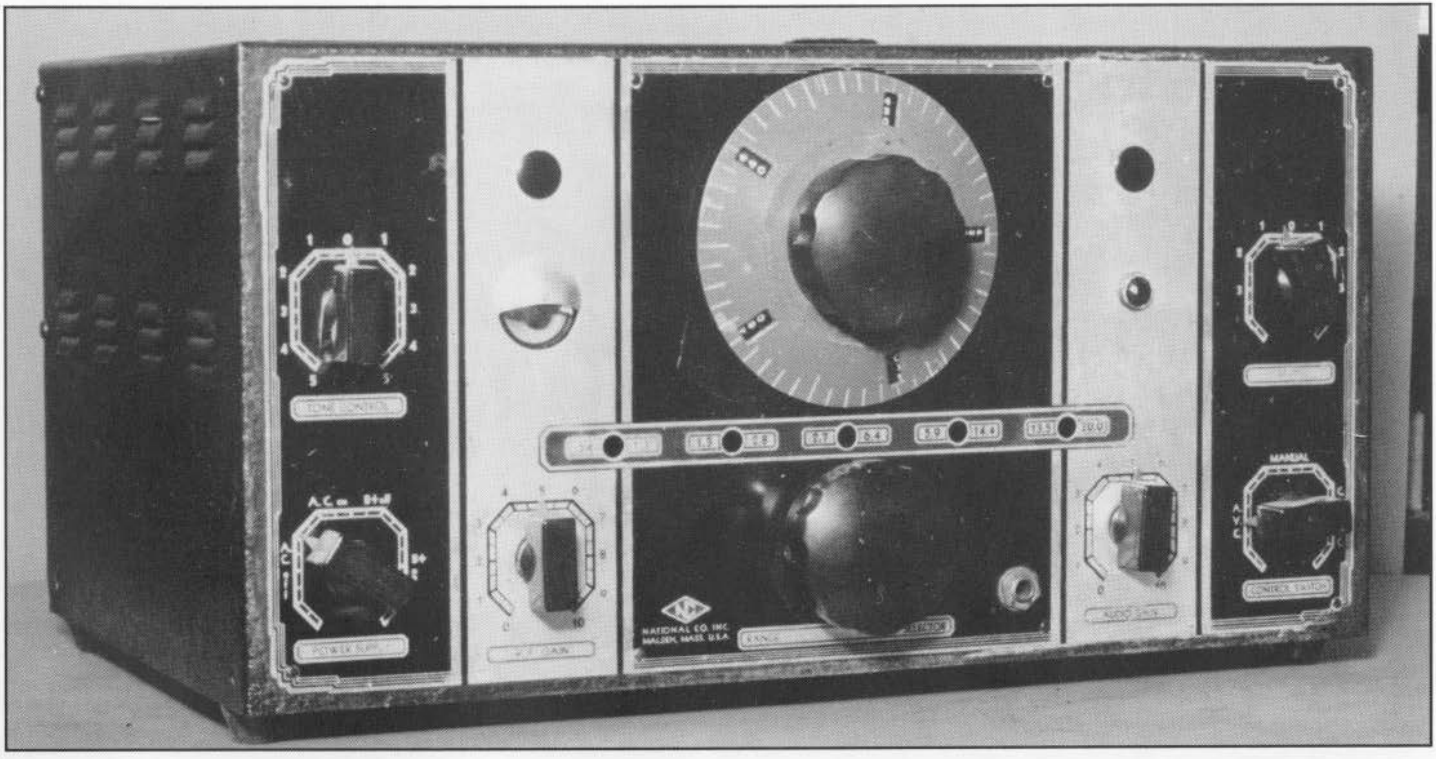


Figure 1. *The 1936 National Company NC-100, the first of the famous sliding-coil receivers. This relatively scarce receiver is noted by its "art deco" design, with a horizontal red stripe delineating the bands, and alternating silver and black vertical columns. The original main dial was finished with a gray enamel. This particular receiver does not have a crystal filter. (Photo Credit: Niel Wiegand.)*

THE NATIONAL COMPANY, INC. — THE COIL-CATACOMB RADIOS AND VARIATIONS ON A THEME...

Lawrence R. Ware
Winter Park, Florida

Introduction

The National Company, Inc. introduced the first of its now famous "coil-catacomb" radios with a brief announcement in 1935, and deliveries of the first radio of the series, the NC-100, started in 1936. The amateur version, the NC-101X, followed soon thereafter.

I have identified over sixty variants of the coil-catacomb design, not counting the battery-model versions, over the production years from 1936 to 1949. Today, few of these radios change hands at over $300, and most can be found for far less. To the radio collector, this is a target-rich environment!

In the beginning the NC-100 was not a great hit. The NC-101X did better with the amateur community, but National initially sold most of the coil-catacomb designs into the industrial and government market. The later NC-100A, with its direct-reading dial, addressed the most common complaint of users, that of having to interpolate the dial readings on the standard NC-100.

Quite a few variations of this series were built in the years leading up to World War II. During the war both National and Wells-Gardner, (using National parts) manufactured a large number of military variations. The majority were built for the US Navy. Large numbers of most of these radios were made, and quite a few survive into the present. National coil-catacomb radios were very common during the salad days of war surplus in the 50s.

I'm going to attempt to trace the family tree for you, and tell you a little something about each member. It is a given for a project like this that we will miss a few, but hopefully all the major branches will be covered. I have included a section, very similar to Raymond Moore's work, which details all the minor differences I'm aware of from version to version.

Those of you, like myself, who collect National coil-catacomb radios will find an almost bewildering array of minor variations. Someday I hope to own a least one example of each of the major family branches, but I'll leave the exhaustive and inclusive collecting of every variation to those with far more time and money than I have.

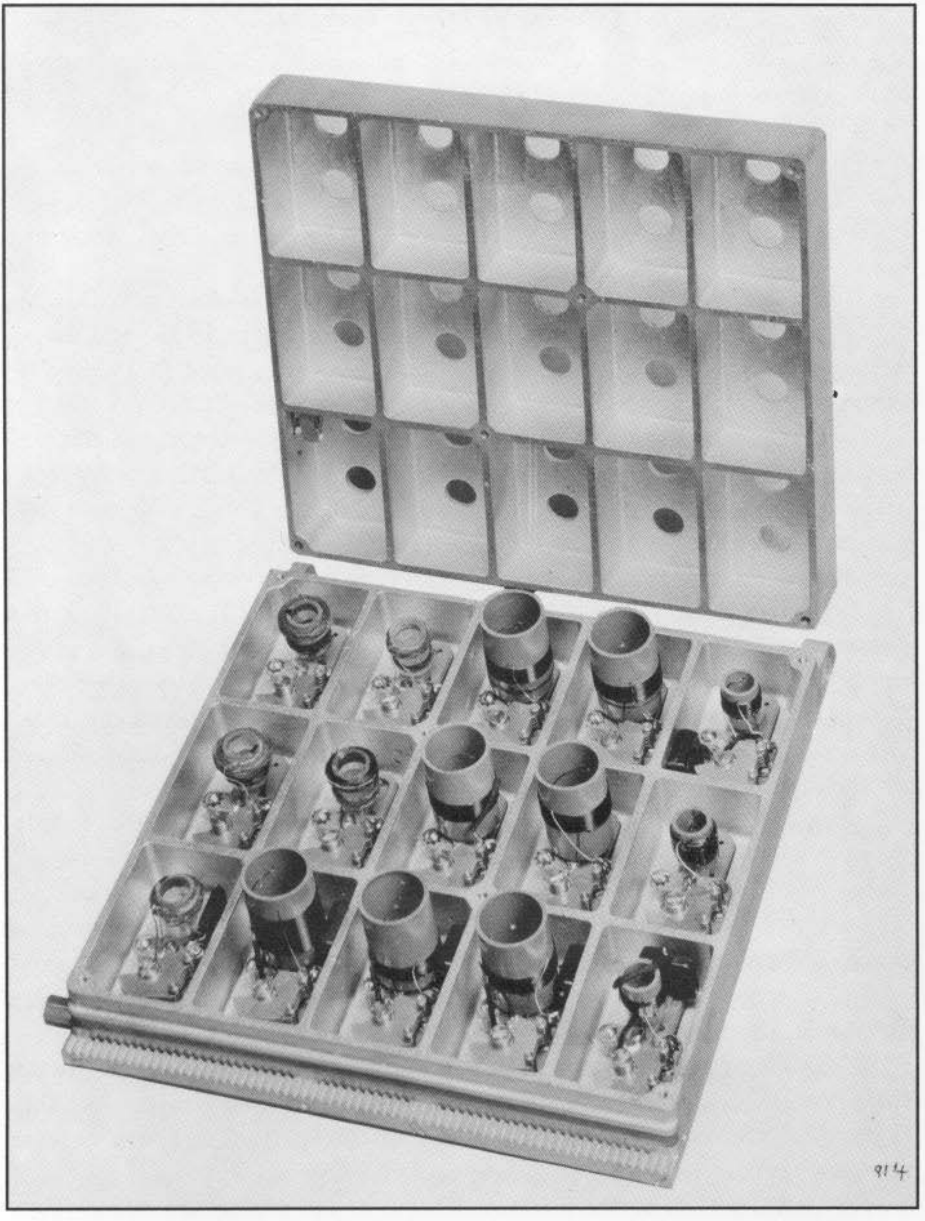


Figure 2. *The cast-aluminum coil tray with the three sets of RF transformers for each band. The steel rack gear is in the front. When closed, each coil is totally shielded from all the others.*

In 1936 the National Company, Inc., under the guidance of James Millen, began shipping the first of what was to become one of the most famous radio designs of the golden age of communications receivers, the technically-advanced and mechanically-brilliant NC-100 line. Equipped with an innovative cast-coil catacomb on a gear-driven sliding tray for band switching, the series represented the first truly high-performance communications receiver that did not require plug-in coil sets.

First announced in the 1935 National catalog, this design was to flourish throughout the years of World War II and continue in continuous production until at least 1948, a thirteen-year span that covered at least fifty different variations and thousands of units. By any standards a stunning success, the "coil-catacomb" design radios were used for every imaginable purpose, from living rooms to US Navy ships and submarines to commercial aircraft communications.

National called this innovation the "Movable-Coil Tuning Unit." Coupled with their "Micrometer Dial" system, commonly called the "PW" dial, they set the standard for repeatable tuning systems.

Notes On Nomenclature And Model Series

All commercial/industrial, amateur and consumer coil-catacomb Nationals of the era had model codes starting with NC-, as in NC-100, NC-100A, etc. Most but not all industrial and military variations had other model codes assigned to them (RAO-, RBH, RCP, etc.) Typical are the RAO-6 and RCK types. There were exceptions (see the NC-127) and some confusing overlapping (see the NC-120.) Also, some other nomenclature codes were sometimes assigned.

The Army, Navy, and Coast Guard all had their own numbering system in those days, and government organizations like the CAA (now the FAA) had yet another. This resulted in an almost bewildering array of model numbers, suffixes and revision numbers. Many military versions had three different model codes assigned: For example, the NC-156-2. This is the model number on the front panel of the radio. Seems simple - right? Yet, the radio was also known as the RBH-2 and as Radio Receiver type CNA-46188.

Fortunately, there are a few general guidelines we can use to help understand these radios. For example, a radio without the "A" suffix (NC-100, for example) prior to the NC-200 has the PW or Micrometer-type dial. An "A" as part of the suffix denotes the "A" series with a direct-reading dial, as with the NC-100A.

An "X" as part of the suffix denotes the addition of a crystal filter (NC-101X, NC-100XA or sometimes NC-100AX,) except when the radio was not available without one (see NC-200 and later.) There are as

many exceptions to these rules as radios that follow them, but fortunately most are military or industrial variations. Some models that were available with a 200 - 400 kHz band as an option are sometimes referred to as "LF" versions, as the NC-100ALF, etc. I have been unable to locate any National factory literature that uses this designation, so I believe it is either incorrect or highly specialized with a limited use.

From early National literature:

"The Movable-Coil Tuning Unit, heart of the NC-100, is an invention that makes it possible to shift plug-in coils by the twist of a knob... ... The turn of a knob slides the cast aluminum shield along its smooth-running track, and locks the desired set of coils into exact position directly below the tuning condenser... Each of the fifteen coils is in its own shielded compartment, and idle coils are completely out of the way. Rugged, silver-plated, side-wipe contacts provide dependable circuit connections... Air dielectric condensers are used for trimming circuits and R-39 is used for insulation.... The calibration of the NC-100 is permanent and precise... ...Vital to the precision of the tuning system are the geared tuning condenser and the Micrometer dial, with readings direct to one part in five hundred..."

This was quite a design achievement for 1935. Frequency accuracy was good, but repeatability was superb for the time. If you logged the BBC at 410 on the dial, it was at 410 night after night. Comparing this to other receivers of the day, only the HRO (also with a PW Micrometer dial) could even come close.

From the 1935 National Company, Inc. Catalog, page 17:

The NC-100 Receiver

A new receiver, to be known as the NC-100, is now in preparation. This new receiver will employ a very advanced type of tuning system. Coil ranges will shifted by a knob on the front panel, but no switch will be used. Instead, a set of plug-in coils, each in its own shield can, will be moved into position and plugged into the circuit by a built in mechanism. This system is admittedly the best from the electrical point of view, but its mechanical difficulties have discouraged its use in the past. The NC-100 receiver presents so many unusual features that it is not practical to make a complete description in the catalog, and consequently we are preparing a special booklet describing the receiver in detail. We plan to make first deliveries of the new receiver during December, and expect the price to be under $100.00. In the meantime, those desiring a copy of the booklet are invited to write us (give name and address) and we will forward a copy as soon as it is off the press.

From late 1936 National Company advertisements:

Announcing: The National NC-100 12-Tube Superheterodyne

The NC-100 is more than a newly-designed receiver, it is a new invention! Although coil ranges are shifted easily and quickly by the twist of a knob on the front panel, no coil switch is used. Instead, an ingenious mechanism moves efficient plug-in coils into position close to the tuning condenser and tubes, and plugs them in. Each of the fifteen HF coils is shielded in heavy cast aluminum, each is of a high-Q design, each has low-loss insulation, and each has its own individual air-dielectric padding condenser. Idle coils are completely isolated. Leads are short. Calibration is permanent. For the first time the uncompromised efficiency of plug-in coils has been combined with the convenience of the coil switch.

The precise and efficient Movable Coil Tuning Unit is just one of the many details that make the NC-100 so outstanding. Every tube in the NC-100, and there are twelve of them, contributes its full share to the remarkably high overall performance. The circuit employed on all ranges consists of one stage of RF, separate first detector and high frequency oscillator, two IF stages, a bias- type power detector and a transformer-coupled push-pull output stage. Maximum undistorted audio output is ten watts. A separate tube is employed to provide amplified and delayed AVC action, and a separate beat oscillator is included for CW reception. A built-in power supply provides all voltages required, including the speaker field.

But equal in importance to the circuit and tube layout is the long list of small details that make the NC-100 the superlative receiver that it is.

There is no substitute for quality. The heavy cast-aluminum coil shield, the thorough use of low-loss insulation, the high-Q coils, and the air-dielectric padding condensers, as well as a host of smaller details ranging from silver-plated contacts to the non-microphonic speaker cabinet, all contribute to high intelligibility on weak signals.

Particular attention has been paid to the convenience of the operator in the NC-100. Swift control of every function of the receiver is at your fingertips. The Movable Coil Tuning Unit permits instant selection of any one of five coil ranges, ranging from 540 kc. to 30 Mc. Matching the accuracy of this precision unit is the Micrometer Dial, direct reading to one part in five hundred, and having an effective scale length of twelve feet. The tuning of the NC-100 is as smooth as its logging is precise.

A 6E5 tube acts as an indicator both when tuning and when using the RF gain control for signal strength measurement. (Author's note: The tuning eye system was replaced in all but the earliest versions by a balanced-bridge type S-meter circuit.) *Panel switches permit optional use of automatic volume control and of the CW oscillator, and provide*

for cutting the plate voltage during periods of transmission. In addition to RF gain, an audio gain control and a tone control are included. These together with the (optional) single-signal filter give the operator complete control of receiver characteristics. Even the phone jack has received its share of attention, for it has been carefully located so that the phone cord will interfere as little as possible with the manipulation of controls and the use of the operating table.

Advantages Over Plug-In Coils Sets And Early Band-Switched Radios

No discussion of the NC-100 family would be complete without evaluating the pros and cons of the "Movable Coil Tuning Unit" or coil catacomb against the competing designs of the day. The competition can be summarized as follows:

A. Plug in coil radios like National's own HRO.
B. Bandswitched radios like many of the early Hallicrafters.
C. Single-band or fixed-frequency radios in general.

The contemporary National HRO receivers had slightly better book specifications, but minor differences in performance usually disappeared into the noise in the real world. The HRO could be ordered with custom, special coil sets by any customer willing to pay for them. In addition, the ability to have both general coverage and amateur-band bandspread coil sets used in the same radio did confer greater flexibility on the HRO until the introduction of the NC-200 series, around 1940. Both radios used the Micrometer (PW) tuning dial and both had very good performance for their time. Unlike the NC-100 line, HROs of the time also required an external power supply.

Most early bandswitched radios suffered to some extent from stray resonances and tuning peaks and valleys. These problems were much more prevalent in the lower-cost entry-level equipment sold to many new amateur-radio operators and short-wave listeners. Few if any of the competition ever came close to matching the repeatability of the custom-built National coil catacombs, tuning condensers and Micrometer dial. Even National's entry into the low-cost "starter" radio end of the market had good performance. (See the NC-80X/81X.)

Some single-band and fixed-frequency radios of the era exhibited equal performance. However, even those often lost out in large contracts to modified coil-catacomb-based designs. (See the AGR series.)

(Excerpt from the 1938 National NC-100 manual:)

For many years, we have used only "plug-in" inductors in National high-frequency receivers, because only by so doing could we build into these receivers the outstanding performance for which they are so well known. We have, of course, realized that a switching arrangement would be more convenient to the operator. Inasmuch, however, as the use of any switching arrangement that we know of would have resulted in a definite decrease in performance, we have steadfastly continued to use plug-in inductors. In the NC-100 receiver, we have now reached a design of plug-in inductor that is in every way equal to the switch in convenience, and at the same time retains all of the superior electrical and mechanical advantages of the original plug-in inductors.

Overview Of Family Tree And Production Timelines

1935: First mention in catalog of new receiver to be released.

1936: October: Full-page advertisements for the new NC-100 in *Short Wave Craft*, *Radio Craft*, and other popular magazines of the era. (These continued through December.)

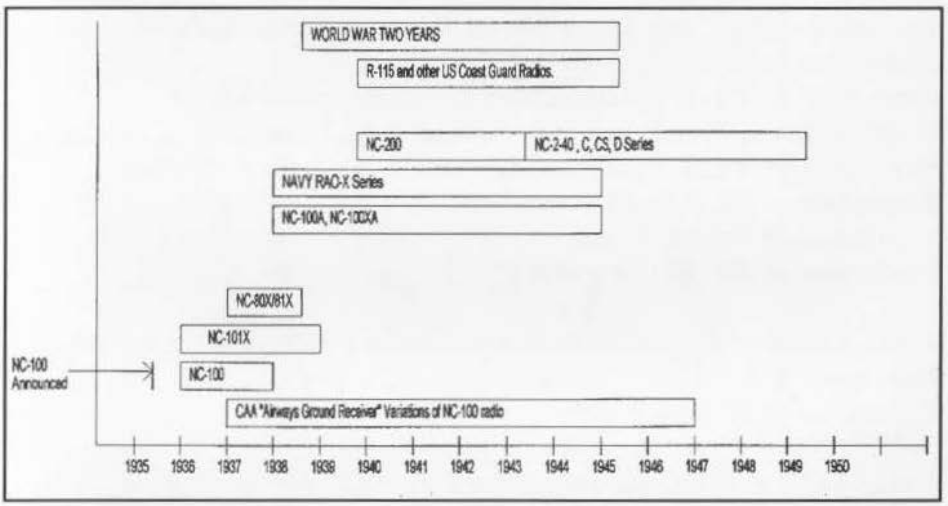


Figure 3. *Approximate years of manufacture of the National coil-catacomb receivers.*

1937: February: *QST* ad for NC-101X amateur-bands-only version of NC-100; also has crystal filter, still has tuning eye tube. Price $125.00.
Sometime in early 1937 about 100 type RCD radios were made under a CAA contract.
June: RCK type reported made as part of VF Radio Equipment No. 6736. (Pvt. communication)
October: First RCE types produced for CAA, Order # 38-2832 and #38-2833.
October: RCK type produced for CAA by Westinghouse, Order # 38-2833.
1937 National catalog lists the NC-100 (tuning-eye version) complete with tubes and speaker at $120.00
The battery model is $110.50 Adding the optional crystal filter brings the price to: $142.50
Also listed: The NC-80X at $88.00 complete with tubes and speaker. The NC-81X is available at the same price.

