Heathkit of the Month #098:
by Bob Eckweiler, AF6C

Heathkit

MISCELLANEOUS:
Heathkit RC-1
Radiation Counter

Introduction:

In October of 1962 the world worried; the Cuban missile crisis was in progress, a nuclear stand-off between the Soviet Union and the US over Soviet nuclear missiles in Cuba. I was living on the east coast at the time, attending high school on Long Island; there was serious concern, and I remember riding on a school bus, as part of our high school soccer team, to an away game. The crisis was near its peak, so it was the topic of discussion among many team members, some talked bravely, but fear was in the back of our minds. Someone mentioned that we all needed to have a Geiger counter, just in case….

I remembered seeing a "Radiation Counter" kit in an older (at the time) Heathkit catalog, and after getting home I looked through the current catalog. The kit had been discontinued. It was shown in an earlier catalog, but at $80 it was beyond my budget. Luckily, the crisis ebbed and the discussions on the bus rides went back to sports and girls. But since then, the thought of owning a geiger counter seemed a good idea even in times of peace. Heath offered the GDP-341 Family Radiation Measurement Set in the then current catalog, but it was a big step down from a Geiger counter.

Here is a link to the index of Heathkit of the Month (HotM) articles:

http://www.w6ze.org/Heathkit/Heathkit_Index.html

Figure 1: The Heathkit RC-1 Radiation Counter (Geiger Counter) less probe. Photo courtesy of Chuck Penson - WA7ZZE.

The RC-1 Radiation Counter:

This month's article looks back at that Heathkit Radiation Counter kit, the RC-1 (**Figure 1**).

The RC-1 was introduced in the Summer 1956 Heathkit flyer, and it actually got top billing on the front cover (**Figure 2**). Heathkit called it a "professional radiation counter" kit,

Figure 2: The Heathkit RC-1 as shown on the cover of the 1956 Summer Flyer.

and the cover illustration shows a family picnicking, while in the foreground the husband prospects with his RC-1. Uranium prospecting was popular around the time Heath's Geiger counter was introduced. The kit remained in production until sometime in 1961; it didn't make the main 1961 US catalog, but did appear in the Italian 1961 Heathkit catalog.

The RC-1 Radiation Counter, often called a Geiger counter, weighs 6½ lbs. It runs on three batteries, A 67½ volt 'B' battery and two 1½ volt 'A' batteries (standard 'D' cells). The 'B' battery is good for about 200 hours of operation and the 'A' batteries, which power the tube filaments, are good for about 20 hours of operation. The end-of-life voltage for the batteries are 40-volts and 1-volt respectively. Specifications for the RC-1 are shown in **Table I**.

Time Constant:	0.5, 1, 5, 10 seconds.
Ranges:	0 – 100, 600, 6,000, 60,000 CPM.* 0 – 0.02, 0.1, 1, 10 mR/Hr.**
Meter:	Calibrated 4½" scale; 200 µa movement.
Probe:	Satin aluminum and chrome-plated probe case. 6306 bismuth Geiger tube.
Speaker:	2-1/2" square (no impedance specified)
Calibration:	Calibration control on front panel. Radioactive calibration sample furnished.
Batteries	2 each 1.5 volt carbon-zinc "D" battery 1 each 67½ volt 'B' Battery NEDA 200 (2-13/16" W x 1⅜" D x 3-45/64" H): Burgess XX45, V45 Eveready 467, 468 Mallory M200 Ray-O-Vac 200 RCA VS016, VS125.
Size:	9½" high x 6½" wide x 5" deep.
Weight:	6½ lbs.
Shipping weight:	8 lbs.

* Counts per minute. ** milliroentgens per hour

Heathkit RC-1 Radiation Counter Specifications
Table I

Vacuum Tubes:		
V1	1U5	Amplifier
V2	1U4	Amplifier
V3	1U5	½ Monostable multivibrator
V4	3V4	½ Monostable multivibrator
V5	5841	Corona Voltage Regulator (900 V)
Geiger Müller Tube:		
V6	6306	Counter tube (bismuth-argon)
Semiconductor:		
	2N109 GePNP –25 Vceo 165 mW	

RC-1 Tube and Transistor Lineup
Table II

The RC-1 uses six tubes[1]. Four of these are vacuum tubes designed for portable operation, three with 1.5 volt filaments and one with dual 1.5 volt filaments that may be run in series or parallel (these tube's filaments are also their cathode). The fifth tube is a five lead subminiature gas-corona voltage regulator tube, and the sixth is the Geiger-Müller detector tube which mounts in a probe assembly and is connected to the chassis via a shielded coil-cord. **Table II** lists the tubes and the one transistor.

