115 VOLTS Volume Control on Full ANTENNA GROUNDED
RANGE SWITCH SET ON BROADCAST POSITION DIAL TUNED TO 540 KC.



IMPORTANT: Use a high resistance meter of 1000 ohms per volt.
NOTE A: The grid bias on the 6F6 output tube is —16.5 volts, measured across the resistors 17A and 17B.
NOTE B: The grid bias on the 6J7 amplifier tube is —1.7 volts measured across resistor 17B.
Speaker field resistance is 1300 ohms with coil warm.

Compare the R-136 circuit schematic shown here with that for the 1925 set given in the previous article, to see the tremendous progress made in receiver design during that 10 year period. Locally produced sets of 1935 were very similar.

is of the double ended or 'airplane' type, the centre being reminiscent of a Roman shield. There is no tuning backlash and settings are repeatable, even at the highest frequencies.

Tidy interior

On looking inside the cabinet, the first things to catch the eye are the full set of metal valves. These, together with square coil and IF transformer cans, give the general impression of a tidy and uncluttered chassis. The eight-inch electromagnetic field speaker was almost a *de facto* standard in medium sized receivers, with consoles using twelve-inch speakers.

Two features were behind the term 'Ferrodyne' (techno-Latin-Greek for 'iron power'). One was the use of iron dust cores in the IF transformers — today used universally to improve efficiency in high frequency coils and inductors of all types. Stewart Warner has been credited with pioneering the use of iron cores, and these were first used in the R-136 chassis.

The other ferrous application was the use of the octal based metal series of valves. In May 1935, General Electric had marked their return to radio manufacturing by announcing their intention to equip their receivers with a full range of specially developed metal valves. In September, the first of these GE receivers appeared, and the circuit of the Stewart Warner R-136 chassis was published. It should be noted that despite the advertising fanfare and publicity surrounding the first series of metal valves, most were in fact existing types in new packaging.

Circuit details

Even a casual comparison of the circuit with that of the model 300 is sufficient to show that design had come a long way in 10 years, and readers may be interested in a detailed description of the R-136. Note that components are identified on the circuit by part numbers.

The aerial is switched between the primaries of the three aerial transformers. The broadcast and 6-17MHz coils are in shield can number 29, with the 1.5-6MHz coils in 38. A good feature is the provision for a balanced doublet aerial for the top band. The aerial transformer secondaries are connected at their lower ends to the AGC line and are switched to the tuning capacitor and the grid of the 6K7 RF amplifier valve by the band switch.

An interesting feature is the operating conditions for this and the IF amplifier valve. For broadcast band operation, additional cathode bias resistors 23 and 35 are switched in to reduce gain overall by something like 15dB. This helps match performance between the broadcast and shortwave bands, and makes handling on the broadcast band more tractable. A compensating resistor, component 22, is switched in to keep the screen grid voltages correct with the higher broadcast band bias.