1938: Production of retail (standard) version of NC-100 ends.
Production of retail (standard) version of NC-100A starts.
Production of Navy RAO series begins with first RAO (no suffix) model.

1939: May: James Millen announces that he is leaving National and forming his own company, the James Millen Company, to manufacture and sell radio equipment:
June: First RCF types produced for CAA, Order # 39-2748
October: James Millen Company first ad in *QST* and catalog appears.
October: First RCH types produced for CAA, Order # 40-1760.
Production of NC-80X/81X discontinued
Production of NC-101X ends
Production of NC-100XA starts.

1940: October: NC-200 introduced to replace NC-101X among others.
December: R-115 Coast Guard contract TCG-23454.
Production of NC-200 begins.

1941: May: R-116 Coast Guard contract: TCG-33675.
June: RBH Navy contracts for type CNA-46144: contract 87668. (NXsr-87668?).
September: RC-120 Coast Guard contract: TCG-33991.

1943: 1943 *ARRL Handbook* (catalog section) lists both the NC-100A and NC-101XA along with options. Several versions (NC-101X, NC-101XA) are listed as "temporarily discontinued" because of the war.
January: RBH-2 Navy contracts for type CNA-46188: contract NXss-19881.

September: RAO-6 Navy contract: NXsr-38306.
Production of NC-200 ends.
Production of NC-2-40 begins (replaces NC-200).

1944: June: RAO-6 Navy contract: NXsr-38306.
NCRM experimental diversity system produced late 1944- early 1945.
Production of NC-2-40 ends.

1945: January: RAO-6 Navy contract: NXsr-38306.
May: RAO-7 Navy contract: NXsr55614.
October: Type RCP made for CAA, Order 46-1467.
NC-100A still in 1945 catalog, at $220.00 with speaker.
NC-100XA with speaker is $261.25.
NC-200 still in 1945 National catalog at $265.83 W/O speaker.
1945 Catalog has a picture of the NCRL and very brief mention. (P-21)
Experimental triple diversity NC-127D system built. Only one system believed made.
Production of NC-2-40C begins.
Production of retail version of NC-100A ends.

1946: April: War surplus has become available. In a Newark Electric Company ad, a National NC-100-ASD, complete with speaker in cabinet, is $115.00. Spare parts kit is $4.95.
Production of NC-2-40C ends according to Moore's 4th. It is still in the 1946 National catalog, along with the model NC-2-40CS, which has a low-frequency 200 - 400 kHz band.
Production of NC-2-40D begins according to Moore's 4th.

1947: Production of NC-2-40C ends (according to SRPP).
Production of NC-2-40D begins (according to SRPP).
May: James Millen unveils the "Designed For Performance" DFP201 and DFP501 at a Chicago trade show.

1948: February: Type RCQ made for CAA, Contract # CCA-26227.
August: CAA ordered field retrofit for RCP radios currently in service. Main change was addition of noise-limiter circuit. The modification order and instructions, (CAA Communications Engineering Division Circular # 41) was issued on August 17, 1948.
NC-2-40D still in National 1948 catalogs, at $241.44 with matching speaker.
Production of NC-2-40D ends according to SRPP.

1949: Production of NC-2-40D ends according to Moore's 4th.

THE MAJOR BRANCHES

The NC-100

The NC-100 receiver is a twelve-tube superheterodyne covering all frequencies, from 540 kHz to 30 MHz, in five ranges. The design in general consists of one RF stage, a separate first detector or mixer, a high-frequency oscillator, two stages of IF amplification, a bias-type power detector, and two stages of audio amplification. Another tube is employed for amplified AVC action. A separate beat-frequency oscillator (BFO) tube and circuit is included.

Civilian versions usually used a push-pull audio output design, while military versions usually had a single-ended output configuration.

A built-in ac power supply is included (except battery models) which provides all voltages required, including excitation for a speaker field coil.

From the NC-100 manual:

Controls:

The main tuning dial is located near the center of the front panel and operates the three-gang tuning condenser. This dial is of the multi-revolution type operating through a spring-loaded gear train having a step-down ratio of 20 to 1. In tuning across any one coil range, the dial makes ten complete revolutions and since its diameter is four inches, the equivalent scale length is approximately twelve feet. There are fifty divisions about ¼" apart around the circumference of the dial and the index numbers are changed automatically as the dial is rotated by means of an epicyclic gearing, so that the calibration is numbered consecutively from 0 to 500. The index numbers are actually changing continuously, the shift occurring at the bottom of the dial where it is not ordinarily visible.

Through this mechanism it is thus possible to obtain a continuous dial reading from 0 to 500, with the result that all signals are well spread out on the scale, making tuning and logging both convenient and precise.

The tuning system is so arranged that the dial reading increases with frequency, as shown by the calibration curves.

Immediately below the dial is the range-selector knob, which actuates the coil-changing mechanism. This knob must be rotated approximately one turn to change from one range to another. The arrangement is unique in that each individual coil is completely shielded from all the others and that only the coils actually in use are in any way connected to the circuit.

This automatic "plug-in" coil system is extremely efficient. Dead spots, often occurring when using unshielded coils in conjunction with a switch are, of course, completely absent and the particular coils in use

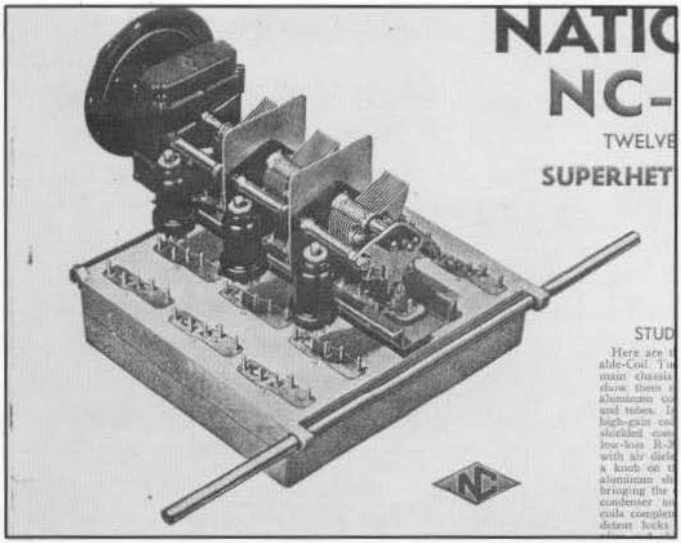


Figure 4. *A National Company introductory ad showing the relationship of the coil tray to the tuning capacitor and the front-end tubes, emphasizing the short, heavy signal paths for each band.*

are in the best position both mechanically and electrically. The relatively large movement of the coils, when changing from one range to another, makes possible the use of rugged contactors of such construction that trouble-free performance is assured.

The five coil ranges are marked on the front panel in a horizontal line directly over the range selector knob. Each of the range markings has a small window in back of which an indictor appears when that particular coil assembly is plugged into the circuit.

Starting at the left-hand side of the front panel, the uppermost knob is a tone control for varying the frequency characteristic of the audio amplifier. When the control is rotated to the extreme counter-clockwise position, high-frequency cut-off occurs at about 1500 cycles. In the mid-position the characteristic is flat from 50 to 10,000 cycles. At the extreme clockwise position, low-frequency cut off starts at 300 cycles, and the characteristic rises (about 6db) between 1000 and 5000 cycles.

When receiving strong signals free from interference, best audio quality will be obtained with the tone control set to zero. When receiving fairly weak signals through considerable interference, it is often helpful to retard the tone control so that noise will be reduced in relation to the signal.

Below the tone control is a combination switch. In the extreme counterclockwise position the receiver is turned off; in the mid-position all heater circuits and the rectifier are turned on but no B voltage is

applied; in the clockwise position the B+ is turned on to place the receiver in operating condition.

There are two insulated terminals mounted at the back of the receiver chassis, which are connected in parallel with the B+ switch. They are intended to serve as a convenient means for connecting a relay for automatically turning the receiver on and off.

To the right of this switch is the manual RF gain control. This control is ordinarily used only for receiving CW signals but may, of course, be used as a conventional volume control if the operator does not wish to use the AVC system. With the automatic volume control circuits in operation, as explained later, the RF gain control is limited in its action and is useful principally in adjusting the maximum sensitivity of the receiver.

For instance, if local noise and static level is high, the RF gain control need only be advanced to the point where the disturbance is just plainly audible. Signals may then be tuned in with the AGC on but inter-channel noise will not be objectionably high. It will be found that after a signal is tuned in, further advancing the control has no effect on output, inasmuch as the AVC characteristic is practically flat.

To the right of the range selector knob is the audio gain control, the primary purpose of which is to control volume (on either headphones or speaker) when using AVC. When using the manual RF control, the audio gain should not be retarded too far. If for instance, it is set below three or four on the scale, audio output will be limited to the point where IF overload may occur before maximum output is reached.

The knob at the lower right-hand corner of the front panel is a combination switch having three positions. In the counterclockwise position the AVC circuits are in operation; mid-position the AVC is turned off; in the clockwise position the CW oscillator is turned on, the AVC still being off.

Above this switch is the CW oscillator vernier tuning control, which varies the frequency of the oscillator over about 10 kc.

Near the tuning dial is mounted a pilot light and an electron-ray tuning indicator. The pilot is lighted at all times when the ac switch is turned on, but the tuning indicator is lighted only when the B+ switch is on. The purpose of the tuning indicator is to provide a visual means of accurately tuning phone signals. The shaded portion of the tuning indicator normally covers a sector of about 90 degrees. When tuning in a signal, the shaded area will become smaller, correct tuning being indicated by the smallest angle....

On models of the NC-100 having the crystal filter (NC-100X) two additional controls are provided, and these are mounted at the right-hand side of the tuning dial. The uppermost knob is the selectivity control of the crystal filter. With the filter in use, minimum selectivity will be found with the pointer nearly vertical. Rotating the knob in either direction

from this position will increase selectivity. When the filter is not in use, the knob should be set at the point giving maximum volume and sensitivity.

Immediately below the selectivity control is the phasing control and crystal filter switch. Turning this control to zero disconnects the filter; at any other setting between 1 and 10, it acts as a phasing condenser for balancing the crystal bridge circuit, eliminating heterodynes, etc.

The NC-101X (first amateur model)

On May 11, 1976 James Millen wrote a letter to William Orr of Eimac in which he briefly discussed the NC-101X. Some excerpts from the letter:

"... But I do well remember traveling around the country in the early NC-100 days visiting ham dealers in the daytime and attending local ham club meetings in the evenings promoting the NC-100 sales. The reaction was that no matter how intriguing the band-switching construction, (Author's note: JM is referring to the coil-catacomb design) *the styling, (front panel) the lack of band-spread tuning and the price, while fine for the new breed of "short wave listeners" was just not what the ham wanted.*

"As well as I can recollect, this point was hammered home to me at an impromptu meeting with a group of Pittsburgh hams one evening at the old Cameradio Amateur Supply Co. and then, again, later that same week in Chicago with another group...

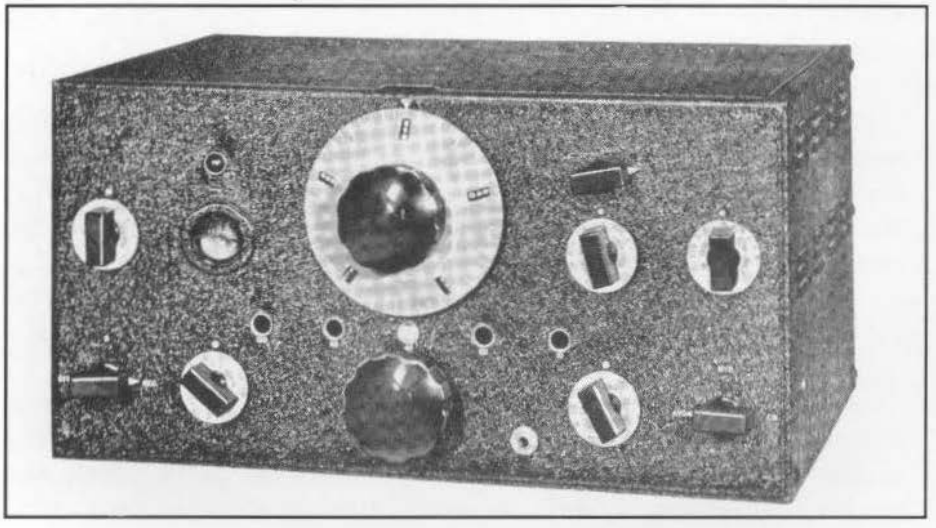


Figure 5. *The 1937 NC-101X, the amateur-band version, covering the five low-frequency amateur bands then in use.*

"... In the back of their pioneer ham supply house, CHIRAD, on hotel stationery, the sketches and notes for the evolution of the 101 from the 100 were completed and sent to Malden before I ever got back to North Reading and the lab."

William Orr reported (*CQ*, October, 1978) that:

"It appears that the problem was turned over to three amateurs: Dana Bacon (W1BZR), Calvin Hadlock (W1CTW) and Tom Leonard. These three, under the supervision of Phil Eyrick, a machinist-model maker, turned out a prototype NC-101X receiver in short time. The first commercial receiver for amateur-band only reception."

Thus, the NC-101X was born...

Later in the same letter, JM refers to the later "A" model with direct reading dial:

"...The more conservative front panel of the 101, plus the desire to incorporate a direct-reading calibrated scale, led to the 100A with the length of the telescoping dial pointer controlled by the coil catacomb position and consequent operating band."

The NC-101X is essentially the same radio as the NC-100X, the only difference being the amateur-band-only tuning by the use of a different main 3-gang tuning capacitor. Early models have a tuning-eye tube, while later versions have a S-meter. I do not believe this radio was available without the crystal filter.

From the National Special Instructions for the NC-101X receiver:

The NC-101X is a special model of the NC-100X receiver, employing the same circuit, etc., but covering only the five low-frequency amateur bands. Each of these bands is spread out over the major portion of the dial and, as shown by the calibration curves, each band starts at 50 and ends at 450. The curves are accurate to about 0.25% of the operating frequency.

The National NC-100A Series:

When introduced in 1938 the NC-100A specifically addressed what was perceived as the major failing of the NC-100, the lack of a direct-reading dial. The NC-100, while doing well in the industrial market, had been a disappointing sales failure for National in the rapidly growing short-wave listening (SWL) market in America. The "A" line directly addressed the most common complaint by incorporating both a new

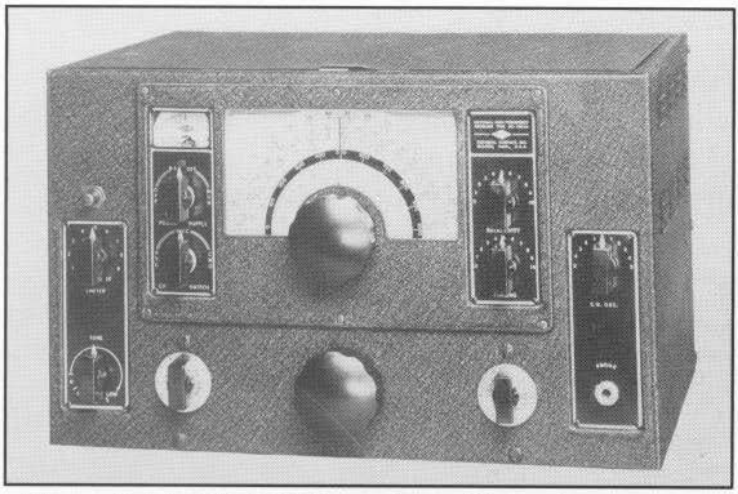


Figure 6. *The NC-100 XA receiver, with the direct-reading dial. The X signifies a crystal filter.*

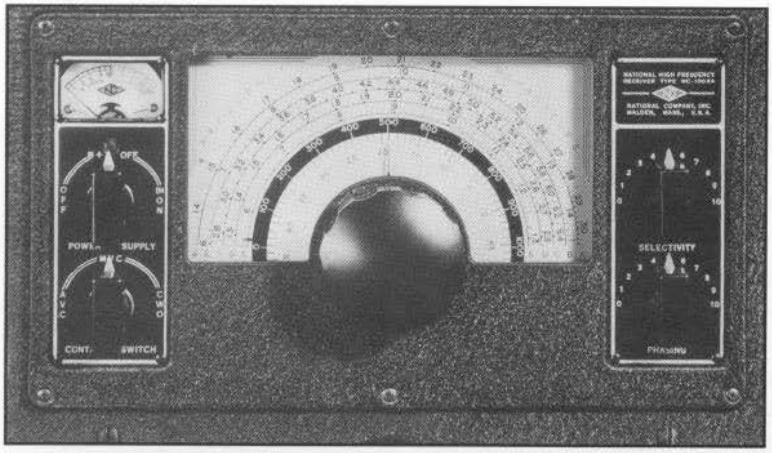


Figure 7. *A close view of the NC-100 A dial calibrations.*

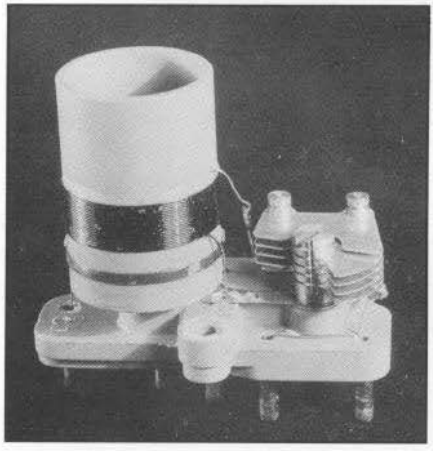


Figure 8. *One of the coil assemblies.*

Figure 9. *A desk group of the now-rare National NTX 30 transmitter paired with the NC-100 XA receiver and matching speaker.*

direct-reading dial system for frequency, and a moving pointer to indicate the selected band. Somewhat taller than its predecessor, the 100A also included the much easier-to-use S meter, replacing the tuning-eye. As far as I'm aware, all "A" models also incorporated National's "noise peak-limiter" circuit. NC-100AX models included crystal-filter circuits.

A number of variations of the NC-100A were built. They were available as the X version with a crystal filter, and with a LF band (200 – 400 kHz) instead of the standard 540 – 1,300 kHz "low" band.

There were also at least two versions of the battery models. The first needed external B+ and 6.3-volt filament power supplied, and the second contained an internal vibrator power supply and required only six-volt dc power to operate.

The direct-reading dial system had five bands or scales calibrated for the five sets of band-tuning electronics in the coil catacomb. The band-change knob moved the coil catacomb along the internal rail to select the appropriate band. The direct-dial system also was equipped with an auxiliary numerical dial with 100 divisions on it. The dial made ten revolutions as the tuning capacitor rotated through 180 degrees. This allowed for logging and a very high repeatability, with a direct reading to one part in a thousand.

The basic NC-100XA design was incorporated into many Navy variants (see the RAO Series.)