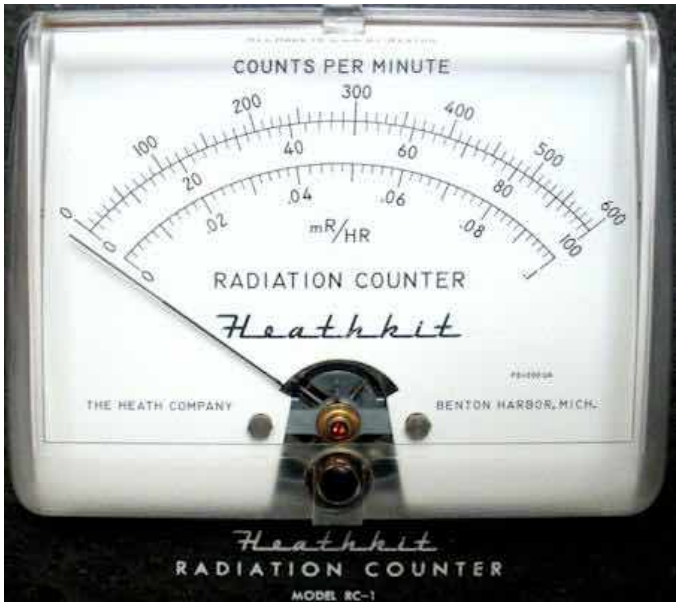

Figure 3: Heathkit RC-1 Radiation Counter meter scales.

Heathkit RC-1 Controls:

The panel of the RC-1 has a large 4½" 200 µA meter, a carry handle, two rotary switches: **RANGE** and **TIME CONST.** and a tone **PITCH** control. It also has a **CALIBRATE** control with a protective cover, a speaker, a phone jack for an **EXT. METER** and a connector for the **PROBE**. The panel layout is described in detail in **Table III** and the meter face is shown in **Figure 3.**

Heathkit RC-1 Operation:

Operating the RC-1 is not difficult. There are only two switches you need to set and a control you can use to make your listening more comfortable. The first switch is RANGE. It is set so the meter is on scale and indicating a reading. The second is TIME CONST. This is the time over which the meter reading is averaged. At the shortest time constant the meter may jump quickly responding to changes in radioactive levels. At the higher time constants the level will change more slowly averaging the levels. The manual states:

> ***"The choice of time constant has been made available so that you may use a time constant appropriate to your speed in covering the area in which you are prospecting. The shorter time constants are advantageous when covering ground rapidly, as when in a vehicle or mounted on a horse or burro. The long time constants enable a more accurate reading to be made when checking ore samples or when grid prospecting a suspected anomaly. When prospecting, a time constant sufficiently short to enable the instrument to indicate any change in the normal background count is normally used."***

No, the burro is not part of the kit, nor is the horse or vehicle!

The only other control you might use in the field is the PITCH control. Heathkit, instead of sending clicks to the speaker, turns each click into a short burst of tone, making it easier on your ears, as well as easier to distinguish in a noisy environment (also distinguishing it from the clicks created by the internal HV power supply assembly).

Top Row:
Meter 4½-inch, 200 µA full-scale
Top Scale: **0 – 600 COUNTS PER MINUTE**
at 10 counts per small division (60 div. total)
Middle Scale: **0 – 100 COUNTS PER MINUTE**
at 2 counts per small division (50 div. total)
Bottom Scale: **0 - 0.1 mR/HR**
at 0.002 mR/HR per small division (50 div. total)

Second Row (L to R):
RANGE mR/HR–CPM 5 position rotary switch -:
Power **OFF**
mRX100 / 60K CPM
mRX10 / 6K CPM
mRX1 / 600 CPM
mRX.2 / 100 CPM
Plastic Handle - Extends downward to bottom of panel.
TIME CONST. SECONDS 4 position rotary switch:
10, **5**, **1**, **.5**

Third Row (L to R)
CALIBRATE 100 KΩ Potentiometer
No scale markings, Plastic shaft lock/protector
Speaker X" dia. Square frame
PITCH 2 KΩ Potentiometer
CCW circular arrow, **OFF** at full CCW position.

