At the Repair Bench – LF&C Survey Meter – February 2024

Not long ago, I wrote in this column about a geiger counter repair that I was asked to take on. As you may (or may not) recall, I wrote at that time that the club member for whom I was making these repairs actually brought *two* “geiger counters” in for repair. The previous article described the operation and repair of a Victoreen CD V-700 Model 6A Radiological Survey Meter. Now, I am telling the rest of the story, as Paul Harvey used to say. This month, I am describing the operation of and repairs to a Landers, Frary & Clark CD V-715 Model 1A Radiological Survey Meter (Figure 1).

Figure 1 - CD V-715 Radiological Survey Meter

As I explained in the previous article, these geiger counters and radiological survey meters were manufactured under the auspices of the federal Civil Defense program, each being made to a specific standard for its CD type designation, but with the specific circuitry and operational design left up to the individual manufacturers of the equipment. Thus, there were several different makers of the CD type V-715 meter. Landers, Frary & Clark (LF&C) was just one of those manufacturers.

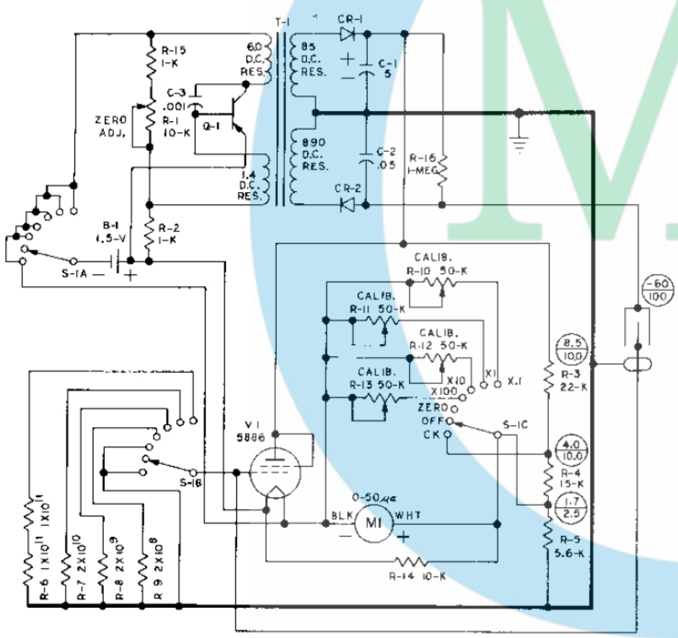

Figure 2 - LF&C V-715 schematic diagram

While the V-700 meter described in the earlier article is a geiger tube instrument, the V-715 utilizes an ionization chamber as the sensing element instead of a geiger tube. As a result, the V-715 is not *really a “geiger counter*”, though that term has been loosely used to describe meters of this type as well.

One thing that sets this type of instrument apart from the others is that it uses some resistors having *extremely* high through resistances. Connected to the range switch in this unit (refer to Figure 2 and Figure 4) are resistors having the following values, all of which are specified as 500mW 20% metal film types as below:

- 2 pieces, series connected, of 1 x 10^{11} ohms (100,000,000,000Ω) each;
- 1 piece of 2 x 10^{10} ohms (20,000,000,000Ω);
- 1 piece of 2 x 10^{9} ohms (2,000,000,000Ω); and
- 1 piece of 2 x 10^{8} ohms (200,000,000Ω).

The *lowest* of these values is 200 megohms, well above the capability of most ohmmeters to measure. This poses a bit of a problem when attempting to validate the condition of such a resistor. One method of determining the resistance would be to apply a fixed voltage source to the resistor and then to measure the current flowing through it. But, at 200 megohms, a testing voltage of 100V will cause only 500 nanoamperes (0.0000005A) to flow – well below the measurement range of most typical ammeters. So… how is the resistance measured? One method that often works is to first isolate the resistor under test, and then to place a resistor of known value in parallel with the resistor under test. Measure the parallel resistance and work the arithmetic backwards to determine the value of the resistor under test. However, even this method is not useful in this circumstance due to the sheer magnitude of the resistances of the resistors to be tested. Placing a 1MΩ 0.1% tolerance resistor in parallel with the smallest of these high-value resistors, the 200,000,000Ω one, gave me a measured resistance of 994,130Ω. This value is outside the tolerance range of the 1MΩ 0.1% resistor (100,100,000Ω to 999,000Ω), but would be a resultant value that is well within the tolerance range of the 200,000,000Ω 20% resistor (240,000,000Ω to 160,000,000Ω) and 1MΩ resistor placed in parallel, so the arithmetic would be meaningless in determining the actual value of the high-value resistor. It should be noted that the 994,130Ω reading obtained is pretty close to what would be expected with a 200MΩ and a 1MΩ resistor of close tolerances in parallel with each other – – (200,000,000 x 1,000,000) / (200,000,000 + 1,000,000) = 995,025Ω.