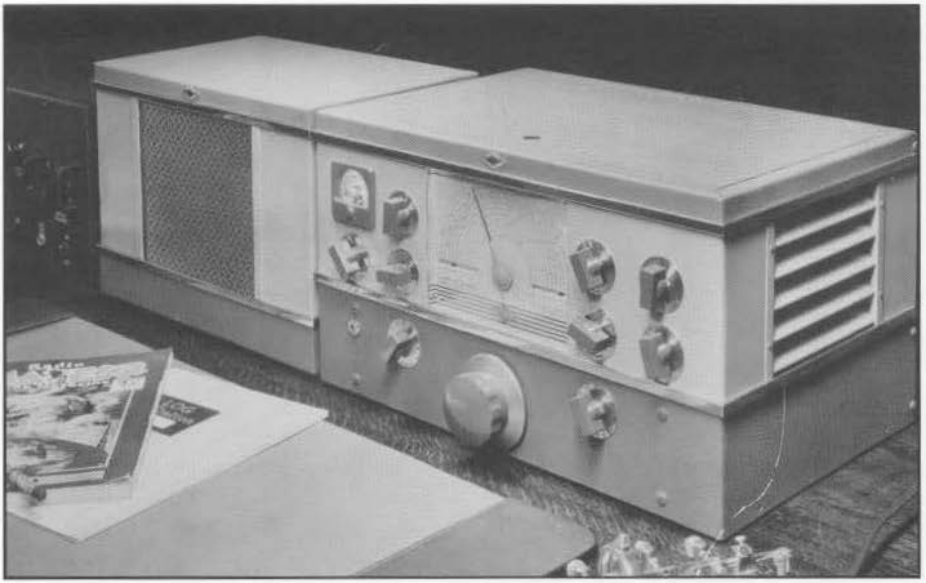


Figure 10. *The NC-200 receiver and matching speaker.*

The NC-200 Series:

The NC-200, developed about 1940, was the first National coil-catacomb radio to combine both tuning and band selection into a single main control. Called a "Universal Communications Receiver" in the National manuals, where earlier models used two large control knobs, one for band switching and one for tuning, the NC-200 had a single, integrated frequency-control system. "Pulling" the main control out engaged the bandswitching function and allowed the operator to select any of six general-coverage or four amateur-bandspread ranges. Pushing the main control inward linked the tuning drive to the tuning capacitor and the direct-reading dial.

Needing to manufacture only one receiver for both, the general coverage and amateur markets offset the added complexity of both the main control and far more complex coil-catacomb. SWL (short wave listening) was a popular pastime during the war years, so the ability to use the radio for both SWL and amateur radio should have been a strong selling point. The radio used a good sounding push-pull audio output system (two 6V6s), and came complete with a crystal filter and matching speaker in a more modern and consumer-oriented case than the typical back-wrinkle finish of the earlier National receivers. Large "cooling" louvers on the sides gave it a very modern look.

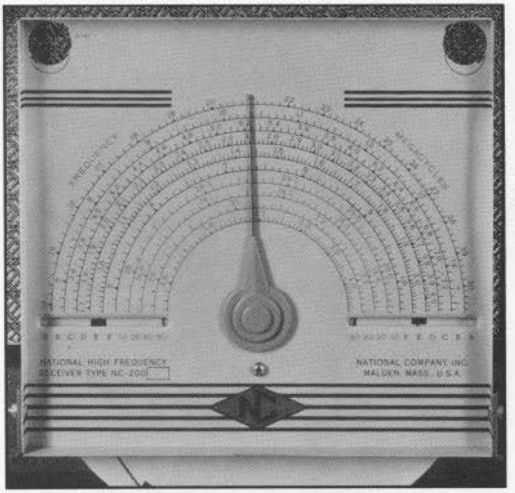


Figure 11. *A close-up view of the NC-200 dial.*

With the exception of the new tuning mechanism and ten bands in one radio, the NC-200 was a conventional National superheterodyne design. The series noise limiter and Lamb-type crystal filter were included. The NC-200 evolved into the NC-2-40, which became the NC-2-40C, -CS and eventually the NC-2-40D, the last of the line for National coil-catacomb receivers.

The National NC-2-40 Series:

The NC-2-40 series radios are conventional twelve-tube superheterodyne designs with continuous-frequency coverage from 490 kHz to 30 MHz. The receiver was designed to allow the amateur operator to use bandspread on the 80, 40, 20, 11, and 10-meter bands without sacrificing performance in general-coverage applications.

Figure 12. *NC-2-40 receiver with external power pack. This is a developmental version, and it is doubtful that any reached the market.*

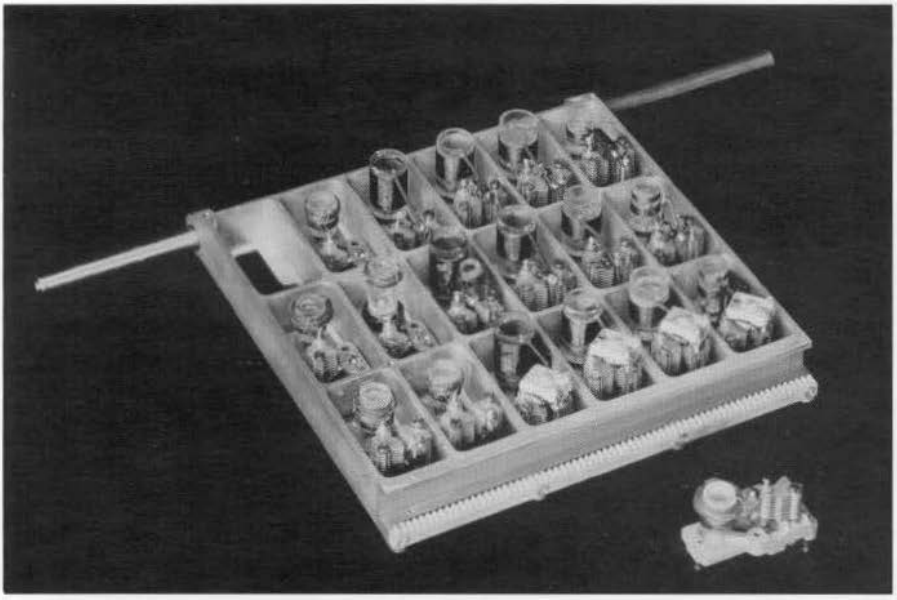


Figure 13. *Coil tray and coils for the NC-200 receiver.*

The - 2-40 series were extremely sensitive receivers with a specified output of one watt of audio for a one-microvolt antenna input signal. National touted high-frequency improvements based on molded polystyrene coil forms, Isolanite condenser parts and tube sockets, etc.

Most of the - 2-40 series included cadmium-plated chassis to provide positive grounds and better conductivity as well as a nicer appearance.

The National "Airways Ground Receiver" (AGR) Series

From 1937 to 1948 the government bought many modified NC-100 (non-A) series radios for aviation-ground-station related use. The CAA NC-100 variants are known by a series of model codes. All have three letters (RCD, RCE, RCK, RCL, RCP, etc.) and reflect changes in the basic design and also some by the government sub-contractor.

All of these radios started out life as National NC-100s. National was well known as a primary supplier of both components and sub-assemblies to many other radio companies. It would only have been a small step for them to move into supplying complete radios to other government contractors. Perhaps the non-converted radios already belonged to the CAA? I have been unable to locate any records that could shed light on this aspect of the AGR's history.

An unresolved question about the NC-100-based "Airways Ground Receiver(s)" is: How many were originally built and sold to the CAA by

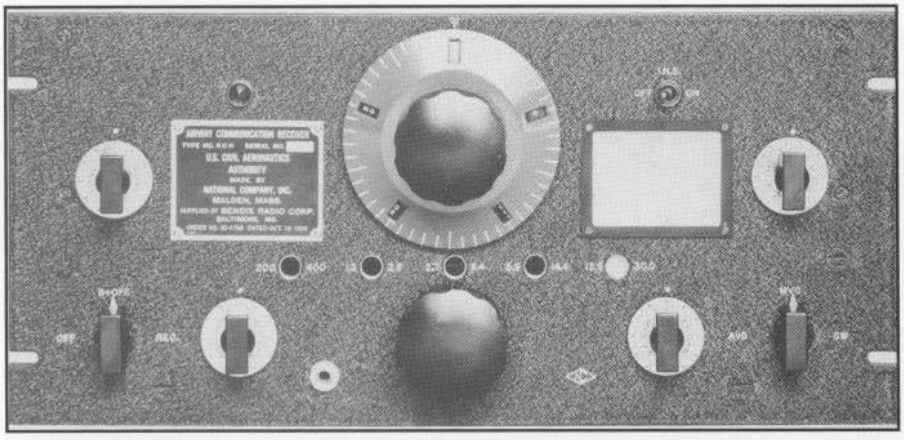


Figure 14. *The 1939 CAA model RCH receiver.*

National (the RCD Series) and how many NC-100 radios were modified by other contractors? The available records are inconclusive, but it appears that National worked very closely with the identified vendors for the AGR series and may have done a large portion of the modifications made to these radios in-house, simply allowing the primary contractor to attach data plates to the radios.

CAA Versions

Later versions started out life as type RCE, RCF, RCH, RCK and RCL radios and were then modified into type RCP and RCQ radios under multiple "retrofit" contracts.

Both my type RCPs started out life as type RCK radios, and all the IF transformers are ink stamped "RCK." All of these radios bear strong resemblance to their NC-100 origin. All have the National sliding-coil catacomb design with the white or orange band marker which shows through the respective hole in the front panel. All have the famous PW-type dial, geared tuning drive and the National three-section tuning capacitor. There are several extra controls related to fixed-frequency operation and the CONS (carrier-operated noise suppression) system on the front panels of most the CAA variations. Most also have a "dial lock" stud located next to the PW dial. Some earlier versions have a sharp/broad control on the front panel for changing the IF band-pass characteristics.

As you can see, the records I have are still missing quite a bit of information. I have manufactures' manuals for types RCF, RCL, RCP and RCQ and at least some information such as schematics on several of the others. I've noted that Moore's 3rd refers to several of these radios

Figure 15. *The CAA model RCK-1 receiver.*

Known variants:

TYPE:	Contract/ Order codes:	Contract/ Order date:	High S/N reported:
RCD	Order # 37-7383		101
RCE	Order # 38-2832	?	478
RCE	Order # 38-2833	October 1, 1937	187
RCH	Order # 40-1760	October 19, 1939	?
RCF	Order # 39-2748	June 30, 1939	118
RCK	?	June 30, 1939	235
RCL	?	?	?
RCP	CCA-24653		
	Order # 46-1467	October 30, 1945	825
RCQ	CCA-26227	February 5, 1948	404

as NC-100A-based units. This is incorrect. All were based on the original NC-100 (non-A) PW-dial design. Moore corrected this in his recently released 4th edition.

The earliest known contract for Airways Ground Receivers seems to be Order # 37-7383, not long after the NC-100 started coming off the National production lines. National built this radio, the RCD, directly, unlike many of the later versions that were modified by other contractors.

The RCD is the only model in the series that I'm aware of with both a crystal filter and push-pull audio output circuits. Later models had no crystal filter and only a single-ended output circuit. With the exception of the 200 – 400 kHz low band, the RCD seems to be electrically identical to the early NC-100X, complete with the 6E5 tuning eye tube. Appearance wise, it looks identical to the early NC-101X amateur receiver.

Contractor modifications that seem to have been made to all the later CAA radios include an "Interchannel Noise Suppression" (INS) or "Carrier Operated Noise Suppression" (CONS) system. This was an interesting early squelch system controlled by a relay in one of the tube plate circuits, usually a 6F8.

All of the later series radios seem to have been modified for fixed-frequency operation by allowing the high-frequency local oscillator to operate under crystal control. Typical "channel" frequencies appear to be 3,025, 3105, and 6120 kHz.

Typical specifications:

Five bands: 200 - 400 kHz, 1.3 - 2.8 MHz, 2.7 - 6.4 MHz, 5.9 - 14.4 MHz, and 13.5 - 30.0MHz. IFs are 455, or 457 kHz, with variable bandwidth modification.

Unusual tone-control circuit, (steep audio roll-off below 100 Hz and above 2 kHz.) Fixed-frequency-operation option, and INS or CONS system. No S meter or crystal filter seem to have been used. This is consistent with reports that the radios were commonly used in remote locations.

A typical tube line up in these radios (this one is for the type RCL) would be:
6K7 RF amplifier, 6J7 mixer, 6J5 high-frequency oscillator, 6K7 1st IF amplifier, 6K7 2nd IF amplifier, 6C5 detector, 6F8G 1st audio amplifier and squelch, 6J7 beat-frequency oscillator, 6J7 AVC amplifier, 6J7 CONS amplifier, 6V6 audio output, 80 rectifier.

Variable bandwidth I.F. Transformers

Many of these radios were built with unusual modified National IF transformers. Besides the normal primary and secondary windings these also have a third (tertiary) winding used to affect the coupling coefficient of the transformer. This allowed two different bandwidths (sharp or broad) controlled by a

switch which connected one end of the tertiary winding to ground. Late models of these radios (RCP, RCQ) had this feature (switchable bandwidth) removed and the transformers hard-wired, as either sharp or broad.

The tertiary windings on these are one turn above the upper winding in the IF can, and one turn below the lower winding in the can, connected to the shield can (ground) at one end and either an external wire or a spring contact on the other.

Series Noise Limiter Modification:

In the type RCQ the 6C5 was replaced with a 6H6, with the second diode in the 6H6 used for National's "Series Noise Limiter "system. Some RCPs also received this modification.

There was a CAA-ordered field retrofit for RCP radios currently in service to install the noise limiter circuit. The modification order and instructions, (CAA Communications Engineering Division Circular # 41) was issued on August 17, 1948.

Later models went through a number of small changes as problems with the interaction of IF bandwidth, RF gain, and CONS set points were addressed. The entire 1948-contract RCQ incorporated National's "Series Noise Limiter" design, which had first appeared in the NC-100A in about 1942.

The primary use of these radios seems to have been in a fixed-frequency mode. Perhaps the main airport "call-up" frequency for the tower? Close examination of the design shows extra effort was made to insure receiver stability. Temperature coefficient of components in the local oscillator, IF chain and RF front end were selected and specified with frequency stability clearly in mind. The early CONS squelch system, coupled with the unusual audio filter in the radio, clearly point to clarity and reliability of voice communications as a design priority. CONS allowed the radio to effectively ignore random background noise, yet produce a high-level signal out when an approaching air crew called.

Excerpts from the type "RCP" manual:

... Designed for use at Civil Aeronautics Administration Airway Communications Stations.

... The high-frequency oscillator has been modified so that it may be made either crystal controlled or tunable by means of a switch on the front panel.

... to facilitate the AVC and CONS circuit... the second-detector circuit has been changed...

... The audio-amplifier circuits of the receiver have been redesigned to

give a frequency characteristic which is fairly flat from 100 to 2000 cycles and falls off slowly to give a response of more than 15 dB down at 5000 cycles.

Excerpts from the type "RCQ" manual:

... This receiver was originally a Type RCK or RCL receiver. The type designation was changed to RCQ at the time these modifications were made to distinguish it from its original type.
... The AVC circuit has been completely changed to correct several conditions. Before modification, the AVC action was proportional to the peak-signal input and thus was unduly affected by static crashes and modulation peaks. This feature was considered undesirable, therefore the AVC circuit was changed so that it responds to the average carrier input.
... The CONS circuit has been changed.... This modification has been made because the CONS control was so badly interlocked electrically with the RF gain control that it had to be reset each time the RF gain control was changed.

Unusual Output Panels

All of the later units have an unusual terminal-board output-connector panel on the rear. This is one of the easiest ways to quickly identify one of the AGR-series radios.

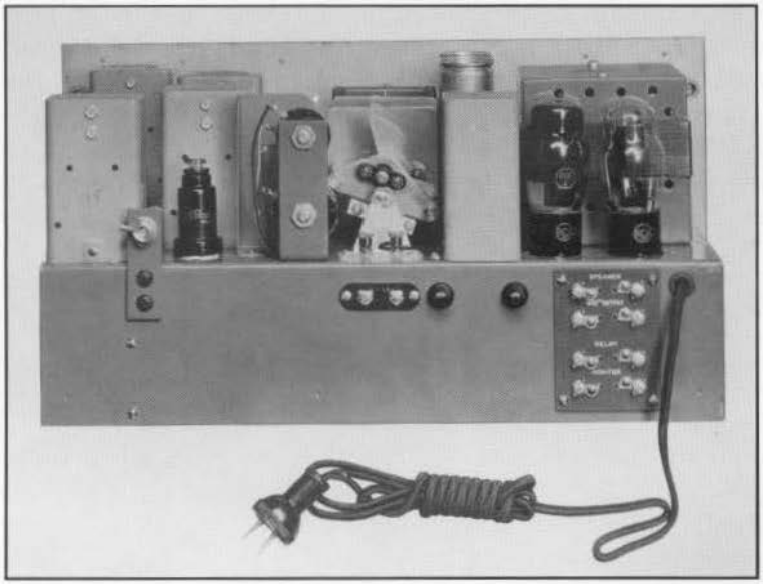


Figure 16. *Rear view of the RCK, showing details of the output panel.*

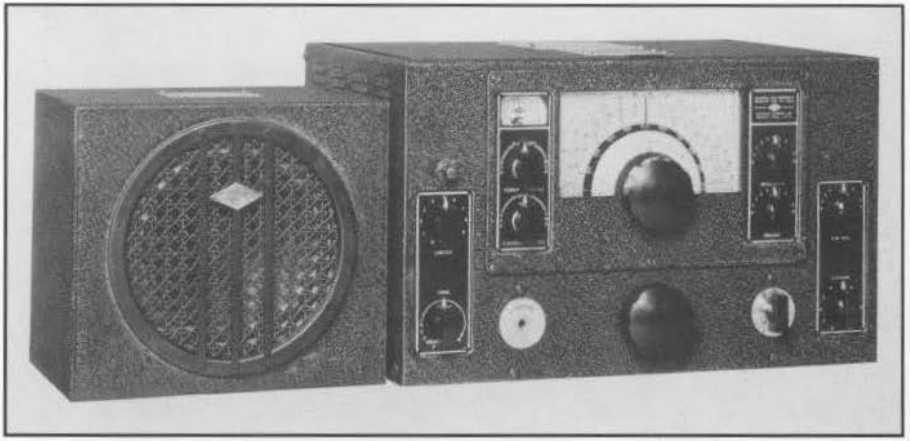


Figure 17. *The RAO-1 equipment. This receiver, with the military labels on the top of each piece, is actually an NC-100XA.*

Labeled output terminals included: "monitor" and "600 ohm," as well as speaker terminals. This would allow the audio to be easily piped into a local audio system for output on monitor speakers throughout the building or tower.

All of the CAA radios except the very early RCD also have single-ended 6V6 audio outputs. (This was common in military versions of the NC-100 and NC-100A, but the civilian and amateur versions usually had push-pull output circuits.) As you can see, these radios contain some interesting engineering changes from the standard NC-100.

Production contracts that I have at least some information on point to production runs from 1937 to 1948. Contracts over an eleven-year span tell us that they filled a real need in the pre- and post-WW II aviation arena.

These radios show up from time to time at ham fests in the $50-100 price range. With good performance, and a ton of interesting history attached to each one, I rate them as a definite "buy" for any National collector.

The RAO series: (RAO, RAO-1 to RAO-9)

Born in the days of World War II, the US Navy RAO series of National NC-100As have some unique features that make them quite interesting.

All but the quite rare RAO (no suffix) and RAO-1 have an extra RF tuning stage ganged onto the back of a modified NC-100A chassis. This extra sub-chassis is attached with a combination of bolts and spot welds. Other changes included single-ended audio output, provision for external dc power as well as 115 Vac, and several variants with Panadaptor outputs.

Figure 18. *The RAO-2 in its mounting rack. The added RF preselector stage is on the back.*

The extra RF-preselector stage common to most RAOs has a lot of interesting speculation and misinformation surrounding it. It is commonly believed these preselector stages were added to many Navy radios to prevent enemy forces from DFing (direction finding) the local oscillators in the radios themselves.

The E.H. Scott Radio Company apparently started this with a series of radios equipped with shielding and preselector circuits for marine use. I have been told that they advertised the unique features of the radios in trade journals of the era, suggesting that radios without these features could get a ship sunk by enemy U-boats!

However, a check of published information reveals no evidence that Germany or Japan ever claimed a kill based on DF of local-oscillator circuits. They did report kills based on locating convoys and other shipping from two-way communications (ship-to-ship and ship-to-shore messages.) And, also, many from the reception of spotting reports transmitted from Axis long-range patrol aircraft.

The Navy specifications of the time were very strict in this regard. Several of the RAO series Navy manuals state that oscillator radiation must be below 400 micro-micro-watts as measured at the antenna terminals. That is less than 400 pico-watts of radiated leakage!

Another common belief is that these preselector circuits actually served a much more important, but far less exciting purpose. Warships, since the dawn of electronics communications, have always been an extremely high-intensity electromagnetic-field environment. This is even more true

today than during the years of World War II. Even then, multiple transmitters and receivers for all types of uses had to coexist without interference to each other.