Bottom Row (L to R):
EXT.[ernal] **METER** ¼" 3 circuit (TRS). phone Jack
Bottom of handle (from second row)
PROBE SO-239 UHF connector

Table III: Panel Layout

Heathkit RC-1 Calibration:

So how does the typical layperson calibrate a radiation counter? With each kit Heath sent a 'safe' radioactive sample[2] to use for calibration (See **Figure 4**). New, the sample has a radiation level of 1 mR/Hr and is used to calibrate the mR/Hr X10 position, adjusting the CALIBRATE control to 1 mR/HR on the meter

Figure 4: Heathkit PN 419-1 Radioactive Sample used for calibration. It produces 1 mR/hr. Photo courtesy of Chuck Penson - WA7ZZE

scale with the marked side of the sample placed against the middle of the probe body along its circumference (**Figure 5**). Due to the use of precision capacitors, the other ranges should follow this one calibration point.

Assuming the calibration sample is radium, whose half life is 1,600 years, the calibration sample after 60 years will have decayed by just over 2.5%[3]. For it to decay by 10% of its original radioactivity would take over 244 years.

The Heathkit RC-1 Circuit:

A schematic for the RC-1 can be found at the end of this article (**Figure 15**). The output of the Geiger-Müller tube is negative pulses. These pulses are amplified by V1 and further by V2, which also acts as a limiter at about a quarter volt to insure the pulses properly trigger V3. Since each of these two stages inverts the pulse, the pulses coupled to the grid of V3 are also negative going.

V3 and V4 are connected as a "one-shot" monostable multivibrator. In the stable position V3 is conducting lightly and V4 is cut-off. V3 is conducting due to the positive bias on its grid from the 2.2 MΩ and 1 MΩ voltage divider. V3 and V4 share the same 15 KΩ cathode resistor and the voltage drop across that resistor makes the cathode of V4 positive with respect to the grid which is returned to common through a 1 MΩ resistor, holding V4 cut-off.

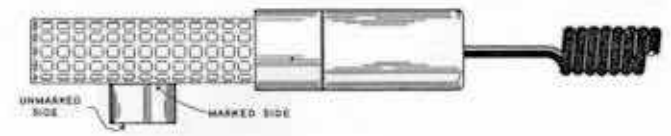

Figure 5: Calibration showing proper placement of sample and probe. (Heath Manual - Figure 12)

When a negative pulse is applied to the grid of V3, the tube turns off. This raises the V3 plate voltage which is coupled to the grid of V4 through one of the four RANGE capacitors turning V4 on. V4 draws significantly more current when on than V3, hence the voltage drop across the common 15 KΩ cathode resistor keeps V3 cut-off. After a period of time, determined by the value of the RANGE capacitor, the voltage across the capacitor reaches equilibrium cutting off V4 and returning the circuit to its V3 on stable state.

The more counting pulses that occur per minute the longer V4 is on over that minute and the higher the average plate current. The plate current is set by the 47 KΩ fixed resistor and the 100 KΩ calibration control. Since the range capacitors are precision, the calibration holds for the other ranges.

The TIME CONSTANT switch selects one of four large-value capacitors that are across the meter circuit. This capacitance averages out the meter reading over a given period of time depending on the capacitor selected. The purpose of the TIME CONSTANT function was described earlier in the operation section.

Instead of the speaker receiving the pulses (or clicks) directly, Heath built in a small os-

cillator using a single transistor, an output transformer and a couple of resistors. Each pulse draws current through the 2 KΩ PITCH control and a fixed 18 KΩ resistor. This voltage drop powers the transistor and it oscillates, producing a short burst of tone in the speaker instead of a click. Heath claims this makes it easier to hear in a noisy environment, as well as being easier on the ears. When the PITCH control is turned fully counterclockwise the tone oscillator is biased off.

When in the power OFF position the RANGE switch disconnects the B+ battery and each of the two 1.5 V 'D' cells from the circuit. It also shorts the meter circuit to prevent damage during transport. Two separate filament batteries are required since the filament is also the cathode. One 'D' cell powers the multivibrator circuit tube filament (V3 and V4) since they require a common cathode resistor, and the other 'D' cell powers V1 and V2 which share the same cathode bias source. Note that the V1 and V2 filaments draw 100 mA total while the V3 and V4 filaments draw 150 mA total. Thus, one 'D' battery will require changing more often.