My everyday RLC bridge is capable of only 10 megohms, while my HP4284A laboratory RLC bridge tops out at 99.99 megohms in its resistance mode, well beneath the lowest value used in the range selector section of this unit. I decided that I could not measure these resistors by any practical method, so I would have to assume that they were acceptable until some operating condition of the unit showed me otherwise. In reality, based upon the resistor types in place and the age of the unit, I would have to believe that these resistors were replaced at some point in the history of this unit, which belief is reinforced by the fact that one range position (the *x 0.1* position) that called for two series resistors now has a single wire-wound tubular glass device instead.

OK – on to the general description of the unit. This meter is powered by a single standard "D" cell at 1.5VDC, but generates a maximum potential of -60V from the secondary of the power transformer. The primary of that transformer is in the oscillator circuit, which includes a GI 1459 PNP germanium transistor (more about this later).

Figure 3 - Ionization chamber

As mentioned previously, the sensing element is a hermetically sealed plated steel ionization chamber. This chamber (Figure 3) consists of a shell and an insulated center electrode called a collector, which is mounted to a high-resistance insulated feed-through connector. A strong voltage potential is applied to the collector and ionization chamber shell, which makes the shell (with respect to electrical common) negative by about a sixty-volt differential. This negative charge attracts the positively-charged ions that are formed by gamma radiation passing through the air that is contained within the ionization chamber. The ions striking the ionization chamber shell cause a current to flow in the collector. This current is proportional to the number of ions striking the shell, and therefore proportional to the strength of the radiation field. What appears to be a date (June of 2011) is penciled on the top of the ionization chamber. It is a possible surmise that this is an historical replacement date for the ionization chamber.

Depending upon which range has been selected by the range selector switch, this very small collector current flows through and develops a measurable voltage across one of the extremely high value resistors discussed earlier and clearly visible, attached to the range switch in the Figure 4 photo. This voltage is applied to the grid of the triode-connected 5886 Electrometer Tube, causing a small current to flow in the grid circuit. To give some idea of just how small this grid current really is, I took a quick look at the *Tung-Sol 5886 Pentode Electrometer Vacuum Tube Datasheet*. The *maximum* grid current, in accordance with the datasheet limitations, is 2.5×10^{-13} amperes when the tube is used as a triode, as it is in this circuit. Written in another form, this current we are talking about measures a mere 0.00000000000025 amperes! The grid current causes a proportional plate current to flow in the tube, with any change in the plate current being shown on the 0-50μA meter movement that is the user's indication of a detected radiation source.

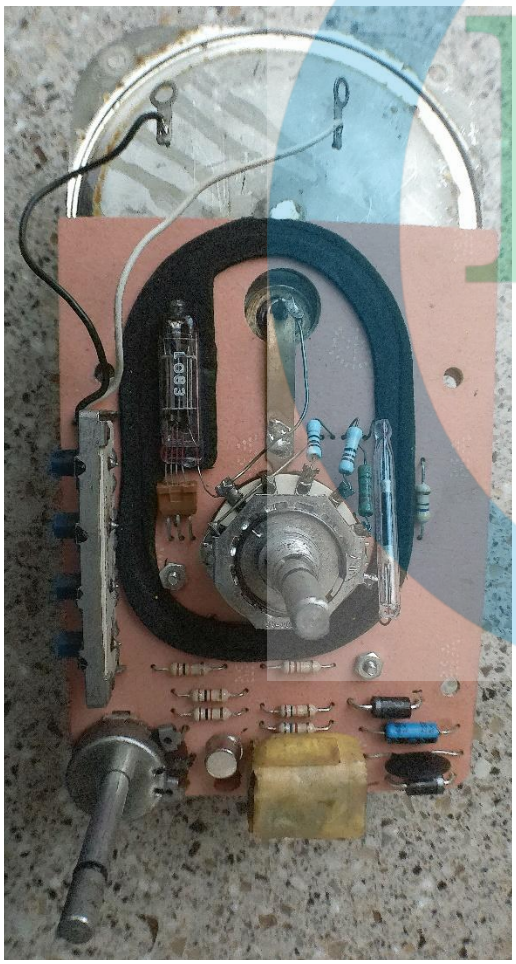

Figure 4 - Complete PCB after repairs

In this unit, there is a transformer that has a pair of primary windings, one of which has a through resistance of 1.4Ω while the other has a through resistance of 60Ω. The secondaries are also isolated, having through resistances of 890Ω and 85Ω, with the 890Ω secondary paired with the 1.4Ω primary and the 890Ω secondary paired with the 60Ω primary. Used as a step-up transformer, the 1.4Ω primary has a 1:635.7 turns ratio, yielding a very high-voltage output pulse compared to the input pulse voltage in that winding pair.