Battleship Sailor, by Theodore C. Mason (Naval Institute Press, 1982) is the non-fictional story of Petty Officer Mason's life as a radioman aboard the battleship *California,* leading up to its sinking during the air attack on Pearl Harbor by Japan. While this book has little to say about the specific radios used in warships of the time, it does go into quite a bit of detail about operating procedures, and how the communications systems on a fleet-command battleship were used. Multiple transmitters and receivers were expected to coexist constantly. In fact, the descriptions of radio operations by the author would be impossible if the onboard transmitters were prone to interfere with onboard receivers nearby.

When you consider that most if not all of such a warship's antennas were in close proximity to each other, the ability of any receiver to reject very strong nearby signals becomes quite critical! High levels of local-oscillator leakage could also play havoc with other nearby receivers.

Speculations concerning the reason(s) behind the stringent leakage specifications of the time continue to this day.

General information that applies to all versions:

Each of these radios was originally furnished with the following:

1 Type CNA-10125 Mounting Base or equivalent.
1 Set of Spare Parts.
1 Instruction manual.

Units also had a "Tender" or "Depot" set of Spare Parts furnished for every ten (10) field units. This was a more complete kit used for maintenance on radios that could not be field repaired.

Some typical weights, (from my RAO-6 manual) included:

Radio Receiver:	75 lbs.
Mounting Base:	5 ¾ lbs.
Spare Parts Kit:	46 lbs.
Tender Spare Parts Kit:	78 lbs.

Typical Dimensions, (for units with the preselector):

Depth:	17 1/4"
Height:	10 21/32"
Width:	17 3/16"
Dimensions (crated):	36 ½" X 22 ¼" X 17 ¼"

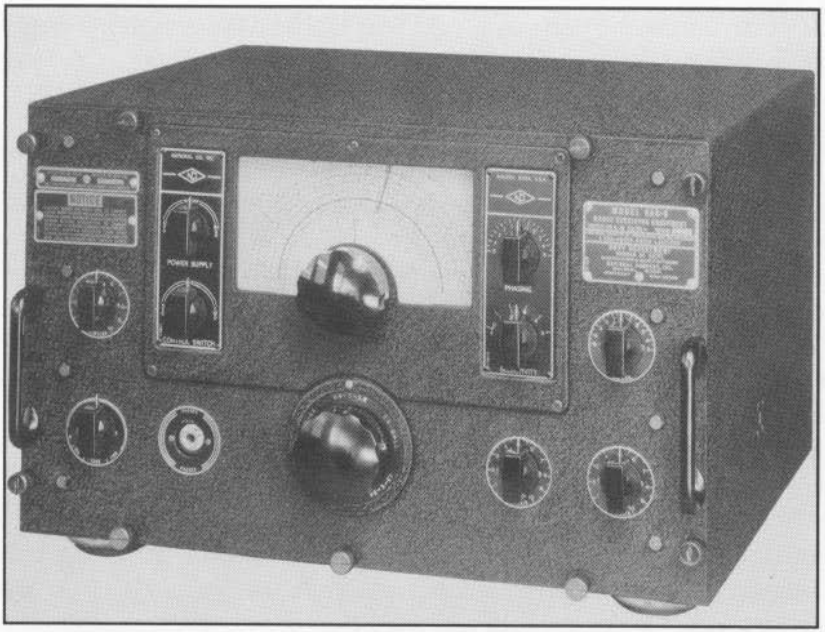


Figure 19. *An RAO-9.*

All RAO-series radios were built on the same basic copper-plated steel NC-100A chassis.
Typical Frequency coverage and bands:

Band E	540 – 1,300 kHz
Band D	1,300 – 2,800 kHz
Band C	2,800 – 6,400 kHz
Band B	6,400 – 14,000 kHz
Band A	14,000 – 30,000 kHz

Even within the same model number differences exist. For example: Most Navy RAO-series manuals specify a 6K6 as the audio-output tube. Many have instead a 6V6 or 6F6 installed, and that number inked near the tube socket. Minor undocumented changes of this nature seem to have been quite common during the war years in the RAO series.

Several of the RAO series have a "Panadaptor" output connector located on the rear of the radio. The SO-239 female connector appears to be standard and correct for this application. (Note that the antenna connectors were either binding posts or an odd military coax connector, so a SO-239 as an antenna connector marks a modified, non-correct radio. Also, the Panadaptor connectors have B+ voltage applied to the center pin so be careful connecting anything to these outputs.)

RAO series with Panadaptor outputs include:

RAO-2/NC-120
Some RAO-6s (Navy field modification that may or may not be installed.)
RAO-7
(See detailed alphabetical listing for more information.)
RAO-9

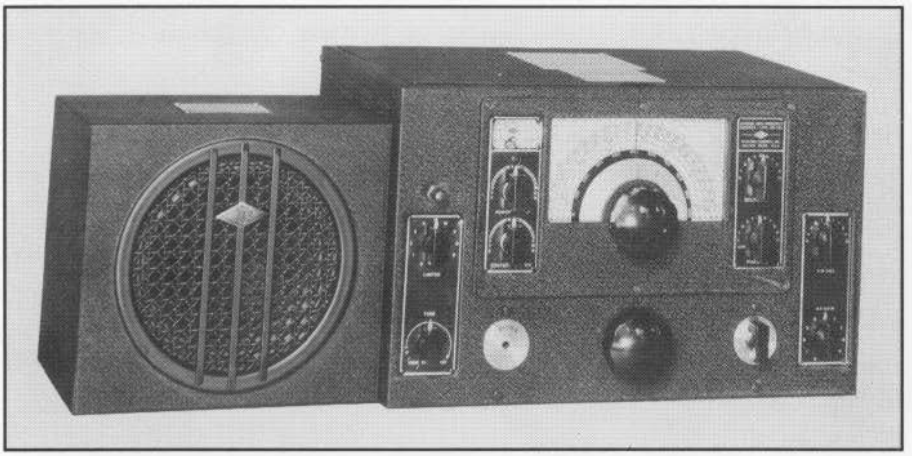


Figure 20. *An RBH receiver with matching speaker. This started life as an NC-156, and is so labeled. There is no added preselector.*

The NC-156, NC-156-1, NC-156-2 or RBH Series:

NC-156 (RBH)
NC-156-1 (RBH-1)
NC-156-2 (RBH-2)

The first of the series, the NC-156/RBH (no suffix,) is a modified NC-100AX design without the extra RF stage of the later models. The radio was also known as a type CNA-46144. Model 156/RBHs all use an unusual 1560-kHz IF scheme instead of the far more common 455 kHz design of most of the other coil-catacomb receivers. All also had the same unique set of available bands: 300 – 1200 kHz for the lowest band, and 1.7 – 16 MHz for the other four.

The NC-156-1 and NC-156-2, (RBH-1 and RBH-2) series are virtually identical to the RAO-3/4 series of radios. They, like the RAO-3/4, have an extra RF stage ganged onto the rear of a standard NC-100A chassis. The only differences are in the local oscillator and IF circuits.

The 156-1 and 156-2 also use the unusual 1560 kHz IF scheme, instead of the far more common 455 kHz design of the RAO series.

Electrically, the HFO runs at a larger offset, 1560 kHz instead of the usual 455 kHz, from the tuned RF incoming signal. This results in minor changes in available tuning ranges. The crystal filter seems to be a hybrid design, falling between the standard Lamb design of the RAOs and the slightly more unusual design of the NC-80X/81X, which also used 1560 kHz as an IF frequency.

Mechanically, the design differs only in the calibration of the direct-reading dial.

The Coast Guard Versions

The R-115:

The Coast Guard R-115 used the same basic chassis and mechanical layout as the NC-200 but instead had only six bands, covering 200-400 kHz, and 490 kHz to 18 MHz. Lack of the amateur bandspread and crystal filter, which were in the NC-200, along with a completely different tube lineup, makes these easy to identify even without the Coast Guard data plates.

The R-115 was an ac-dc radio and contained an unusual tube lineup to facilitate this feature. With four 117N7s, it is quite different from its NC-200 cousin.

The R-116: (see detailed listing section) This prototype probably never reached production.

Figure 21. *The Type R-115 receiver, made for the U.S. Coast Guard.*

The James Millen Company DFP-201 and DFP-501

James Millen believed very strongly in the inherent advantages of his coil-catacomb design, and during the early 1940s he apparently kept several new catacomb-based designs on the back burner until after World War II.

In May, 1947 he announced the soon-to-be-available DFP-210 and DFP-501 radios. Documentation that the 201 was a coil-catacomb based-design is clear. Whether the 501 also used the coil-catacomb design is less clear. Very little information about these radios is available.

The 501 was a cost-no-object *tour-de-force* in radio design. It appears that only one prototype was ever completed. The 201, a reduced cost version of the 501, never reached production either. Reportedly, even the 201 prototype cost over $2,100 each to build in 1948 dollars!

Both the 201 and 501 were quickly withdrawn from the Millen catalogs, and none that I know of were ever shipped to end-users. I know of only one of each in existence.

Millen eventually gave up on the coil-catacomb design, as did National, perhaps because the market was moving to smaller, less-expensive radios. The unique coil-catacomb design was no longer cost effective in an evolving and changing market.

The Low-Cost Versions: NC-80X and NC-81X.

From *QST*, August, 1937...

This is an inexpensive receiver having exceptional operating characteristics. Ten tubes are used in a high-gain superheterodyne circuit as follows: 1st detector, 6L7; HF oscillator electron coupled, 6J5; three IF stages, 6K7s; linear 2nd detector, 6C5; amplified and delayed AVC, 6B8; panel-controlled beat-frequency oscillator, 6J7; beam-power output, 25L6G; and rectifier, 25Z5. The IF amplifier is of entirely new design, operating at a frequency of 1560 kc, and providing a high order of image suppression, better, in fact, than that obtainable in many receivers having elaborate preselectors. The crystal filter (2nd IF stage) is truly remarkable in its performance, since selectivity is continuously variable between 400 cycles for single signal CW, and 5 kc for high-quality broadcast. The range of the phasing circuit (heterodyne elimination) has been similarly extended. With such unusual characteristics, the crystal filter remains in the circuit at all times, simplifying tuning considerably. With the development of the 25L6G beam-power tube having an undistorted output of two watts, it has become possible to design a high-performance communication receiver operating with full efficiency on either ac or dc, 115 volts.

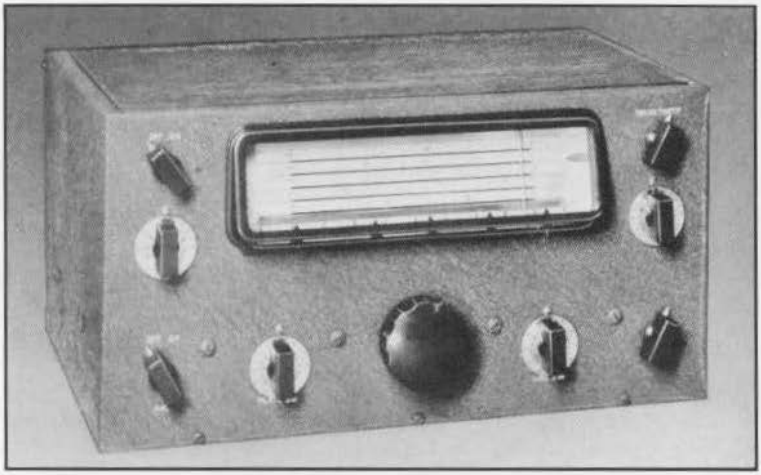


Figure 22. *The economy sliding-coil NC-80X and -81X receivers. There is no RF stage.*

The tuning system, likewise entirely new, employs a multiple-scale dial of the full-vision type, accurately calibrated in megacycles. Several unusual features are incorporated, such as the mirror for overcoming parallax, the auxiliary linear scale (at the bottom), and the adjustable-frequency markers, by means of particular stations, or frequencies, such as band limits, may be "logged" on the dial itself. Two veneer-reduction ratios are available, 16 and 80 to 1, with a separate knob for each.

Automatic plug-in coils are used, controlled by a knob on the front panel, as in the NC-100. This arrangement has proven itself to be thoroughly reliable and efficient. The frequency coverage is continuous except for a small gap at 1560 kc, from 550 kc to 30 Mc in four ranges.

The NC-81X is a special amateur model covering the following bands only: 1.7 – 2.0 Mc, 3.5 – 4.0 Mc, 7.0 – 7.3 Mc, 14.0 – 14.4 Mc, and 28 – 30 Mc. The dial is calibrated in megacycles.

Only one month later (9/37) in his now famous monthly *QST* column, James Millen had this to say about the new NC-80X/81X radios:

"... Designed by Dana Bacon and his staff..."

"... Most amateurs do not need to be told that when a communication receiver is to be sold for as low a price as the NC-80X it is necessary to make compromises..."

Thus the low-cost versions of the coil-catacomb line were born. Economies in the NC-80X/81X included removal of the preselector circuits on the grounds that a good one would cost too much, and a cheap one wasn't

worth owning. Provision to control image rejection and provide usable signal-to-noise ratio fell onto the newly designed crystal-filter circuit. By using a 1560 kHz IF frequency, the image frequency is 3120 kHz removed from the desired signal. It was enough that image rejection remained adequate. The new crystal-filter design promised great things, according to Jim Millen:

"... By operating with optimum selectivity, the noise can be reduced sufficiently to make the signal-to-noise ratio fairly good (CW-noise equivalent approximately 0.3 uV).... "

Jim goes on by making a silk purse out of a sow's ear concerning the ac-dc power supply of the NC-80X. He praises the cool running and good power regulation of such a design, then points out that the new beam-power amplifier tube give two watts of audio, which he calls "ample."

Jim winds up his monthly column by saying: *"... Of course the schemes described above are mostly only devices to make it possible to build a good receiver at a low price... "*

James Millen revisited the NC-80X/81X radios in his column of December, 1937. He also touched on National component-manufacturing processes and how components not made in-house are specified and purchased from other vendors:

"... When production sets came through it became apparent that these condensers would not do. The ganging was not good enough and backlash was perceptible when using the high selectivity of the crystal on bandspread amateur bands... "

National addressed the problem by refitting PW condensers into the NC-81X amateur-bandspread version:

"... We found that by careful refitting these were satisfactory for the NC-80X (which has general coverage ranges) but not the NC-81X (which has extreme bandspread on the amateur bands.)... "

"... This refitting brought the cost up as high as a PW condenser, so what the heck... "

"... receivers are so late. NC-81X receivers with PW condensers will be delivered about the same time this page is published... "

He goes on to describe how they are currently filling NC-80X orders with refitted condensers, and how later production NC-80X receivers will also use PW-style condensers exclusively.

(Author's note: My NC-80X has one of these "bought" condensers. I've never seen an NC-80X with a National PW condenser in it, and I speculate that very few, perhaps none, were ever made.)

Figure 23. *The RBL-6 model.*

The RBL Series (NC-100A look-alike):

The RBL series of VLF-LF Communications Receivers get a brief mention here because they strongly resemble a National NC-100A. They are often mistaken for the NC-100A, because of the large direct-reading dial, band-change knob in the same location as the NC-100A, etc. Perhaps the easiest way to spot an RBL is the low-frequency dial calibration, coupled with the existence of a regeneration control on the front panel.

Built with the same basic front panel and chassis as the NC-100A, internally they are very different. The RBL series are non-superheterodyne systems with two stages of tuned-radio-frequency (TRF) amplifiers, followed by a regenerative-detector circuit. Two stages of audio, with a limiter in between, finish the basic signal path. Typical frequency coverage is from 10 or 15 kHz to 600 kHz in five bands.

The National NC-1-39 & NC-1-39S:

This is a pair of odd radios apparently designed for special-purpose military-related uses. (See detailed alphabetical listing)

***Series Noise-Limiter Notes:**

During the production years of the NC-100s, NC-101Xs and NC-100As National introduced a new series-noise-limiter circuit to many of its models. This change was documented in a brief four-page addendum supplied with the owner's manual.

A 6C8G and a 6F8G replaced the 6C5 second detector and the 6J7 AVC tubes previously employed. The 6C8G comprises an infinite-impedance diode second detector and the new series-valve noise limiter, while the 6F8G is used for AVC and a new first audio stage. The circuit was described in some detail in the October, 1939 issue of *QST*.

The really interesting thing about this noise limiter is that the design change was made in mid-production for many of the early Nationals, without a model number change. The collector will run across later radios with the change and earlier radios without it.

Alphabetical Listing Of All Known National "Coil-Catacomb" Radios And Variants

For explanations of the references following each model refer to the bibliography on page 232.

Model designations are in alphabetical order.

AN/GRR-3 (M3, p. 95).
GRR-3 (M4 p. 110). World War II years? NC-100ASC, according to Moore.

BC-903-A (M3, p. 95)
WW II vintage. Range 0.54-30 MHz. No crystal filter. Navy version of NC-100A, according to Moore. BC-903-A is perhaps an Army Signal Corps designation.

NAO (AWA)
A very odd radio, that perhaps never went beyond the prototype stage. (?) Appears to be another NC-100A variant with the extra RF preselector stage on the rear (see RAO series.) The front panel has a direct-reading "A"-type dial and a catacomb bandswitching knob, small rack handles, and front-mounted fuse holders. It does not appear to have a crystal filter.

Shown in National photographs as a rack-mount system, it is complete with a dual dynamotor rack-mount power supply. It appears to have navy-gray paint instead of the classic black-wrinkle finish. Post war? No other information is available.

Figure 24. *The NAO receiver. It is configured for both ac and dc power sources. It also has a separate RF preselector on the back.*

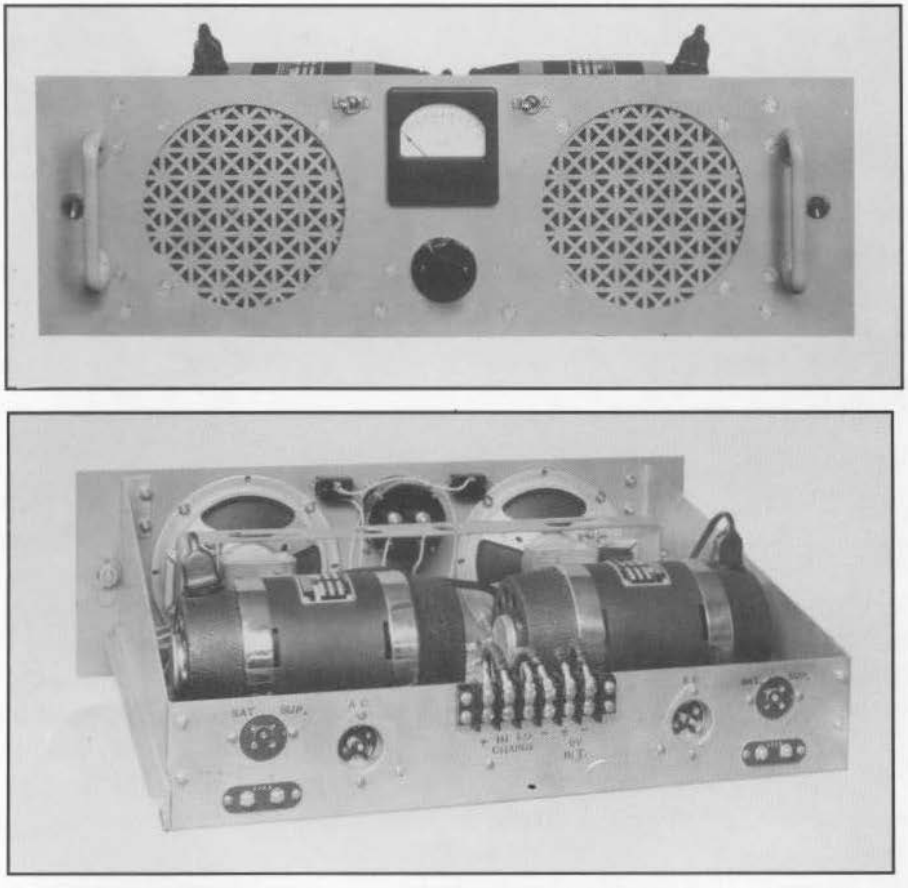


Figure 25, 25a. *Battery-source power pack for both the NAO and NBL receivers. The meter is 10 Vdc full scale.*

NBL (AWA)
Another very odd radio. Appears almost identical to the NAO, except for an added ¼" phone jack, labeled "XTAL," and another extra control labeled "OSC TEST." Appears to be another NC-100A variant with the extra RF-preselector stage on the rear (see the RAO series.) The front panel has a direct-reading "A"-type dial and a catacomb bandswitching knob, small rack handles, front-mounted fuse holders. It does not appear to have a crystal filter. It is shown in National photographs as a rack-mount system, complete with a dual-dynamotor rack-mount power supply. It appears to have a Navy gray paint finish instead of the classic black-wrinkle. Perhaps another post-war prototype? No other information available.