Figure 6: The Victoreen #667 HV unit, with the cover unsoldered, used in the Heathkit RC-1. Note the inductor/transformer, the relay, the foam mounted tube (type unknown), one tubular capacitor and some disc ceramic bypass capacitors.

The RC-1 HV Power Supply Sub_Assembly:

The 6306 counter tube requires a high voltage of 850 to 950 VDC at a very low current to operate. The kit is supplied with a prebuilt and solder sealed HV power supply assembly. This Victoreen #667 may have been made specifically for Heath? Little can be found in the manual or on the Internet. It is a three terminal device with a +67.5 volt input, a +1,200 VDC output and ground. **Figure 6** is a photo of the inside of the #667 regulator that was found[4]. It reveals many of the components inside. These include a relay, an inductor or transformer, some capacitors and an electron tube mounted in foam by a spring band. The tube type is unknown. The ***Test and Calibration*** section of the manual starting on page 20 states: ***"A rapid, uniform clicking will be heard coming from the power supply unit. This is normal and indicates the power supply is working.*** The relay is causing this clicking, and evidently it is breaking the current through the inductor, producing the high voltage, which possibly is isolated by the tube and filtered by some of the capacitors. Since no filament voltage is supplied to the tube it is probably some sort of gas rectifier? The operation of the #667 HVPS mentioned here is an educated guess.

The output voltage is regulated at 900 volts by V5, a 5B41 voltage regulator, also manufactured by Victoreen. This tube is a corona discharge type regulator tube; a lot of discussion is included in the RC−1 manual on how it operates and is worth reading if you are interested further. Suffice to say it regulates ±1.5% at 900 volts from 5 to 50 μA.

The RC-1 Probe and Geiger tube:

The probe containing the Geiger Müller tube has its own assembly section in the manual titled: ***"CONSTRUCTION OF THE GEIGER***

COUNTER PROBE MODEL GC-1" [5]. The 6306 tube itself is very fragile due to its thin walls and mounts a thin plastic collar which, in-turn, mounts inside the mesh probe barrel. The probe handle, which screws into the probe barrel, contains a socket and is wired to a shielded coiled cable. A PL-259 UHF connector mounts on the other end of the coiled cable and mates with the SO-239 connector on the front panel of the RC-1.

The 6306 counter tube (See **Figure 7**) is a thin walled tube filled with argon gas along with an unspecified organic quench gas. It is designed for detecting gamma rays. Inside the outer thin aluminum cover is a plating of bismuth. Inside that a lining of copper screen is added for mechanical strength. The tube itself measures 4⅛" L x 51/64" D. Its active length is 2¾". The tube is sensitive to high energy beta rays above 160 K eV (Kilo electron Volts). and gamma rays from below 25 K eV to above 800 K eV.

The 6306 Geiger Müller (G-M) Tube Operation: It is surprising that Heathkit gave a very small description of the 6306 tube; especially after their long description of the 5B41 corona regulator tube. The 6306 description in the manual just states: ***"A thyrode counter tube is a gas diode designed to produce an electrical pulse when its sensitive volume is penetrated by an ionizing particle."***

Figure 7: 6306 Geiger Müller tube manufactured by the Victoreen Instrument Company,

Victoreen appears to have coined the name "Thyrode" for their series of Geiger Müller tubes. The tube consists of a sealed cylinder with a thin conductive wall that makes up the cathode. The anode is a wire running along much of the cylinder's axis. The cylinder is filled at a low pressure with a halogen gas (argon for the 6306) and an organic quenching gas. A high voltage, on the order of 900 volts, is applied between the anode and cathode.

When a high-energy beta ray or a gamma ray strikes the tube it ionizes some of the gas within the tube. It may also knock some electrons loose from the tube wall. When a gas molecule ionizes it creates an ion and a free electron. The electrons are attracted to the anode, and as they get close they accelerate, colliding with and ionizing more gas molecules. UV photons are also created, and these particles are not affected by the anode charge. Many travel parallel with the axis of the tube causing more ionization along the length of the tube. Overall a large avalanche is created causing current to flow in the anode. This current creates a negative voltage drop across the 1 MΩ anode series resistor.