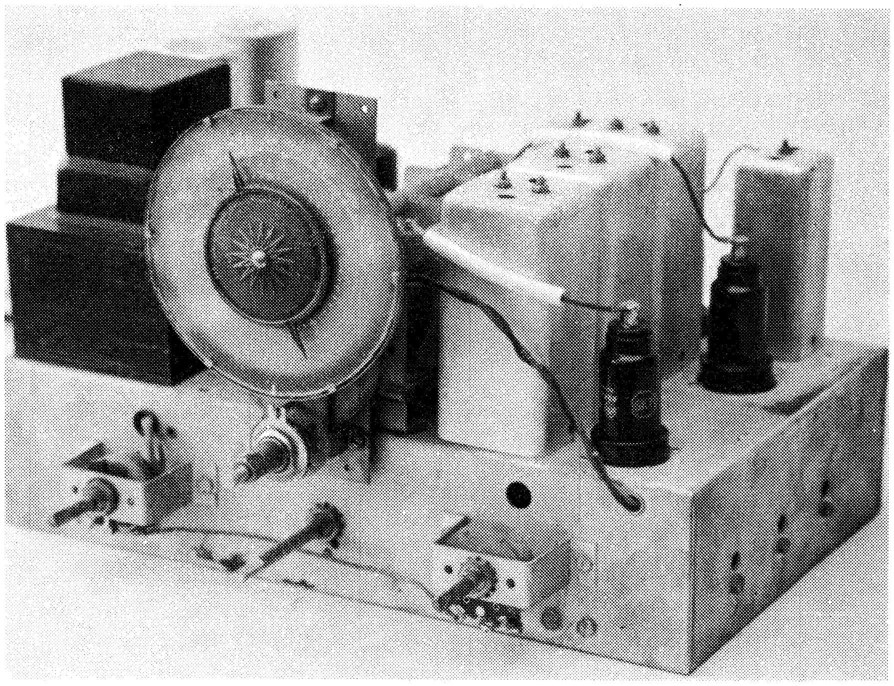


Fig.2: The uncluttered chassis of the Stewart Warner R-136. Below the dial is the planetary reduction drive and one of the brass gear wheels, a more sophisticated system than the string-driven pointer that later was to become fashionable.

No local/distance switch

Automatic gain (or volume) control had come into common use during the early 1930's, but it had its critics. One problem with high gain receivers was the rise in noise level as the gain increased during tuning between transmissions. Another was that by flattening out the tuning peak, AGC made accurate tuning of strong signals difficult.

A common method of minimising these problems was to provide the option of reducing receiver gain with a local/distance switch. Rather than provide a separate switch, Stewart Warner compromised with a permanent modest gain reduction for broadcast band reception. Overall gain is still more than can be fully used.

The RF amplifier feeds the pentagrid 6A8 mixer by means of the RF coupling coils. AGC is applied to this stage via resistor 10. By using a form of Hartley oscillator with the padder in the feedback path, oscillator performance is more consistent than with the conventional arrangement, but does not eliminate one problem common to pentagrid mixers. Above 15MHz, strong signals can 'pull' the oscillator frequency, making tuning a bit critical.

IF, AGC and detection

Apart from the bias switching, the IF amplifier is quite conventional, and with the double-tuned iron cored transformers it has plenty of gain. Designers seem to have been divided in their opinions as to whether or not automatic gain control should be applied to IF amplifiers. Each method has its merits, but in the case of the R-136 chassis, the amplifier is left uncontrolled.

The detector uses one of the few new valves developed for the 1935 metal octal series, the 6H6 double diode with separate cathodes. Instead of the familiar single diode detector, there is a fullwave biphase detector fed from a centre-tapped transformer winding. This system was used for a few years, but was going out of fashion in 1935. It has the advantage of requiring minimal RF filtering, but develops only half the output of a half wave detector, requires a centre-tapped IF transformer winding, and there is no delay in the AGC voltage.

Potentiometer 18A is a standard volume control, while potentiometer 19 is used as a combination AGC filter resistor and tone control.

High gain audio

The audio output of the R-136 is rated at 3 watts — 200 times the power capability of the 01A valve of the model 300. The resistance-coupled 6J7 and 6F6 valves used in the audio amplifier were the same internally as the existing 6C6/77 and 42 pentodes.

A minor criticism is that with only about 0.15 volts needed on the grid of the 6J7 to drive the 6F6 to full output, there is an embarrassment of gain which is quite unnecessary even with weak short-wave signals. This results in the use of no more than the first 30° of the volume control's range. A smaller value of load resistor for the 6J7 would make the receiver more docile.

By 1935, power supply design had become standardised. Filtering is provided by two 16uF capacitors (27 and 28) and the field winding of the electromagnetic speaker. The diagram shows a smaller field winding in series with the voice coil and output transformer. This is the 'hum bucking' coil, a few turns of heavy wire producing an out of phase voltage to cancel hum generated by the ripple in the HT current flowing in the main field winding.

Grid bias for the audio stages is provided by the voltage drop across resistors 17A and 17B in the negative return of the power supply. Cathode bias for audio amplifiers, although preferable technically, was not very popular during the 1930's, probably because low voltage electrolytic bypass capacitors were then rather unreliable.

The 5Z4 rectifier used here was the one unsuccessful member of the introductory range of metal valves. It proved to be unreliable and pending its redesign, the old faithful 80 was recalled as a stop gap. Given an octal base, and renamed the 5Y3G, it continued to be used for many more years.

In the 10 years following 1925, radio technology made tremendous advances. Whereas the Stewart Warner model 300 is just an interesting museum piece, receivers like the R-136 are still capable of providing good service, with a performance that compares very favourably with their modern counterparts.