NC-80X (M3 p. 88, M4 p. 101)
1937-38. Four bands, 0.55 to 30 MHz.
1560 kHz IF, crystal filter, balanced and unbalanced antenna inputs, ac-dc power. A slide-rule dial, low-cost catacomb radio.
Tube lineup: 6L7 mixer, 6J7 HFO, 6K7 1st, 2nd, and 3nd IFs, 6C5 detector, 6B8 AVC, 6J7 BFO, 25L6 audio output, 25Z5 rectifier.

NC-80XB (M4 p. 101)
Battery version of NC-80X, 6V6 AF output, needs 135V B+ and 6V heater power.

NC-81X (M3 p. 88, M4 p. 102)
1937-39
Amateur-band-only model of NC-80X.
Five bands; 10, 20, 40, 80, 160 meters.

NC-81XB (M4 p. 102)
Battery model of the NC-81X.

The radio that started it all.
NC-100 (M3 p. 88, M4 p. 102, Man, Riders, NC1937, others)
1936-1938, five bands, 540-30,000 kHz
455 kHz IF (M3, M4), 456 kHz IF (Riders 8),
No crystal filter, PW-dial system.
Tuning-eye tube version.

This and the NC-100X are the so-called "Art Deco" design Nationals. A horizontal bright red strip, and silver and black vertical stripes set these apart from all the other coil-catacomb models.

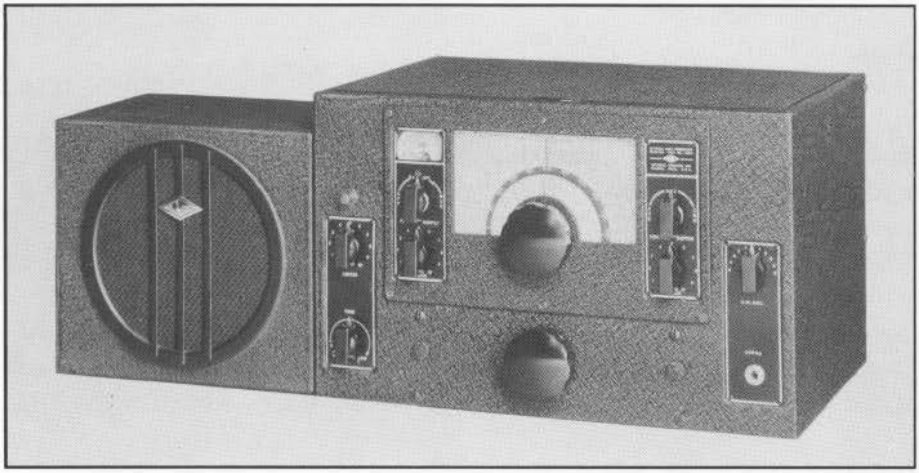


Figure 26. *This is the NC-100 ASC model. The panel label reads simply NC-100 A.*

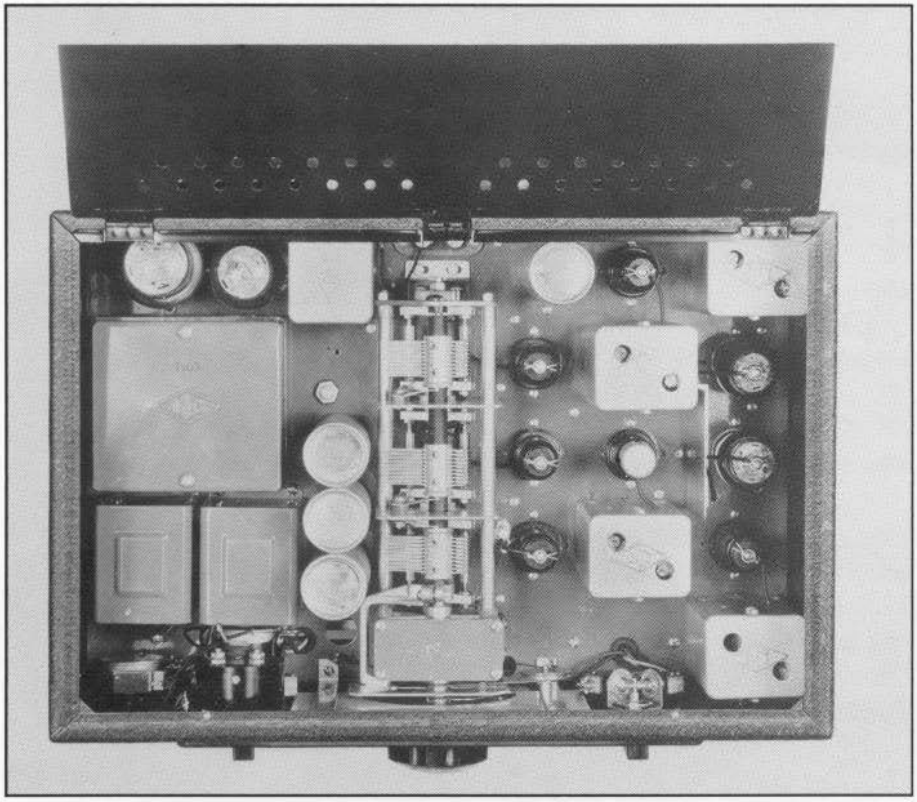


Figure 27. *Top inside view of the NC-100 ASC receiver.*

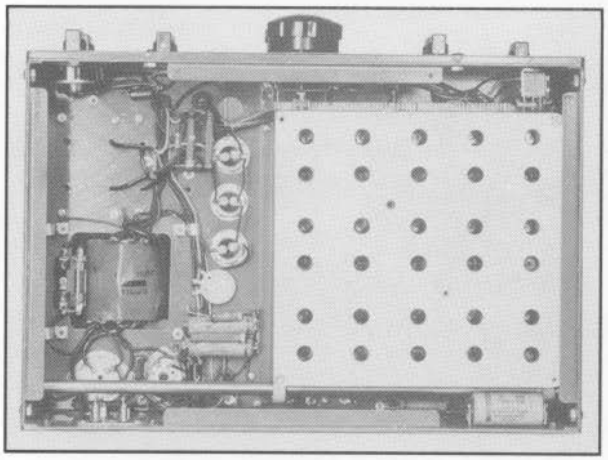


Figure 28. *Bottom view of the NC-100 ASC model. These designs are noted for easy access for servicing. What appears to be a fuse next to the transformer is actually a piece of brass rod, to select the proper input voltage.*

Tube line up: (from manual, agrees with M3, M4, & Riders)*
6K7 RF amp, 6J7 mixer, 6K7 HFO, 6K7 1st and 2nd IFs, 6C5 detector, 6J7 AVC, 6J7 BFO, 6E5 tuning eye, 6F6(2) (push pull)audio output, 80 rectifier. **See Noise-Limiter Note*
References include:
1935 National catalog (#250) p. 17, text block describing new NC-100 radio in preparation. (Possible first-ever reference in print to the NC 100.)
Sept. 1936 article in *Short Wave Craft* magazine: The New National NC-100 Receiver, by James Millen and Dana Bacon.

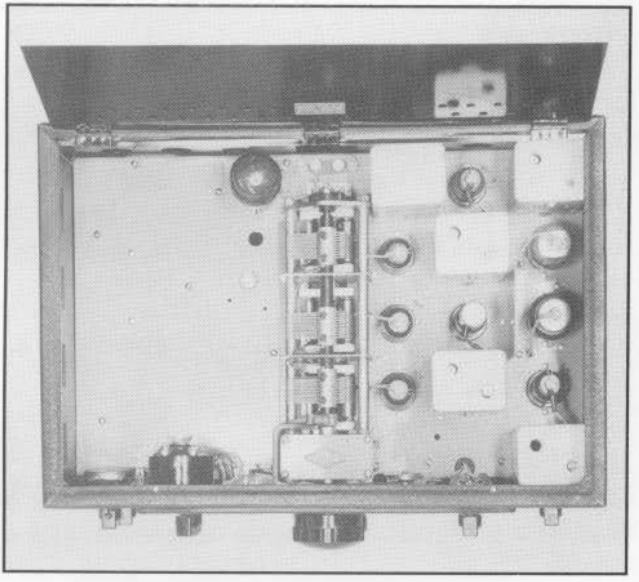


Figure 29. *The NC-100 AB receiver. This set has no internal power pack - the power area is covered over with a blank plate.*

Oct. 1936 issue of *Short Wave Craft* magazine ad.
Dec. 1936 issue of *Radio Craft* magazine ad.
Dec. 1936 issue of *All Wave Radio* magazine ad.
Feb. 1937 issue of *All Wave Radio* magazine ad.
1938 *National Company Engineering Bulletin*, "Notes on Amateur Radio Transmitter Design," by James Millen, 1938; "The National NC-100 Receiver," by James Millen and Dana Bacon.
Riders Volume 8.

NC-100 Battery (M3 p. 88, M4 p.102, Man)*1936-38, battery version of the standard NC-100
**See Noise-Limiter Note*

NC-100A (M3 p. 88, M4 p. 102, Man) 1938-45
The "A" variant. A new, direct-readout tuning dial replaces the PW type. Five bands, 0.54—30 MHz, 455 kHz IF, S meter.
Tube lineup: 6K7 RF amplifier, 6J7 detector, 6J7 HF oscillator, 6K71st and 2nd IFs, 6C8 2nd detector/limiter, 6F8 AVC/1st audio, 6J7 BFO, 6F6G(2) push-pull audio, 80 rectifier.
(Note: The NC-100A and XA were also available in two different battery-powered versions; the first and more common required external B+ and filament power. The second, unusual version contained an internal vibrator-based power supply and required only 6 V dc to be provided.)

NC-100A special (M3 p. 88, M4 p. 102, PC)
NC-100A with LF band, 200-400 kHz (sometimes incorrectly called the **NC-100ALF.**)

NC-100ASC (M3 p. 88, M4 p. 102)
Moore's 4th says see GRR-3. (AN/GRR-3)

NC-100ASD (M3 p. 88-89, M4 p. 103, Man)
200-400 kHz and 1.3 MHz to 30 MHz, five bands, S meter, 456 kHz IF
Band 1: 200-400 kHz
Band 2: 1,300-2,800 kHz
Band 3: 2,800-6,400 kHz
Band 4: 6,400-14,000 kHz
Band 5: 14,000-30,000 kHz
115V 60 or 25-Hz ac power supply.
Binding-post antenna connectors. Built to Army Signal Corps standards, this had a push-pull S-meter on-off switch instead of the more common toggle.

Tube line up: (from manual, agrees with M3 and M4)
6K7 RF amp, 6J7 first detector, 6J7 HF oscillator, 6K7 1st and 2nd IFs, 6F8G 1st audio + AVC, 6C8G 2nd detector + 2nd audio, 6J7 BFO, 6V6G audio output, 5Z3 rectifier.

NC-100S (M3 p. 89, M4 p. 103)*
NC-100 with special 12" speaker.
**See Noise-Limiter Note*

NC-100X (M3 p. 89, M4 p. 103)*
NC-100 with crystal filter. This is the other National "Art Deco" design coil-catacomb radio. It was also available with a 200 – 400 kHz low-frequency band. This is sometimes incorrectly called the NC-100XL or XLF.
**See Noise-Limiter Note*

NC-100X battery (M3 p. 89, M4 p. 103)*
NC-100 battery-powered model with crystal filter.
**See Noise-Limiter Note*

NC-100XA (M3 p. 89, M4 p. 103)
An NC-100A with crystal filter. (See Fig. 17)

NC-100XAL special (M3 p. 89, M4 p. 103)
Has a crystal filter, a special 200-400 kHz LF band, and binding-post antenna terminals.

NC-100XS (M3 p. 89, M4 p. 103)*
The NC-100X with 12" speaker.
**See Noise-Limiter Note*

NC-100XAM (M3 p. 89, M4 p. 103)

NC-101X (M3 p. 89, M4 p. 104), 1937-39. An amateur-band only version of the NC-100, PW dial, tuning eye, crystal filter, 455 kHz IF. Five bands; 160, 80, 40, 20, 10 meters.
The tube line up is identical to that of the NC-100, above. The earliest reference to this radio I have found is an ad in Feb. 1937 *QST* magazine. I also have a photocopy of a letter from James Millen to Bill Orr briefly discussing this unit.

NC-101X variation (M3 p. 90, M4 p. 104)*
S meter replaces the "eye" tube.
Push-pull S-meter switch.
**See Noise-Limiter Note*

NC-101X battery (M3 p. 90, M4 p. 104). The battery version of NC-101X. Needs 180V B+ @ 35 ma and 6V heater power. The tube line up is identical to that of the ac version, with the exception that the audio output is a single 6F6 to conserve power.

NC-101XA (M3 p. 90, M4 p. 104), 1939-41. The amateur band version of NC-100A. S meter, noise limiter, crystal filter, 455 kHz IF. Five bands;160, 80, 40, 20, 10 meters. The tube line-up is the same as the NC-101X, above, with the exception that the 6C5 2nd detector is replaced with a 6C8G combined 2nd detector/noise limiter.

NC-120 (M3 p. 90, PC, M4 p. 105, AWA)
Similar to the NC-100A with an added RF stage bolted/welded to rear of cabinet, with a separate coil catacomb and variable tuning capacitor ganged to the main controls.
S meter, S-meter switch, crystal filter, 455 kHz Panadaptor output (SO-239 type.)Some have binding-post type antenna connectors and some have a coax antenna-input connector.

I have conflicting information concerning the NC-120. An original National photograph (thanks to Alan Douglas) of this radio is also marked "RAO-2". I know of at least one NC-120 with the contract data plate still attached that says it is part of radio type CAN-46187. Yet this radio continues to be a minor mystery. Virtually identical to the RAO-3/4 and RAO-6, it is clearly a member of the family, yet my copy of the RAO 3&4 manual states that the manual is unsuitable for use with the RAO-2 due to significant differences between the radios. Mine also has a panadaptor output, which is shown in only SOME of the National NC-120/RAO-2 rear-view photographs. Antenna connections are another problem; mine has standard National type binding posts, yet National Company photographs show an unusual coax connector as correct. My antenna-binding posts are clearly unmodified.

Five bands, 540-30,000 kHz	
Band A	14-30 MHz
Band B	6.4-14 MHz
Band C	2.8-6.4 MHz
Band D	1.3-2.8 MHz
Band E	0.54-1.3 MHz

Tube data from my radio: 6K7 1st RF amplifier, 6K7 2nd RF amplifier, 6J7 1st detector, 6K7s 1st and 2nd IF amplifiers, 6F8G 1st audio and AVC, 6K6GT 2nd audio, 6J5 HF oscillator, 6J7 BFO, 5Z3 rectifier.

NC-127 (M3 p. 91 & 123, M4 p. 105)
World War II vintage. (Moore's book reports four bands (I believe it should be five) 0.54-30 MHz, 455 kHz IF, crystal filter. Similar to the NC-100XA. Has rack-type handles and front-panel captive-style rack-retaining screws.
Tube line up, from Moore's 3rd, is similar to the NC-120, above, with the exception that the audio tube is listed as a 6V6. Note that both of these receivers have two RF stages.

NC-127D (M3 p. 91 & 123, M4 p. 105)
Used in an experimental triple-diversity system.
Only one system (three receivers) believed to have been made. Added two-position "DIVERSITY" control and a "DIVERSITY IF GAIN" control.

NC-1-39 (M4 p. 105)
Five bands, 0.54-30 MHz, crystal filter.
Moore reports this is another modified NC-100XA with two headphone jacks. Designed for headphones use only; no audio-power amplifier.

Tube line up from Moore's 4th:
6K7 RF amplifier, 6J7 1st detector/mixer, 6J7 HFO, (2) 6K7 IF amps., 6C5 2nd detector, 6J7 AVC, 6J7 BFO, 80 rectifier

NC-1-39S (M4 p. 105)
Five bands, 200-400 kHz, 0.495-1.060 & 1.3-14.4 MHz
Same as NC-1-39 except for band coverage.
Radio is intended for VLF and direction-finding (DF) use.

NC-156 (MAN)
Navy NC-100XA variation, with 1560 KHz IF system, and unusual tuning ranges. Unlike the later NC-156-1 and - 2, the standard NC-156 does not have the extra RF stage. Also known as Type CNA-46144, and the RBH, the manual I have lists the General Electric Supply Corp. as the primary contractor (see RBH.)
Ten (10) tubes, S meter, 1560 KHz crystal filter.
Five bands: 300-600 kHz, 600 kHz - 1.2 MHz, 1.7-3.9 MHz, 3.6-8.2 MHz, 8-17 MHz.
Tube line up: 6K7 RF amp, 6J7 first detector, 6J5 HFO, 6K7s 1st and 2nd IFs, 6F8G 1st audio + AVC, 6C8G 2nd detector + limiter, 6J7 BFO, 6V6G audio output, 5Z3 rectifier.

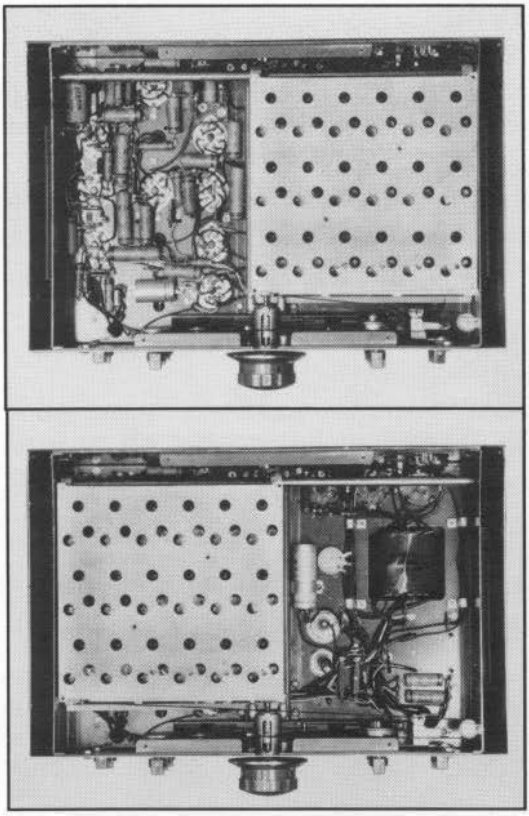


Figure 30, 30a. *Bottom view of the NC-200 receiver. Typical of all these radios, all sub-chassis parts are readily accessible.*

NC-156-1 & NC-156-2 (M3 p. 91, M4 p. 106, PC, MAN, AWA)
Navy NC-100XA with two RF stages and a 1560 KHz IF chain. Eleven tubes, S meter, 1560 KHz crystal filter. Only known difference between the –1 and –2 versions is removal of a "dummy" plug (replaced with a blank plate) on the rear of the radio.
Five bands: 300-600 kHz, 600 kHz – 1.2 MHz, 1.7-3.9 MHz, 3.6-8.2 MHz, 8-17 MHz. (See RBH series)
Tube data from my NC-156-1 radio: (2) 6K7 1st and 2nd RF Amplifiers, 6J7 1st Detector, (2) 6K7 1st and 2nd IF amplifiers, 6C8G 2nd detector & limiter, 6F8G 1st audio & AVC, 6K6GT 2nd audio, 6J5 HFO, 6J7 BFO, 5Z3 rectifier.

NC-200 (M3 p. 92, M4 p. 107, Man, Riders 14, AWA), 1940-43
Ten bands 490-30,000 kHz, 6 general coverage, 4 amateur bandspread on 80-40-20-10 meters. Crystal filter, 12 tubes, S meter. Ten ranges, calibrated frequency dial. This is the first of the coil-catacomb radios to have both "general coverage" and "bandspread" amateur bands in the same radio. The main tuning control has a push-pull function that allows selection of either of the six general coverage or four ham bands as well

as tuning the desired frequency range. This radio has the louvered sides, also seen on the later NC-2-40-series radios. The cast coil-catacomb on these and later models, which have both general-coverage and amateur-bandspread ranges, have a far more complex internal construction than the original designs.