Figure 8: Probe (Heath designation GC-1) that is assembled as part of the RC-1 kit.

As the avalanche continues, many ions are created around the anode. these ions move much slower than the electrons and build a space charge around the anode that reaches a level where it stops the avalanche. As the ions move back to the cathode, they pick up an electron and return to their neutral state, and the anode current ceases.

Unfortunately, when a gas ion reaches the cathode and recombines with an electron it can cause the release a photon, often resulting in spurious secondary discharging. The quench gas is chosen to absorb these photons and help the tube to return back to its normal state. While the tube is avalanching it will not respond to a new event so it is important that the tube recover quickly. The 6306 dead time is specified at 100 µS. The 6306 quench gas is specified only as "organic", however methane is a gas that was commonly used at the time.

High energy gamma rays can travel so fast that they can often pass through the tube without striking an atom in either the aluminum casing or the internal gas, reducing the tube's sensitivity to this type of radiation. To counter this a layer of bismuth is added to the inside of the cathode. Bismuth is a heavy metal and its density is such that the chance of a gamma ray hitting it is significantly improved. The difference in sensitivity for 200 K eV gamma rays between the Victoreen 6306 and its identical, less the bismuth, 1B85 tube is 10 fold.

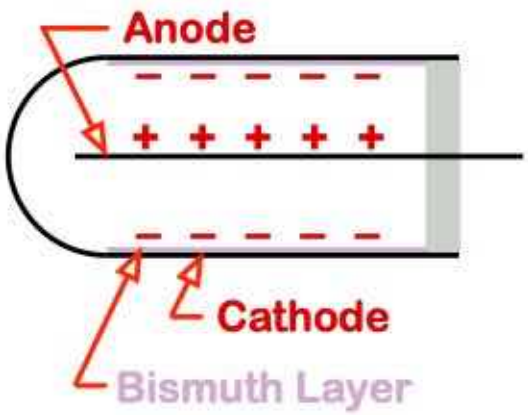

Figure 9: 6306 Geiger Müller tube layout.

Heathkit RC-1 Assembly:

No assembly time is given, but the RC-1 is not a difficult kit to assemble. It could probably be considered a two or three evening kit. The manual is straight forward with seven, mostly full page, pictorials and ten figures showing assembly and wiring details. **Figure 10** shows one of the pictorials in the manual. The whole assembly and calibration section of the manual is just over 14 pages.

Figure 11 is a photo of the B-battery side of the RC-1 with the B battery and case re-

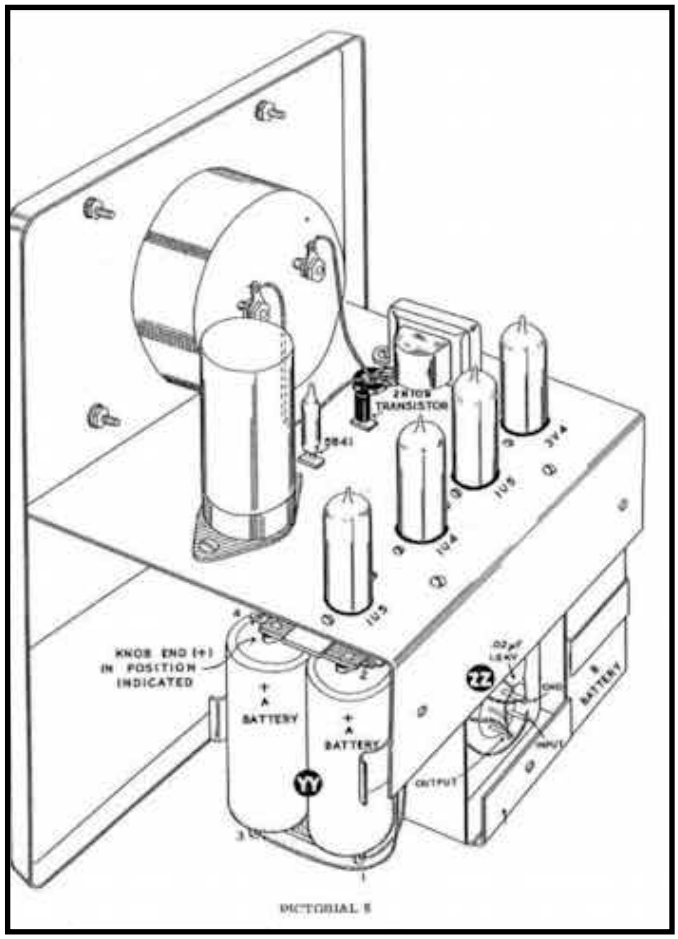

Figure 10: Typical manual pictorial drawing.