The remainder of the circuitry uses a handful (seven to be exact) of 500mW resistors of common standard values, easily tested and sourced for replacement, all but one of which are 5% tolerance types. I found one difference between the schematic and parts list and the physical unit, in that R16, a bleeder resistor for capacitor C1, a 5μF electrolytic type, was installed as a 4.7MΩ resistor while the documentation called for R16 to be a of 1MΩ value. Due to the fact that these seven resistors were all of a type – carbon composition – known to exhibit resistance changes over extended time and use, I decided to isolate and measure each of these resistors. In doing so, I found that several of them had varied by well more that their labeled tolerances. For example, one of the 1KΩ resistors was down to about 400 ohms, while the other was higher than its nominal value, measuring out at 1345 ohms. At 5% tolerance, these resistors should have been no less than 950Ω nor more than 1050Ω. I had all of the required values in stock as modern carbon film 5% tolerance 500mW rated types, so I replaced all of these resistors with new ones, maintaining the 4.7MΩ value as installed for R16.

Next up were the capacitors. Both of the ceramic capacitors tested out as being within specifications and were therefore usable, so they were left in place. The sole electrolytic, on the other hand, had an ESR that was off the top end of the meter scale on my ESR meter, and measured out as about 31.25µF instead of its nominal 5µF as regards capacitance. The top of the ESR meter scale is five ohms, so that capacitor was at least somewhat leaky. It is this leakiness that leads to a higher-than-normal capacitance measurement, as current continues to flow into the capacitor long after it should have stopped if the capacitor had been in good condition. Left alone long enough, that capacitance meter reading would have increased even more – I stopped the test at that point as it was obvious that the capacitor was non-suitable for use. It was replaced with a modern 4.7µF 50V 5% 105°C axial aluminum electrolytic capacitor. Such tight tolerance was not really necessary in this capacitor used as a filtering device, but that is what I had on hand, so I used it. The 4.7µF 50V capacitor is an acceptable replacement for the original 5µF 25V component.

The LC&F meter circuit uses three semiconductor devices – one transistor (mentioned earlier) and two rectifier diodes. The only information provided about the rectifier diodes is that they were "rectifiers", meaning that they were intended for use in a power supply to convert the AC into DC, and that one had a 50V PIV rating, while the other had a 100V PIV rating. It is unclear why two different diodes were chosen here, as the 100PIV diode should have worked in either location. The original diodes had heavy oxidation on their leads, compromising the lead integrity to the point where they both broke off easily when moved slightly during de-soldering. Through test measurements, I was able to determine that they were both of silicon composition, so I replaced them with a 1N5400 50V PIV 3A diode and a 1N5401 100V PIV 3A diode, both of which were in stock. These rectifier diodes are visible in the Figure 4 photo at the bottom right corner of the PCB.

The transistor was a different story. It was obviously defunct, as it failed each and every test to which I submitted it. I could not make any determinations as to type or specifications from the transistor itself other than the fact that it had gold leads, and its markings were of no help at all. The schematic showed it to be a PNP type. However, what I *did* find, in the LF&C manual for the unit, was that the original transistor supplier was General Instruments, and that it was a GI part number 1459 device. You might think that having a manufacturer's name and his part number for the transistor would make it easy to obtain more information about it, right? Not so much, as it turns out. I could not find *anything* resembling specifications for this transistor anywhere on the internet. I then had a brainstorm and turned to my NTE Electronics *QUICKCross*™ cross-reference software, where the first item turned up in a text search using *"1459"* as the search string was the NTE-102 transistor. The datasheet for this device showed it to be a PNP germanium type rated as below:

- Collector-Base Voltage (V_{CBO}) 25V
- Collector-Emitter Voltage (V_{CES}) 24V
- Emitter-Base Voltage (V_{EBO}) 12V
- Continuous Collector Current (I_C) 150mA
- Emitter Current (I_E) 100mA
- Total Device Dissipation (P_D) 150mW

This looked like a good possibility. I mentioned the gold leads because germanium transistors most often have gold leads. I went looking to see who might have stock on this transistor, and I found that Digikey (www.digikey.com) had availability of a direct-ship from NTE with about a five-day lead time. On a whim, I punched *"NTE102"* into an Amazon search box, and to my surprise, Amazon not only had it, but they had it at about half of the Digikey price. To clinch the deal, the Amazon item order page said that I would have it the next day! What a no-brainer! I ordered it in from Amazon and set everything aside overnight.