Tube lineup from manual: 6SK7 RF amplifier, 6K8 1st setector, 6J5 HFO, 6K7 1st IF mplifier, 6SK7 2nd IF mplifier, 6C8 2nd detector/ limiter, 6SJ7 AVC, 6SJ7 BFO, 6F8 1st udio and phase inverter, 6V6(2) push-pull audio output, 5Y3G rectifier.

NC-200RG (M3 p. 93, M4 p. 107)
Rack model of above

NC-200TG (M3 p. 93, M4 p. 107)
Table model of above, (may be same radio: nomenclature issue.)

NC-200TGM (M4 p. 107)

NC-200TG without amateur bandspread.

NC-2-40 (M3 p. 93, M4 p. 108), 1943-44. (Successor to NC-200 according to Moore.)
Six bands, 0.49-30 MHz, 455 kHz IF, crystal filter, 13 tubes, S meter.
Tube lineup: 6SK7 RF Amplifier, 6K8 Mixer, 6J5 HFO, 6K7 1st IF, 6SK7 2nd IF, 6C8 Detector/NL, 6SJ7 AVC, 6SJ7 BFO, 6J51st Audio, 6F8 Phase Inverter, 6V6(2) push-pull Audio output, 80 Rectifier.

NC-2-40C (M3 p. 93, M4 p. 108, SRPP p. 234, Riders 15), 1945-46 (M3, M4) 1946-47 (SRPP)
115-230 Vac, 455 KHz IF, crystal filter, S meter.
Six bands, 490-30,000 kHz. Tubes: 6SK7 RF amplifier, 6K8 mixer, 6J5 HFO, 6K7 1st IF, 6SK7 2nd IF, 6SL7 detector/NL, 6SJ7 AVC, 6SJ7 BFO, 6SN7 1st audio/phase inverter, 6V6(2) push-pull audio output, 5Y3GT rectifier.

NC-2-40CR (SRPP p. 234) Rack version of NC-2-40C.

NC-2-40CS (M3 p. 93, M4 p. 108, SRPP p. 234, Riders 15)
Same as NC-2-40C except has LF band 200-400 kHz and 1000-30,000 kHz coverage.

NC-2-40CSR (SRPP p. 234)
Rack version of NC-2-40CS.

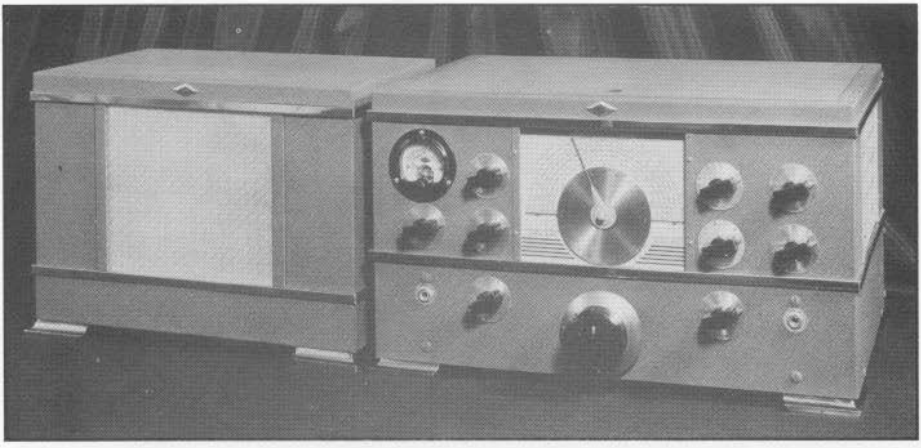


Figure 31. *A representative model of the NC-2-40 series with matching speaker. This is a -2-40 C.*

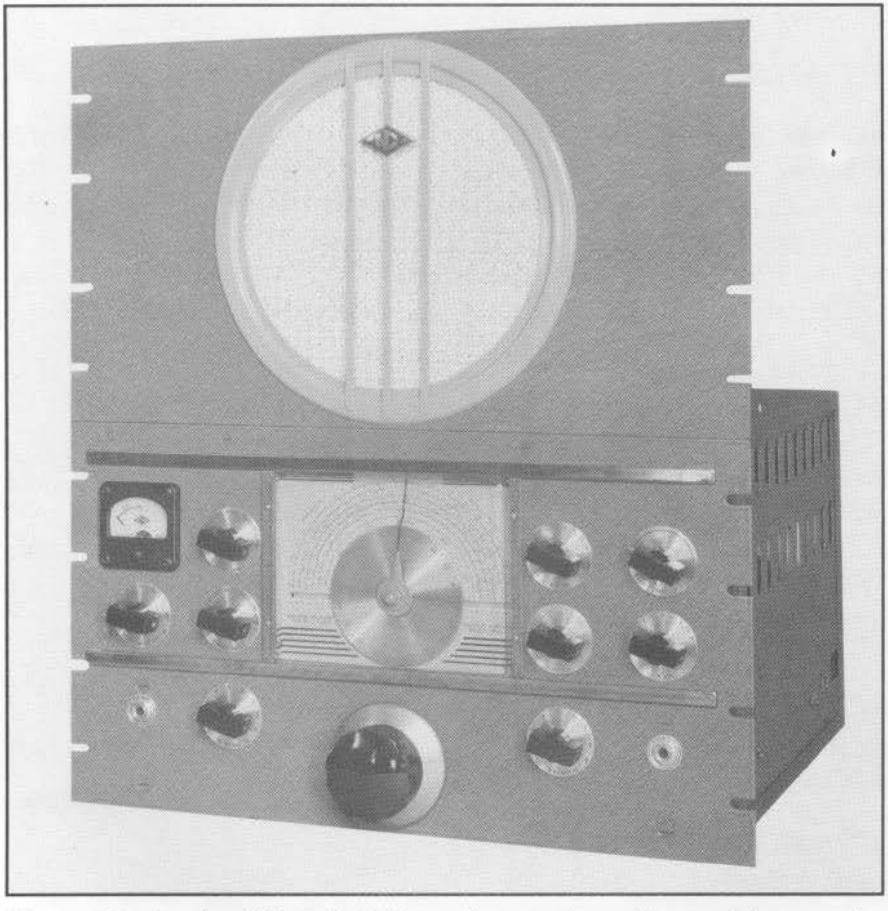


Figure 32. *Another NC-2-40-C, for rack mounting, with matching speaker.*

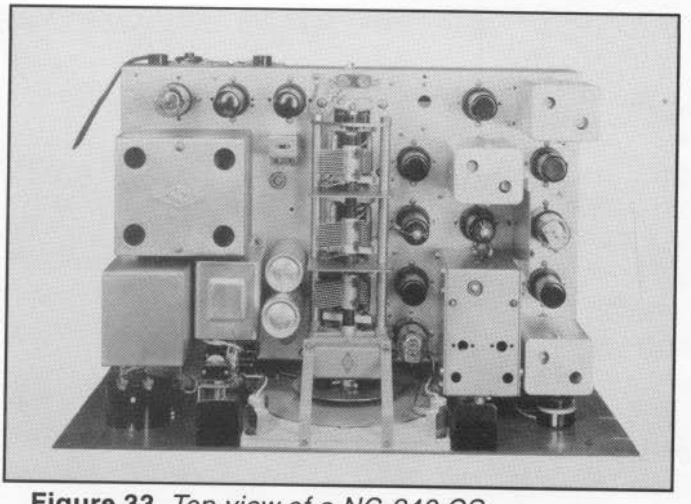


Figure 33. *Top view of a NC-240 CS.*

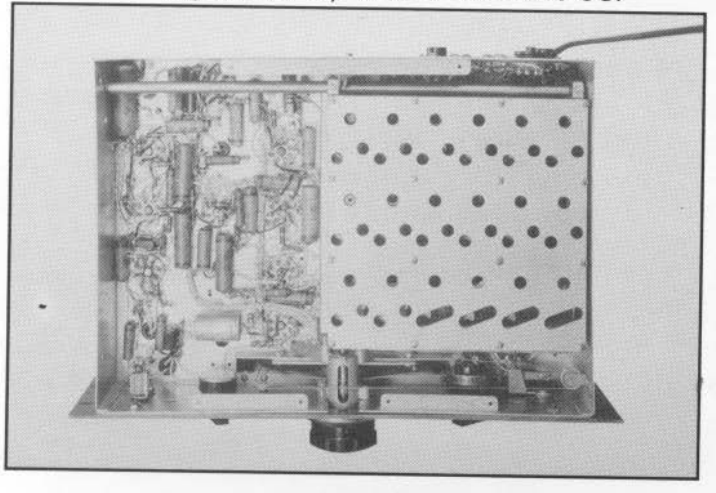
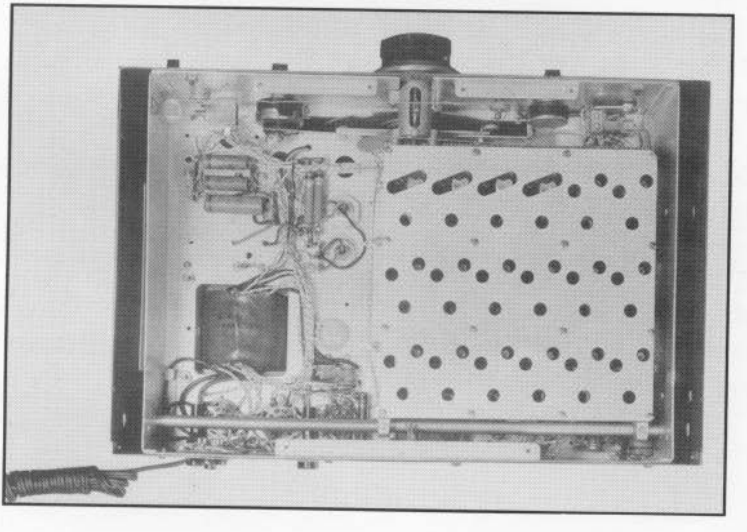


Figure 34, 34a. *Below the chassis of the NC-2-40 D. The inset shows one of the RF transformers.*



NC-2-40D (M3 p. 93, M4 p. 108, SRPP p. 235, Man), 1946-49 (M3, M4), 1947-48 (SRPP)
10 bands, 490-30,000 kHz, 6 GC + 4 amateur bandspread; 10, 20, 40, 80 meters.
455 kHz IF, crystal filter, S meter. Tubes: 6SK7 RF amplifier, 6K8 mixer, 6J5 HFO, 6K7 1st IF, 6SK7 2nd IF, 6SL7 detector/NL, 6V6 AVC, 6SJ7 BFO, 6SN7 1st audio/phase inverter, 6V6(2) push-pull audio output, 5Y3GT rectifier.

NC-2-40DR (M3 p. 93, M4 p. 108)
Rack model NC-2-40D.

NC-2-40DT (M3 p. 93, M4 p. 108)
Table model of the above.

NC-2-40S (M3 p. 93, M4 p. 108, Man)
Has odd coverage of 0.2-18 MHz, but otherwise same as NC-2-40 (according to Moore.) Six bands: 200-400 kHz, 490-1,060 kHz, 1,000-2,400 kHz, 2,200-5,000 kHz, 4,500-10,000 kHz, and 9,000-18,000 kHz .
External type 2-42 power unit required. Cable with 7-prong connector supplied. 115/230 Vac. Binding-post antenna terminals, S meter, crystal filter.
Tubes (from my manual copy): 6SK7 RF amplifier, 6K8 1st detector, 6J5 HFO, 6K7 1st IF amplifier, 6SK7 2nd IF amplifier, 6C8 2nd detector/ limiter, 6SJ7 BFO, 6SJ7 AVC, 6F8 1st audio/phase inverter, 6V6(2) audio output, 6J5 headphone amplifier, 80 rectifier (in power supply.)
Note: The manual copy I have states:
"Made for Pan American Airways System, Chrysler Building, NYC" on the cover.

NRCL (M3 p. 95. M4 p. 110) 1944-45 NC-100 variant for dual-diversity system, part of NCRM system.

NCRM (M3 p. 95) 1944-45 NC-100-based dual-diversity system. Probably experimental. M3 is the only reference so far.

R-115 (M3 p. 95 & 123, M4 p. 111, AWA)
World War II vintage. Made for US Coast Guard. Ac-dc receiver.
Six bands, 200-400 KHz and 490KHz to 18MHz. Similar to NC-200, but without amateur bandspread or crystal filter.

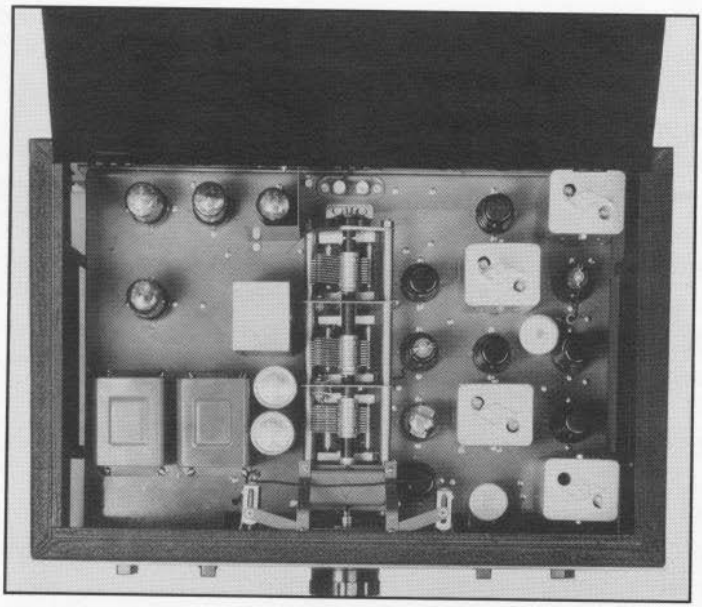


Figure 35. *The unusual ac-dc R-115 sliding-coil receiver made for the Coast Guard.*

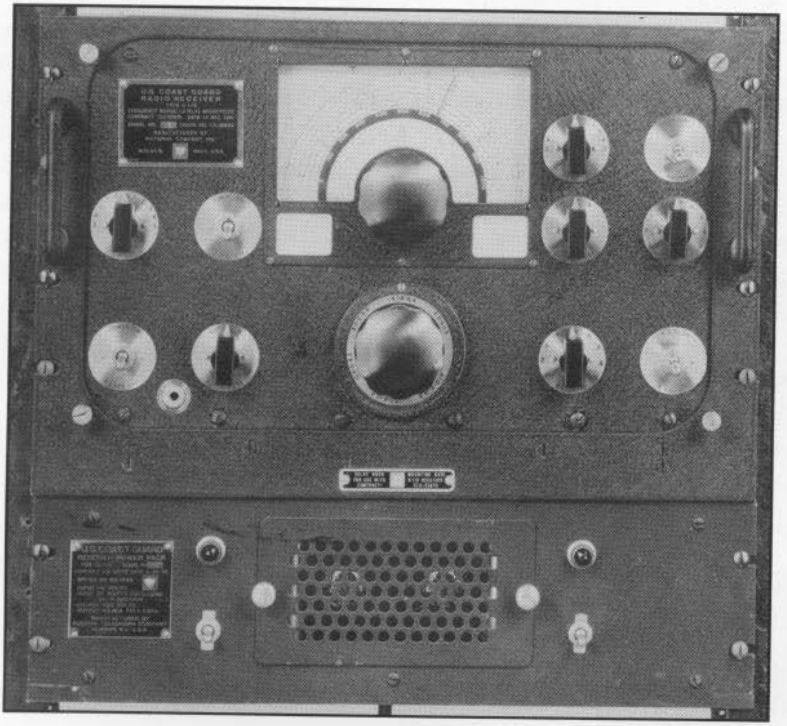


Figure 36. *The R-116 receiver designed for the Coast Guard, with separate power pack, in a sliding rack mount.*

Note: R-115 sounds like a JAN (Joint Army-Navy) designation, which would probably have a AN/SRC-*** (for surface ship) or AN/GRC-*** "system" designation as well.
Tube line up (from Moore's): 4-117N7, 3-12SK7, 1-12K8, 1-12J5, 1-12SC7, 1-12C8, 1-12SR7, 1-12SJ7. (This must be a very odd set...)
Contract: TCG-23454 Order # CG-80110? Date: 10DEC1940

R-116 (AWA)
NC-100A-based US Coast Guard Radio Receiver; may never have proceeded beyond prototype stage.
Mostly unknown, has crystal filter, BFO and AVC control, 300/600 ohm speaker terminals & binding post-type antenna terminals.
Contract: TCG-33675 Order #: CG-80265? Date: 15MAY1941

The RAO Receivers
RAO Notes: Moore's 3rd reports RAO-1 through RAO-8 as identical radios. I have found that this is not the case. Each model has variations enough to justify separate listings. Some radios have S meters, some have aux. "Panadaptor" outputs. Several different "antenna" connectors were used, including binding posts, an odd oversized Motorola type plug and SO-239s? (I continue to wonder how original/correct the SO-239s are.) Minor differences in rear-panel layout of power, speaker, antenna, and battery connectors exist. I suspect that differences between manufactures exist even within the same series number. (At least in tube line up they do: i.e. 6F6, vs. 6V6, vs. 6K6 audio output.) Because the RAO series were built during World War II primarily for the Navy, small engineering changes may have been made from production run to production run just because of parts availability. Information that exactly matches many RAO series radios has proved difficult to locate. Several RAOs I have examined do not exactly agree with the Navy documents for that model. It appears that some units were built only by National, (RAO-2/6?,) some only by Wells-Gardner, (RAO-4?) and some by both companies. I continue to research this issue. Where the National NC-120 fits into this puzzle remains unclear. I own one NC-120 and have seen several others. None exactly match the National photographs.

Moore's 4th adds another variation: On p. 111 is an RAO without a suffix number/code.
(See RAO)

I have also located several references in National documentation to an RAO-9 radio. (see RAO-9)
This remains mostly a mystery set.

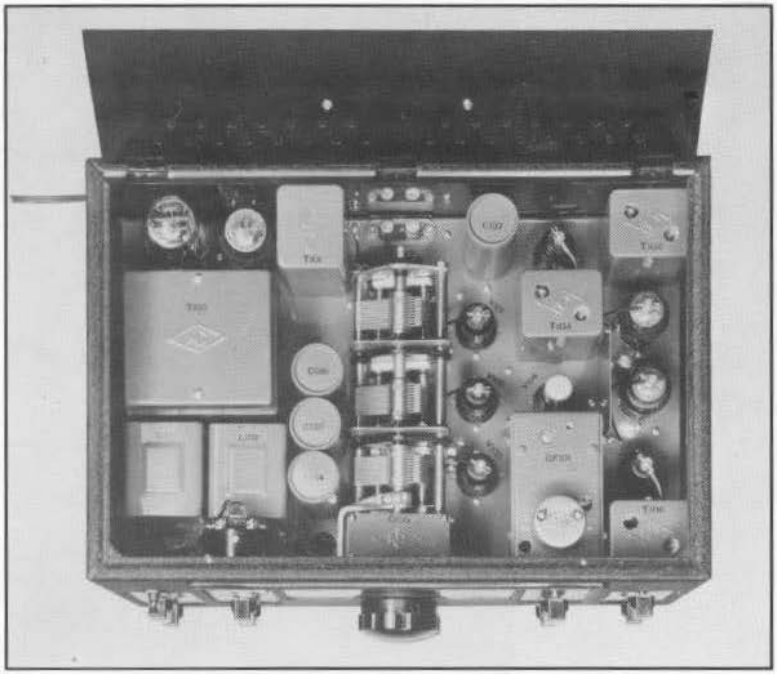


Figure 37. *The model RAO-1 receiver. This is a very early version, starting life as an NC-100 XA (Fig. 17) Note the plug-in crystal unit. There is no added preselector stage on the -1 version.*

Moore's 3rd lists generic data for the RAO-1 through RAO-8 as follows: Crystal filter, added RF stage, 455 kHz IF, five bands, 540-30,000 kHz. Tubes: 6K7 1st RF, 6K7 2nd RF, 6J7 mixer, 6J5 HFO, 6K7 1st IF, 6K72nd IF, 6C8 cetector / noise limiter, 6J7 BFO, 6F8 1st audio / AVC, 6V6 audio output, 5Z3 rectifier.