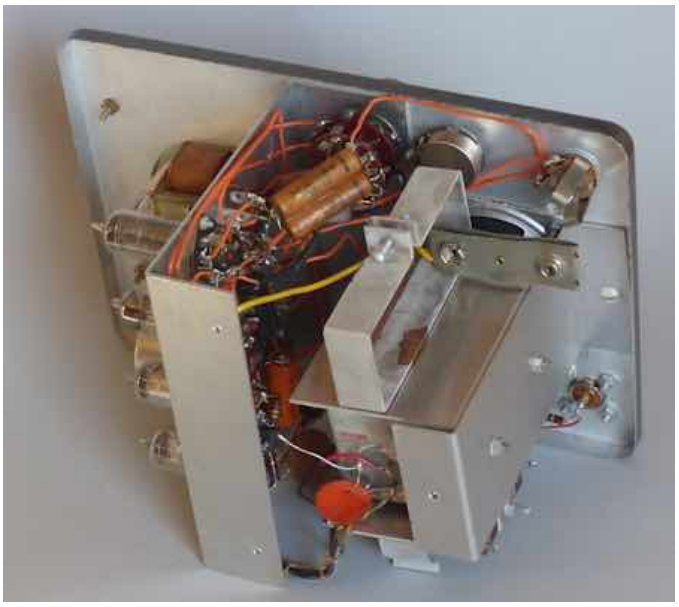

Figure 11: The B-battery, when installed, is held by the bracket, and mates with the snap connector. HV power unit can be seen below the bracket.

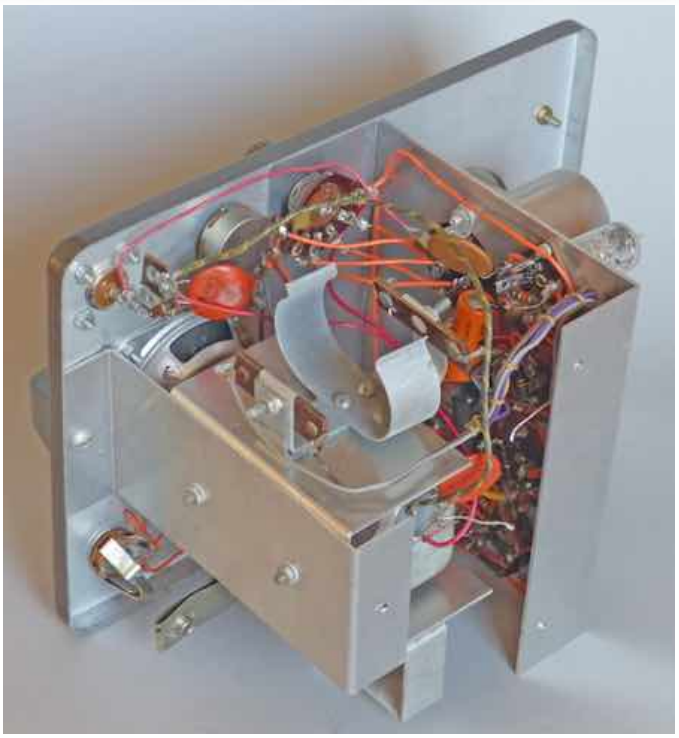

Figure 12: Two 'D' Cells mount in the battery clip to power the tube filaments.

Figure 13: Heathkit RM-4 Pocket Geiger counter as shown in the Spring 1989 (#216) Catalog. It is light, small and uses one standard 9V battery.

moved. The battery connector is clearly visible. The orange disk capacitor (bottom center) is soldered to a terminal of the sealed HV power unit. **Figure 12** shows the D-cells battery side and some of the point-to-point wiring. No printed circuit boards are used.

Comments:

While this was an important kit in its day, newer solid-state radiation counters are available on today's market. They are smaller, lighter more sensitive and use readily available batteries. Heathkit did not produce another Geiger counter kit until the late eighties when they released their RM-4 (shown in **Figure 13**). This unit meets all the requirements mentioned above. When the RC-1 was discontinued Heath sold the GDP-341 Family Radiation Measurement Set. (**Figure 14**) for a short time.