OK – so the next day came and with it came the transistor, as promised. Of course, as this point, I really had nothing to go by, that is, nothing saying that this was the correct part other than the NTE cross-reference. On the other hand, I have found the *QUICKCross*™ software to be quite accurate and reliable with its interchange information. As expected, the leads on the new transistor were in fact gold, and also as expected, based on the datasheet information, was the fact that the transistor was in the same case type, a TO-39 metal can with a tab on its circumference. So far, so good…

Working from the orientation of the original transistor in the PCB and the schematic diagram, the transistor pinout was also correct. The *"pinout"* is the assignment of specific terminals of the transistor to specific pins on the physical device. In the schematic, the emitter is connected directly to the "D" cell positive terminal. The base is connected to one end of the 1.4Ω transformer primary winding, while the collector is connected to the opposite end of the transformer 60Ω primary winding. Having this connection information, it is easily seen which pin of the original transistor was which terminal of the transistor, which then easily translated to a match with the terminal versus pin assignments of the new transistor. Seeing that everything matched up, I was very confident that I had located a proper replacement for the failed transistor in this unit. I went ahead and installed the new transistor, which can be seen at the lower left area of the PCB in the Figure 4 photo, just to the right of the meter "zero" control potentiometer.

Figure 5 - 5886 vacuum tube

Figure 5 shows a close-up view of the 5886 Pentode Electrometer vacuum tube. I illustrate this tube simply for its curiosity value, as it is somewhat different from those devices that we customarily recognize as *vacuum tubes.* None the less, it *is* a vacuum tube. Earlier in this article, reference was made to the fact that the current from the collector of the ionization chamber is directed to both the high-value resistor(s) via the range selector switch and to the (control) grid of the triode-connected vacuum tube. Note the bare wire lead from the vacuum tube, from the right side of the tube as shown in the Figure 5 photo. This lead ties directly to the common terminal of one deck of the range selector switch, and then also connects directly to the collector lead of the ionization chamber. Note that apart from that one wire, which is soldered, the vacuum tube is connected into the circuit by use of a vacuum tube base socket as are most vacuum tubes. A quick look at the schematic in Figure 2 shows that the cathode is directly heated, and that the cathode is tied directly to the emitter of the transistor.

Once the repairs were made and all operational checks were made in accordance with the manual and the schematic diagram voltage callouts, it was time to button this one up. Field calibration is not really feasible – or even possible in most cases – due to the fact that calibration requires the use of a calibrated radioactive field into which the unit is placed. Then, based upon the strength of the calibrated RA field, the unit is placed into its each of its various operating ranges in turn and each successive calibration potentiometer, one for each range, is adjusted to bring the meter reading into agreement with the known field strength. This requires the use of some equipment not generally available to the field user or maintainer of this device. The manual does indicate which potentiometer is related to which range switch position for actually making the calibration adjustments, but the complete adjustment process requires the use of an X-ray or gamma ray field.

One of the more important factors in the successful operation of this radiological survey meter is the fact that it is sensitive to moisture, including local air humidity. Humidity can and will affect the values of the high-resistance resistors used in the range selection stage as well as the operation of the ionization chamber's center collector assembly. The high value resistors, the vacuum tube, and the collector assembly are all also subject to problems from handling, as skin oil contamination on the surfaces of these components can cause leakage currents to flow across the component surfaces. When handled, these components must be properly cleaned of all skin oil residue through the use of residue-free alcohol and a soft cloth or cotton swab. To aid in the moisture reduction inside the closed unit, a bag of dry desiccant granules is placed in the bottom of the lower enclosure, which is sealed to the upper body assembly via the use of a rubberized gasket under the cover and O-rings on the control shafts. A rubber cushion is installed in the lower enclosure in the proper location to aid in keeping the "D" cell in its holder. When the unit is assembled, the "D" cell rests on this rubber pad, keeping the cell securely in place.

To close, a few quick words about the manual are actually overdue. I found two different copies of the factory user and maintenance manual for this unit online with a little bit of searching, one more easily readable than the other. The only catch is that care must be taken to ensure that the manual matches the device at hand. Bear in mind that there were multiple manufacturers who produced V-715 radiological survey meters, and each manufacturer may have produced multiple versions of their device. Just make sure that the manual selected is the correct manual for the device at hand, by manufacturer and by specific model number.

All things considered, this was a pretty typical repair of an unusual device. Apart from the fact that the high-value resistors can not easily be measured, the remainder of this repair was pretty straight-forward and required nothing out of the ordinary in either skills or equipment. This was a repair that any reasonably-skilled technician should, be able to handle with ease.

See you next month!