RAO (M4 p. 111) 1938
Five bands, 0.54-30 MHz coverage, 456 kHz IF, crystal filter.
Moore (4th) lists the Navy designation as CNA-46072, with GE as the contractor. He also reports that this very early version does not have the added RF stage attached to the back.

RAO-1 (M3 p. 95. M4 p. 111)
World War II vintage, built for the U.S. Navy. Similar to the NC-100 XA, without the preselector added to the subsequent models.
May have been built by Wells-Gardner as well as National, using National parts.

Figure 38. *Model RAO-6 receiver in mounting rack. This is also designated an NC-120.*

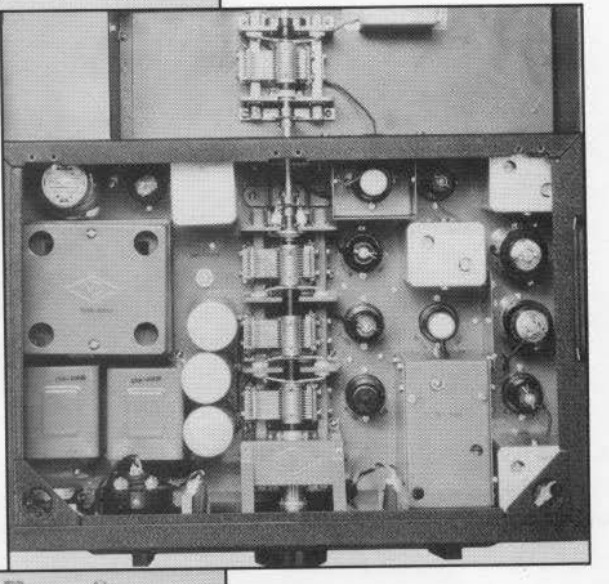


Figure 39. *Top view of the RAO-2. The photo is dated October 14, 1942.*

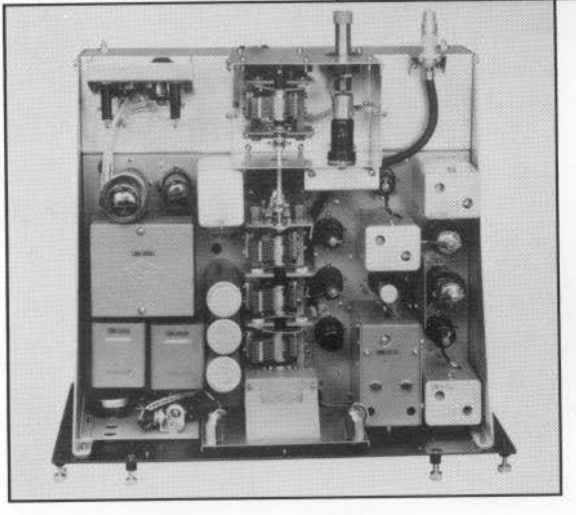


Figure 40. *Top view of the RAO-7, dated Jan./Feb. 1944. Compare this with the RAO-2 in Fig. 39.*

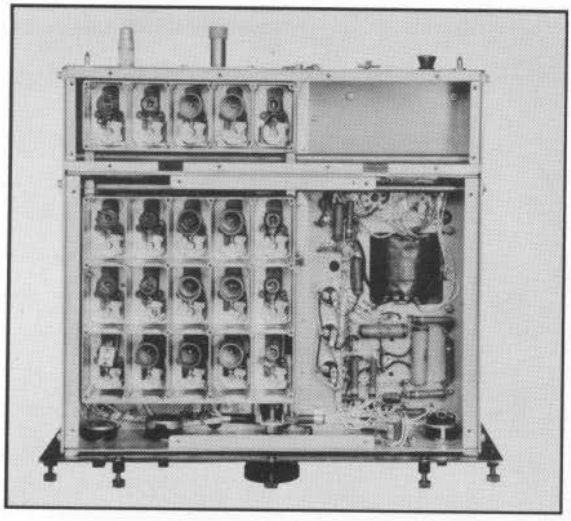


Figure 41. *The RAO-9. Photo indicates this is the same as the -7.*

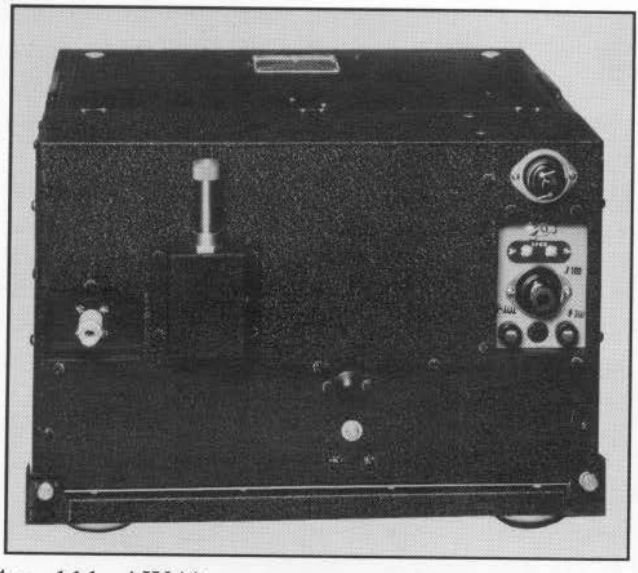


Figure 42. *Rear view of the RAO-6.*

RAO-2 (M3 p. 95, M4 p. 111, AWA)
World War II vintage, built for US Navy, similar to the above. This is the Navy version of the NC-120 radio.
(See NC-120) Part of CNA-46187 radio system.
High S/N known is #2112, date code: 11/20/1943

RAO-3 (M3 p. 95, M4 p. 111, partial Man)
World War II vintage (Navy type CWQ-46187-A), built for US Navy, similar to the above.
Built by National as well as Wells-Gardner, using National parts.
115Vac, 60 Hz. Five bands, 0.54-30 MHz, has odd antenna connector, S meter, with switch, crystal filter, no Panadaptor output.

Known contract(s): NXss-21446 High S/N known: #853, date 11/18/1943. Tubes: (manual) (2) 6K7s 1st and 2nd RF amplifiers, 6J7 1st detector, (2) 6K7s 1st and 2nd IF amplifiers, 6C8G 2nd detector & limiter, 6F8G 1st audio & AVC, 6K6GT2nd audio (output), 6J5 HFO, 6J7 BFO, 5Z3 rectifier.

RAO-4 (M3 p. 95, M4 p. 111, partial man, PC)
World War II vintage. (Navy type CWQ-46187-B) Built for US Navy, similar to the above, by National as well as Wells-Gardner, using National parts. 115 or 230V 60 Hz ac, and except for dual-input main-power transformer, the same as RAO-3. Range 540 kHz - 30 MHz, five bands, odd antenna connector. S meter, S-meter switch, crystal filter, no Panadaptor output.

Tubes: (manual in my files): (2) 6K7s 1st and 2nd RF amplifiers, 6J7 1st detector, (2) 6K7s 1st and 2nd IF amplifiers, 6C8G 2nd detector & limiter, 6F8G 1st audio & AVC, 6K6GT 2nd audio, 6J5 HFO, 6J7 BFO, 5Z3 rectifier.
(Note: My Wells-Gardner RAO-4 has a 6V6 audio output, not the 6K6 the Navy (National) manual specifies. "6V6" is printed (inked) next to the tube socket.)
Known contract(s): NXss-21446. High S/N unknown. (See RAO-3)

RAO-5 (M3 p. 95, M4 p. 111)
World War II vintage. Built for US Navy, physical description as above. May have been built by other contractors (Wells-Gardner, etc.) as well as National, using National parts.
Moore reports (4th) that the USN code for this radio was: CWQ-46229

RAO-6 (M3 p. 95, M4 p. 111, Man, Pvt.)
World War II vintage, Navy type # CNA-46187-D, Part of Navy CNA-46233 Receiver System. Similar to above. May have been built by Wells-Gardner as well as National, using National parts.
Five bands, 540-30,000 kHz, eleven tubes, crystal filter, S meter, 455 kHz IF, has aux. Panadaptor output with SO-239 connector. The odd oversized antenna connector is correct for the Type 6.
Known contract data:
NXsr-38306 high S/N ? Date: 22SEP1943 (from my manual copy)
NXsr-38306 high S/N 648 Date 31JAN1945 (Pvt. communication)
NXsr-38306 high S/N 653 Date 15JUN1944 (Pvt. communication)
Tubes: Identical to RAO-6 above.

RAO-7 (M3 p. 95, M4 p. 111, Man, Pvt., AWA)
World War II vintage, Navy type # CNA-46233
Built for US Navy, similar to above. Has SO-239-type Panadaptor output on back.
NC-127 look-alike, with heavy rack-type capture screws around face. (May have been built by Wells-Gardner as well as National. Still an open question.)
Coverage 0.54 to 30 MHz in five bands. Crystal filter. 455 kHz IF.
Known contracts:
NXsr-55614 high S/N 1587 date: 31MAY1945 (Navy Bureau of Ships)
NXsr-38306 high S/N 444 date: ?
Part of Navy CNA-46233 Receiver System.
In the case of the RAO-7 some interesting information was found in a copy of the "Preliminary Instruction Book, Contract NXsr-55614, 13FEB1945." The document states that: "1073 "receivers" were contracted for, along with 1073 "Spare Parts Sets," 107 Stock Spare Parts Sets," 4146 "Preliminary Instruction Books," (this data is from one of them) 4646 "Final Instruction Books," and 107 unspecified "Additional Spare Parts." (Pvt. communication)
Tubes: Identical to the RAO-6, above.

RAO-8 (M3 p. 95, M4 p. 111)
World War II vintage, Built for US Navy. Similar to above. May have built by Wells-Gardner as well as National, using National parts.

RAO-9 (Brief mention in my National RAO-7 manual, AWA)
Part of Navy System: CNA-46283. Has both small rack-mount handles and capture screws on the front panel, like the NC-127. Crystal filter, Panadaptor output, odd coaxial-type antenna connector. Another NC-100A variant with the extra RF preselector built on the back. No other data available.

RBH Series (M3 p. 96, M4 p. 111, MAN, Pvt.)
(Note: Moore's 3rd & 4th do not differentiate between the three versions.)
Navy NC-100XA-type variations, some with two RF stages, the extra stage bolted to rear like most RAO series. Unusual 1560 kHz IF. (See NC-156, NC-156-1, NC-156-2)
Known contracts:
*RBH Contract # 87668, major part of CNA-46144; contractor was the General Electric Supply Company.

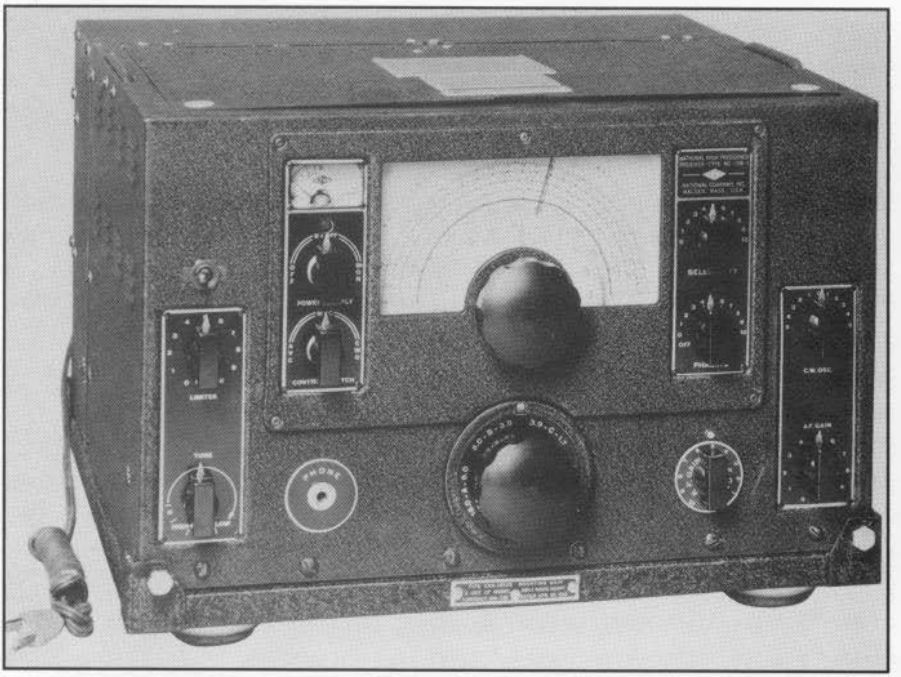


Figure 43. *The RBH-1 set in its mounting rack. Photo dated 2/22/43.*

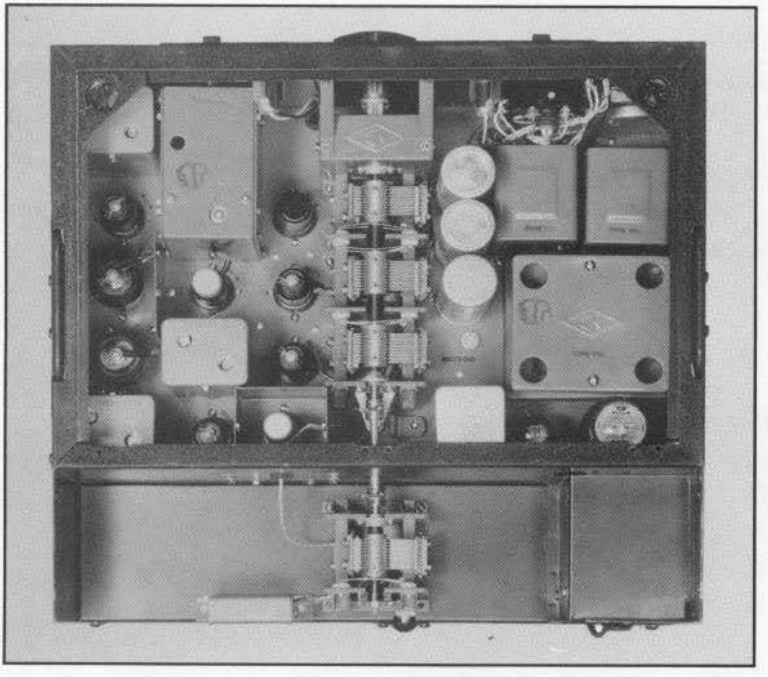


Figure 44. *Top view of the RBH-1. Photo dated 2/22/43.*

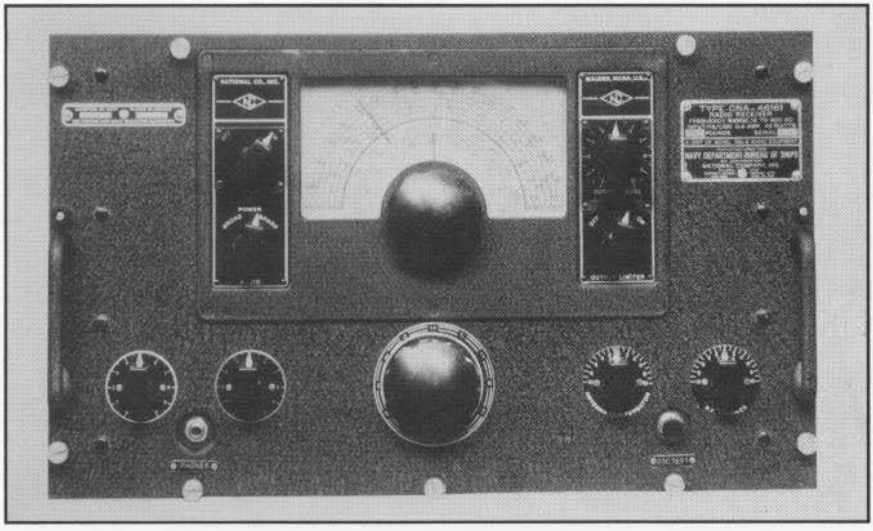


Figure 45. *The RBL-6. This is a sample version for evaluation. Not a coil-catacomb receiver, although it resembles one.*

General Electric Supply Company.
*RBH-1 Contract Number NXs- 738, major part of CNA-46188 system, high serial number unknown; contract date was April 30, 1942
*RBH-2 Contract Number NXss-19881, major part of CNA-46188 system, high S/N known: #1269; contract date was January 2, 1943
*RBH-3 Contract Number NXsr-33381, major part of CNA-46188 system, high serial number unknown; contract date was June 30, 1943

RBL-1 through 5 (PC, Man, AWA)
Built on the NC-100A chassis, this VLF-LF receiver is only a NC-100A look-alike on the outside.
Under the skin, it is a completely separate design based on TRF tuning and regenerative detection.
Range of 10-600 KHz. Made by National and Wells-Gardner using National parts.
World War II years. (A very interesting, and fun-to-use radio. Without a coil catacomb, it doesn't really belong to the NC-100 family. Often mistaken for a NC-100A.)

RC-120 (AWA)
An NC-100A variation built for the US Coast Guard. Range of 2-18 MHz in three bands.
This one has a tuning eye instead of the normal — for the 100A series — S meter. In addition, does not appear to have a crystal filter installed.
Contract TCG-33991? 24SEP1941 (Appears to be a very early 100A variant.)

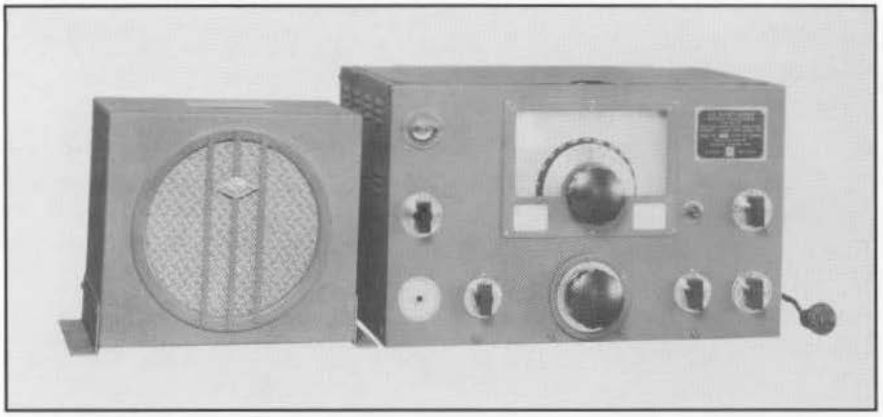


Figure 46. *The RC-120, built for the Coast Guard. Photo dated Oct. 30, 1942*

"Airways Ground Receiver" (AGR) series:
Note: All AGR-series radios were rack-mount versions, designed for the standard 19"-rack environment. They were sometimes supplied with an optional enclosure for desk or tabletop use.

RCD (PC)
Early NC-100X CAA variant. Has crystal filter, and 6E5 tuning-eye tube.
Push-pull audio output. With 200 – 400 kHz low band.
I believe this was the first of the CAA AGR series. This radio seems to be a standard early NC-100 (w/ tuning eye). Equipped with the low-frequency first band option, (200 – 400 KC) in a 19" rack-mount configuration.

Tubes: 6K7 RF amp, 6J7 mixer, 6K7 HFO, 6K7 1st and 2nd IFs, 6C5 detector, 6J7 AVC, 6J7 BFO, 6E5 tuning eye, 6F6(2) audio out (push pull), 80 rectifier.
Known contracts:
Contract (# unknown): Order # 37-7383. High S/N #101.
Built by National; information from data plate on radio.

RCE (M3 p. 96 & 123, M4 p. 112, AWA) "Airways Ground Receiver" *
Modified NC-100 for airport control tower use. From about 1937-38. Five bands, 200 - 400 kHz, 1.3-30 MHz. 457 kHz IF, no crystal filter, binding post-type antenna terminals.
Tube lineup from Moore's 4th: 6K7 1st RF, 6J7 1st detector/mixer, 6J7 HFO, (2)6K7 1st and 2nd IFs, 6C5 2nd detector, 6J7 AVC, 6J7 BFO, 6J7 INS control, 6C5 1st audio, 6V6 audio output, 80 rectifier.

BFO, 6J7 INS control, 6C5 1st audio, 6V6 audio output, 80 rectifier.
Known Contracts:
*Contract (# unknown) Order # 38-2833. High S/N #187
01OCT1937
Built by National, modified by Westinghouse Electric and Manufacturing Co.
*Contract (# unknown) Order # 38-2832 High S/N #78
Date unknown
Built by National, modified by Bendix Radio.

*At least one prototype unit of the RCE was manufactured by National with crystal control. National photographs #938 & 968, 969, 970 & 971.) Labeled as the model RCE-X.