The biggest drawback to using the RC-1 today is the cost of the B battery. In the 1970

Allied Radio catalog it sold for $2.07 ($13.64 in today's dollars[6]). However today's battery price is over $50 when you can find one.

Acknowledgements:
I'd like to take this opportunity to thank Chuck Penson - WA7ZZE, and from across the Atlantic, Gerhard Wagner - DF1DA for providing photos, comments and a PDF manual. Gerhard mentioned the RC-1 in an email and got me interested in writing about it. Credit also should go to whoever is responsible for the PDF manual; it is in searchable/selectable PDF format. Also credit should go to the person who put the video on YouTube that briefly shows the insides of the sealed HV power supply. I was unable to contact him for more information.

73, from AF6C

Notes:

1. A seventh tube is internal to the closed HV power supply assembly. Type is unknown though it is probably a gas type since it uses no filament voltage, It is a 7 or 9-pin miniature tube and has a plate cap.
2. The calibration sample is not specified; it believed to be radium with a half-life of 1,600 years.
3. The formula for life remaining is: $L_R = e^{-KT}$ where *L* is life remaining, *K* is a constant 0.0004332 calculated from the half-life, and *T* is time in years.
4. A video of the RC-1 briefly showing inside the HVPS: https://www.youtube.com/watch?v=DMdB7IPycwg I was unable to contact the uploader for more info.
5. GC-1 is also the model number of the Heathkit ***Mohican*** shortwave receiver.
6. The current (2019) price was calculated using: https://www.usinflationcalculator.com

Remember, if you are getting rid of any old Heathkit Manuals or Catalogs, please pass them along to me for my research.

Thanks - AF6C

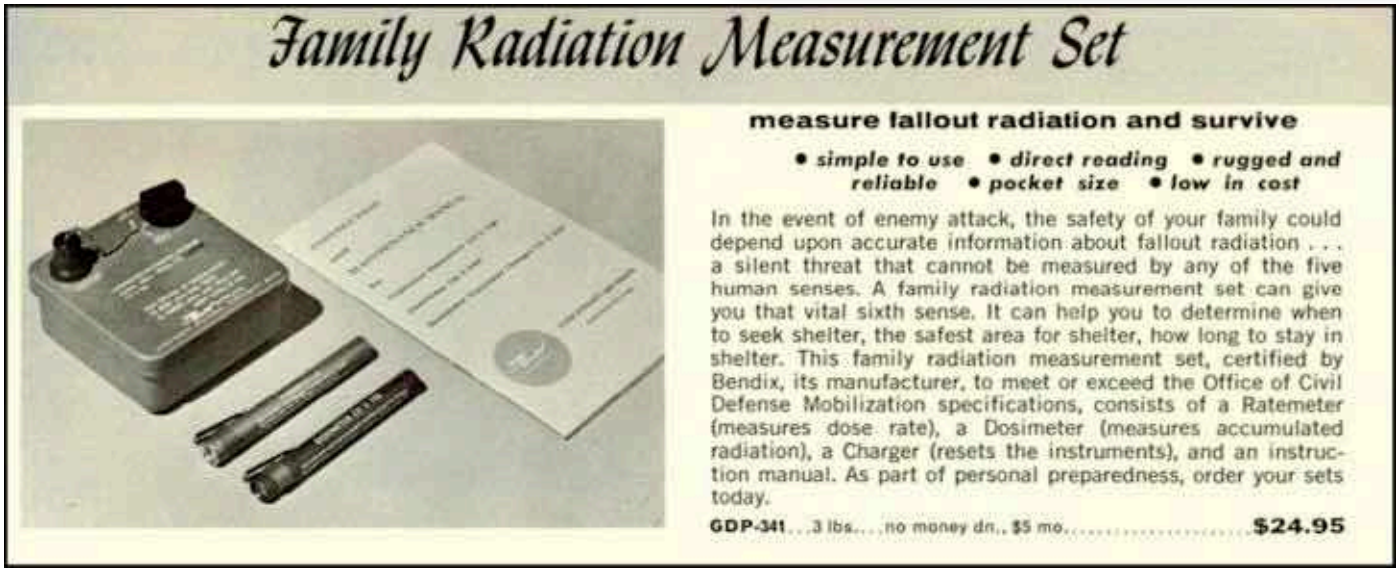

Figure 14: Heathkit GDP-341 Family Radiation Measurement Set. Not a kit but made by Bendix. If you were ever with the Civil Defense in the 60's or 70's you may be familiar with these. This ad appeared in the Heathkit Gift Supplement (80/01) for Christmas 1961.

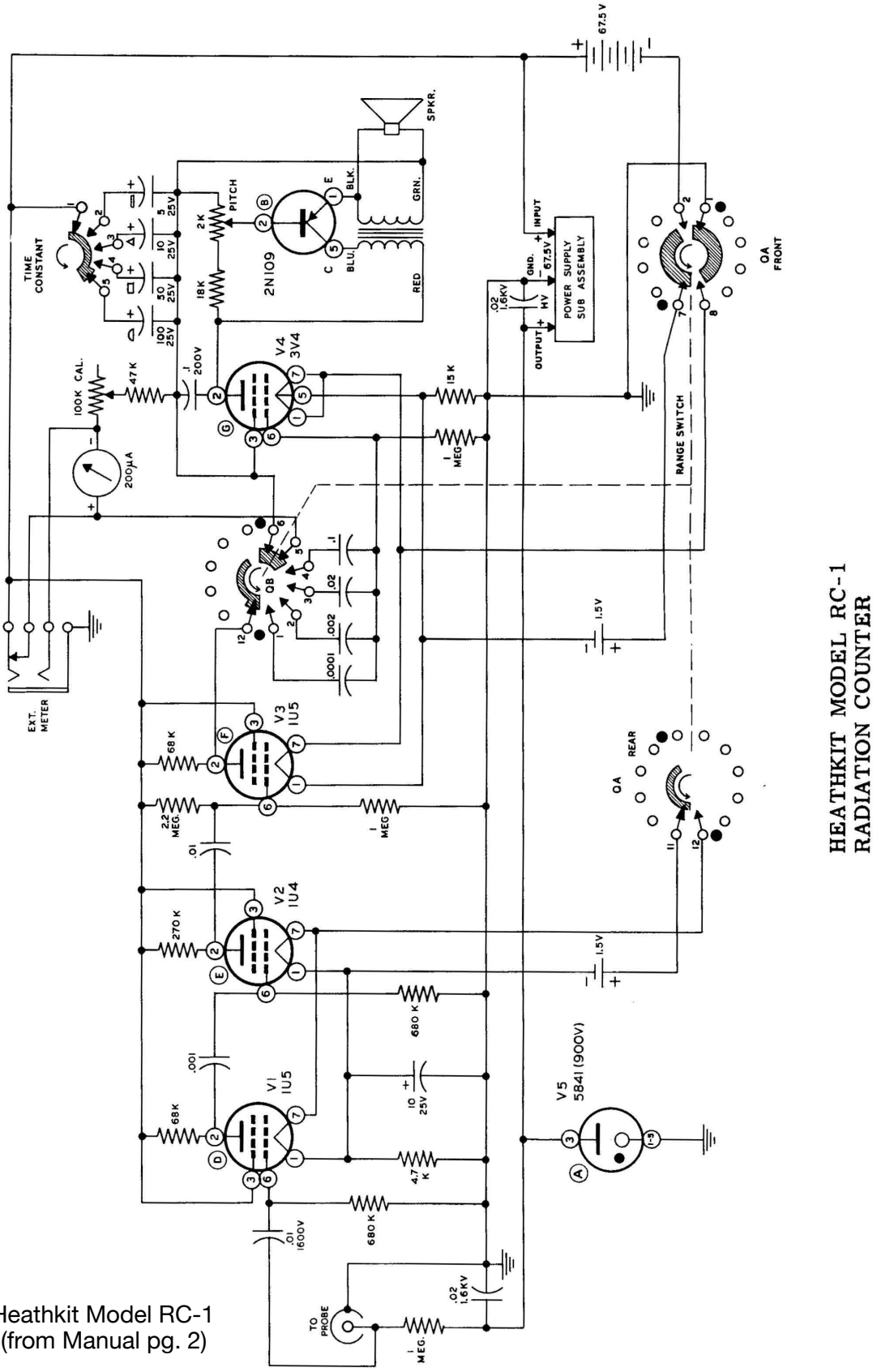

Figure 15: Heathkit Model RC-1 Schematic (from Manual pg. 2)