RCF (Man. Pvt.) "Airways Ground Receiver"
"Interchannel Noise Suppression" radio. 457 kHz IF; does not have variable bandwidth IF transformers.
Does not have crystal frequency control option.
(Interestedly, the picture in the RCF manual of the radio shows a Bendix Radio Corp. data plate.)
Tube lineup from manual: 6K7 RF amp, 6J7 mixer, 6J7 HFO, (2)6K7s 1st and 2nd IF amplifiers, 6C5 detector, 6C5 1st audio/squelch, 6J7 BFO, 6J7 AVC, 6J7 I.N.S. amplifier, 6V6 audio output, 80 rectifier.
Known contracts:
Contract (# unknown) Order # 39-2748 High S/N #118
Date: 30JUN1939
Made by National, supplied by Federal Telegraph Co. Newark, NJ

RCH (AWA photo)
Five bands, 200 - 400 kHz, 1.3-30 MHz. Modified NC-100, PW dial, I.N.S. system.
Known contract(s):
Contract (# unknown). Order # 40-1760, high S/N unknown.
Date: 19OCT1939
Made by National, supplied by Bendix Radio Corp. Baltimore, MD

RCK (M3 p. 96, M4 p. 112, RCP manual p. 5,AWA) "Airways Ground Receiver"
Moore's 3rd calls this a NC-100A, Moore's 4th a NC-100. It is a modified NC-100 (not A) chassis with a PW dial. Mostly an unknown variant, mentioned briefly in the RCP manual. Some National Co. photographs exist of a type RCK-1. They show both C.O.N.S. and variable bandwidth IF, and a dual 120/240 V ac power supply. No crystal-control option.
*Contract Cca-617? Order # unknown. High S/N unknown.
Built by National for General Electric Supply Corp., Washington, D.C.

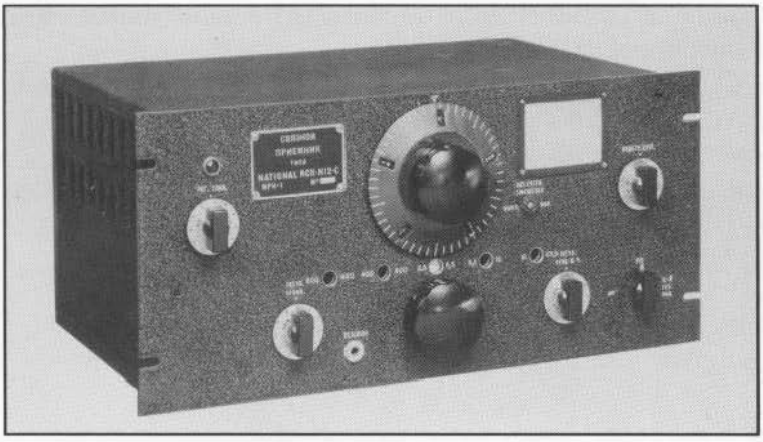


Figure 47. *Receiver designated by National as RCK-N12-C, with Russian language markings. Photo dated July, 1944. Note the unusual frequency ranges.*

*Contract, Cca-978 Order # unknown. high S/N unknown.
Built by National for Bendix Radio Corp.
*Contract (unknown) Order # 38-2833 high S/N 187 Date: 01OCT1937
Built by National, modified by Westinghouse Electric and Manufacturing Co.
*Contract (unknown) Order # unknown. High S/N #235.
Date: 30JUN1939
Part of VF Radio Equipment No. 6736 (Pvt. Communication)

RCL (M3 p. 96 & 123, M4 p. 112, Man, AWA) "Airways Ground

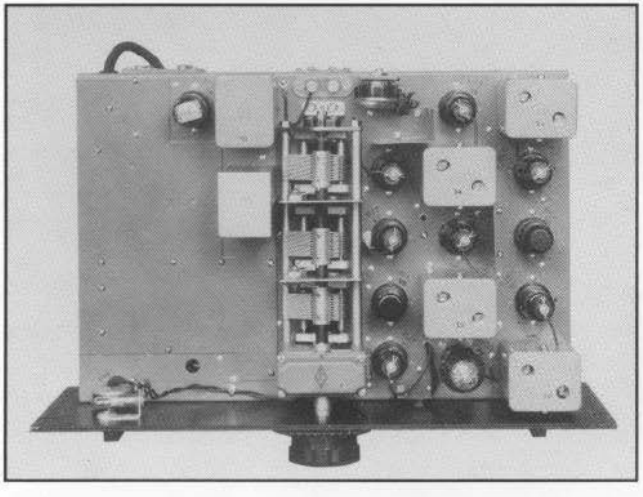


Figure 48. *Top view of the -N12-C. This set uses an external power source.*

Modified NC-100, Roughly World War II vintage. Five bands, 200 - 400 kHz, 1.3-30 MHz. 455 KHz IF with odd modified variable-coupling IF transformers.
The IF coupling can be changed from sharp to broad with a front-panel switch. This feature was later deleted when government contractors refurbished these radios. (See type RCP & RCQ.) Squelch circuit (CONS) added. Crystal oscillator-tuning option added.
Tube lineup from Moore's 3rd & 4th: 6K7 RF amp, 6J7 mixer, 6J5 HFO, (2)6K7s 1st and 2nd IF amplifiers, 6C5 detector, 6F8 1st audio/ squelch, 6J7 BFO, 6J7 AVC, 6J7 CONS amp, 6V6 audio output, 80 rectifier.

RCP (M3 p. 96, M4 p. 112, PC [2], Man, PVT) "Airways Ground Receiver"
Moore calls this a NC-100A on page 96 of his 3rd edition. This is incorrect; it is a NC-100 (no A) chassis with a PW dial. Modified NC-100, roughly World War II vintage. Range 200 - 400 kHz, 1.3-30 MHz.
455 KC IF with three odd modified variable coupling IF transformers. Squelch circuit (CONS) added. Crystal oscillator tuning option.
Known contracts:
CAA Contract # Cca-24653 Order 46-1467, high S/N #825, 30OCT1945, built by National, modified by Schuttig & Company, from an RCK or RCL. (See manual page 5)
Tube data from manual in my files: Same as that for the RCL receiver, above.

RCQ (Man. Pvt.) "Airways Ground Receiver"
A modified NC-100 Communications receiver, range 200 – 400 kHz, and 1.3-30 MHz. 455 kHz IF, with two odd modified variable coupling IF transformers, squelch circuit (CONS) added, crystal oscillator-tuning option.
Tube data from manual in my files: Virtually identical to that of the RCL and RCP above, except that the 6C5 detector has been replaced by a 6H6, serving as 2nd detector and noise limiter.
Known contracts:
CAA, contract # CCA-26227 high S/N #404, dated 05FEB1948, made by National, modified by National Electric Machine Shops, Silver Springs, MD. From a type RCK or RCL. (See manual page 5)
I believe this was the last of the CAA contracts. An acquaintance has reported owning one of these with S/N B366. Unfortunately all the contract data plates are long gone from his radio. Could there have been more than one series?

RHZ (unknown variant, mentioned briefly on page 5 of RCQ manual, Pvt.)
Known contracts:
*CAA, contract # Cca-15856, high S/N #35, made by National, modified by Communications Equipment Corp., Pasadena, CA.
*CAA Contract # Cca-232876, high S/N #1048, made by National, modified by Communications Equipment Corp., Pasadena, CA.
For reference notes on detailed listing data, see the Bibliography section.

Notes on Speakers

Matching speaker information is often as hard to find as the matching speakers are themselves, so this is an incomplete listing.

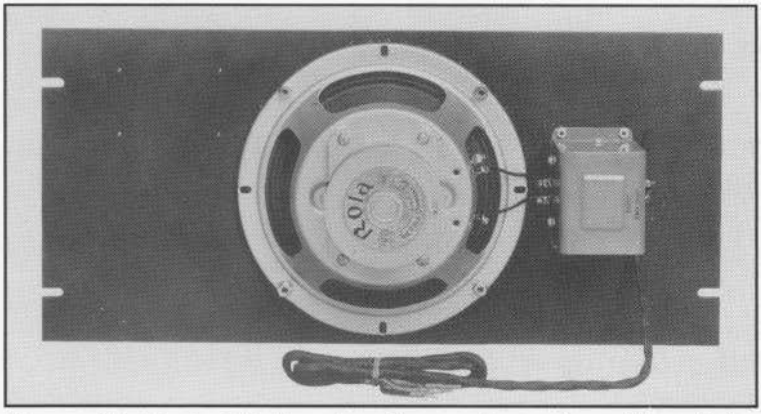


Figure 49. *Typical National rack-mount speaker with matchng output transformer. This is an 8" PM Rola.*

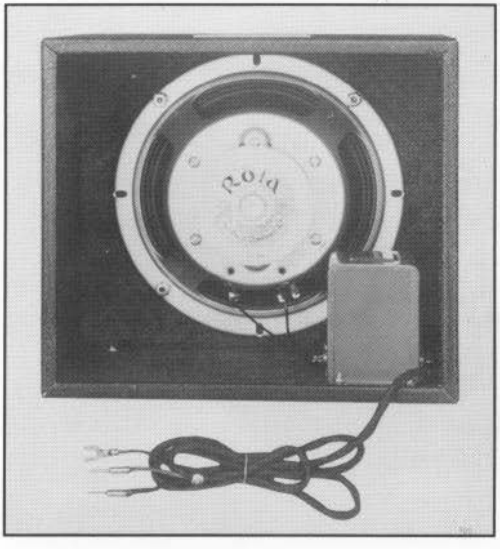


Figure 50. *Another Rola speaker for use with a table-model National radio.*

For the NC-100 and NC-101 series:
The DCS-8 (8") and the DCS-10 (10"), both black with an embossed National Logo.

For the NC-200:
The NC-200-TSG, two-tone gray with chrome trim.

For the NC-2-40 series:
The NC-2-TSG, 10" PM speaker in two-tone gray with chrome trim and feet.
The NC-2 RS, 10" PM speaker on 10 1/2"gray wrinkle-finish rack panel.

A Note On Noise Limiters - Still More Variations

During the production years of NC-100s, NC-101Xs and NC-100As National introduced a new noise-limiter circuit to many of its models. This change was documented in a brief (four-page) addendum supplied with the owner's manual.

A 6C8G and a 6F8G replaced the 6C5 second detector and the 6J7 AVC tubes previously employed. The 6C8G elements comprise an infinite impedance diode second detector and the new series-valve noise limiter while the 6F8G is used for AVC and a new first audio stage. The circuit was described in some detail in the October, 1939 issue of *QST*.

The really interesting thing about this noise-limiter is that the design change was made in mid-production for many of the early Nationals, *without* a model number change. The collector will run across later radios with the change and earlier radios without it.

Some Notes on the Coil Catacomb Assemblies

The cast coil-catacomb assemblies themselves are only superficially identical. There are a number of different variations in the casting. All have the cast-in "bosses" at the rear through which the main rail runs. Some have fiber-insert bushings in the bosses, and these are often in very poor shape. I have had good luck replacing these with small pieces of Teflon plastic tubing which I located at a local surplus store.

The drive teeth, which engage the drive gear, are located at the front of some castings and roughly in the middle of others. The drive mechanism, which controls catacomb position in the radio to select the band, was made in a number of variations. Some (NC-200, NC-2-40, etc.) engage only when the main-control knob is in the pulled-out position. Others, such as in the NC-100, NC-100A, are always engaged. Some NC-100As have a movable dial pointer connected to the band-select system in such a way that the pointer length

shows which band is selected, while others have a rotating ring around the knob to show the band in use.

The NC-200 & -2-40 series allow the selection of up to ten different frequency ranges or bands with a small moving-band indicator along the bottom of the direct-reading dial assembly. All direct-reading dial models are also equipped with an auxiliary-logging dial to improve the repeatability of the system.

The band-switching contacts on the upper side of the cast catacombs are designed to be self-wiping and to provide a positive connection and detent feel as the bands are changed.

The spring contacts that the coil-catacomb assembly engages are located directly beneath the main tuning capacitor in the radio, and are also designed to be self-wiping. Most are silver-plated, phosphor-bronze spring alloy. In most models, one set of contacts (*the oscillator - Ed.)* has a small piece of insulating material between the contacts located in such a way as to allow the contacts to act as a spring-loaded switch. This switch disconnects the screen voltage from the vacuum tubes when the coil catacomb is between bands, preventing extremely loud electrical noises from appearing at the speaker or in the headphones when the band is changed. It also prevents the vacuum tubes themselves from drawing excessive current if the radio is left between bands with the B+ voltage turned on for an extended period.

Some Notes on Common Problems and Failures

Probably the single most common failure in all the old National coil-catacomb receivers is the main power transformer. Almost half of the radios I know of have or have had at one time main transformer failures. The design of power transformers has not changed much in sixty years, but the materials used have. Wire varnishes have improved, sulfated paper has been replaced by poly-based plastics, and cloth-wire insulation has gone the way of the dinosaur. Asphalt pitch no longer "pots" components, and we seldom worry about component stress from high voltages in our new low-voltage world.

Transformers, filter capacitors, chokes and all the rest of the high-voltage (by today's standards) power-supply components need to be treated with care. I strongly recommend the use of inrush current limiters to help preserve these radios. Placed in the 115-120V ac primary-power circuit, they will provide a nice "soft-start" effect that helps minimize the strain on sixty-year old impossible-to-replace components. These can easily be added in an invisible, reversible, manner under the chassis.

Wax-coated capacitors are another common failure. In fact, I've never seen a coil-catacomb National receiver without bad ones. If you wish to power-up the set, replace them all with modern metalized poly parts (get the type

rated for RF use) and your radio will perform much better. In fact, modern capacitors have expected lifetimes far longer than the owners!

Mica "postage-stamp" capacitors are usually still good, but watch out for the larger-value units that may appear to be mica, but are actually paper with a molded exterior. These often show up in decoupling circuits; they are very prone to leakage.

Fortunately none of the coil-catacomb Nationals used unusual hard-to-find vacuum tubes, and all of the RF tubes are still readily available from many sources. The rectifier and audio output tubes are only slightly more expensive and harder to find. The main tuning capacitors and PW dial assemblies are quite rugged, can be cleaned, and will give many more years of service unless they have been mechanically damaged. *(Note, however, that the metal castings on some of these dials have distorted by being exposed to prolonged periods of dampness. They can be restored with careful work...refer to a back issue of the* Old Timers Bulletin *(Nov. 1995, Vol.36, No. 4) for details on the procedure. - Ed.)*

Credits:

Many people contributed freely to my research. While I do not have the space to list each by name, I wish to extend a very special Thank You, in addition to individuals, to the "Boatanchors" Internet mailing list, for a long list of submissions, thoughts, comments, and critiques. Now thriving under the loving care of Jack Hill at Hyperlink (mail to: <boatanchors@sco.theporch.com>), "Boatanchors" is without a doubt the premier Internet information source for serious collectors, restorers and admirers of vintage vacuum-tube communications equipment. Contact Jack at Hyperlink; mail to: <listown@sco.theporch.com>, <listown@jackatak.theporch.com> for information on subscribing and dues.

I would like to extend a special thanks to William Fizette of the A.W.A. for providing both the forum and the encouragement required to complete this article. And also to Alan Douglas for encouraging me when this article was just a "I'll-write-it-someday" idea, and for making available the only still-existing official National Company Marketing Dept. photographs, many of which grace this article. Alan saved them from a dumpster years ago, and every National collector in the world owes him a debt of gratitude for his foresight.

(Note: We have volumes 9-13, 15, 17, 18, and 20. The others are missing and are presumed lost. However, if anyone knows of their whereabouts, please contact either the author or the editor. Ed.)

No work of this nature is ever truly finished, and new information comes to light constantly. Anyone who can add contract numbers, serial numbers, manual copies or any other information is invited to contact me.

Published works such as Ray Moore's books, William Fizette's columns in the AWA Journal, *The Old Timer's Bulletin*, and Alan Douglas's works in *Antique Radio Classified* and other venues have been extensively mined for information. I've tried to properly credit authors throughout this work, but undoubtedly have failed from time to time. All errors, omissions, mistakes, and miss-quotes are mine alone.

The author has attempted to maintain some standards concerning use of electronic terms, which have changed over the years. Where quoting from manuals, magazine columns, etc. the original term has been retained. Thus "condensers" and "capacitors," "1st detector" and "mixer," may be used interchangeably. You will also see dual use of the terms kc. and kHz. Sentence syntax has changed somewhat over the years, but you may rest assured that where it has been badly mangled the fault is mine.

Significant portions of this work have been copied verbatim from much earlier National Company, Inc. and James Millen literature. In each case, the original author wrote something that I feel is of historical importance, and thus has been reproduced here.

Bibliography & Notes

Major sources of information included:

AWA - Photographs from The National Company, Inc., provided to the author by Alan Douglas and William Fizette.

M3 - Moore's 3rd edition: *Communications Receivers, The Vacuum Tube Era:1932-1981*, 3rd Edition, by Raymond S. Moore, RSM Communications, Key Largo, Florida, copyright 1993, ISBN 0-9618882-2-9

M4 - Moore's 4th edition: *Communications Receivers, The Vacuum Tube Era:1932-1981*, 4th Edition, by Raymond S. Moore, RSM Communications, La Belle, Florida, copyright 1997, ISBN 0-9618882-4-5

MAN - Original and photocopy manuals in my files.

MAG - Original and photocopies of magazine articles in my files. From *CQ, QST*, etc.

NA – original or photocopies of National Company, Inc. advertisements in my files.

From magazines, ARRL handbooks, etc.

NC - Original and photocopy National catalogs in my files.

NF - Original and photocopies of National advertising literature in my files.

PC - Radios in my personal collection.

PVT - Private communications with current owners, former National employees, knowledgeable fellow National collectors, etc.

"A Brief History of the National Company, Inc.", by John J. Nagle,K4KJ, Herndon, VA, in *The AWA Review*,Volume 1, 1986, published by the Antique Wireless Association, Inc., Bloomfield, NY, 14469.

"The National Sliding Coil Tray Receivers," and "Restoring the National Company Sliding-Coil Receivers," by William Fizette, in the *Old Timers Bulletin*, Vol. 28-4 and 29-1,1988, published by the Antique Wireless Association, Inc., Bloomfield, NY, 14469.

RIDER XX - John Rider's "*Perpetual Radio Trouble-Shooter*" manuals.

SRPP - *Shortwave Receivers Past and Present, Communications Receivers, 1945-1996*, 2nd edition, by Fred Osterman, Universal Radio Research, 6830 Americana Parkway, Reynoldsburg, Ohio, copyright 1997, ISBN 1-882123-06-9.

Contract data: Contact numbers, Order numbers, dates, S/Ns, etc. are as reported by owners, from manual copies, and my personal radio collection. You are invited to help "fill in the blanks."

Photo captions by the editor.

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Larry first became interested in short wave receivers when still very young, while spending a summer with an aunt and uncle on a WV farm. Seems the uncle had been a Navy radioman during World War II, and had an old black wrinkle-finish communications receiver in the workshop. Larry discovered the joy of listening to the powerful SW BC stations, and was "hooked." Later, remembering the magic of those nights, he studied electronics, acquiring along the way an AS in Computer Science and a BS in Electronics Engineering Technology.

In due course the old radio, an NC-120, became his and after some clean-up it still worked! He then discovered that being an SWL with the big old National is not the same as using a modern solid-state rig. It's at least ten times the fun! The "magic" is back; a dark room, glowing firebottles, and those voices from all over the world. He was hooked again, and has since acquired a whole shopping list of National catacomb and other receivers for his personal collection.

Early in the process of acquiring and repairing the coil-catacomb sets, he found that while volumes of information existed on the HRO, little could be found on the catacomb receivers. He started collecting information, and decided to assemble it into a somewhat coherent and hopefully correct presentation. This paper is the result - to date, he emphasizes.

Larry's professional background includes work experience with Xerox, the FAA, GE, DOE National Laboratory, AT&T, and three years with GTI Telecom as Manager of Technology Development. He is currently owner and president of Wayward Enterprises, Inc., providing telecommunications project management services to the long-distance industry. In his spare time, he provides NOS (new old stock), used and reproduction parts to National collectors, and refurbishes older items of HP, Fluke and Tektronix test equipment. He resides with his wife, Pamela, in the Orlando, FL area.