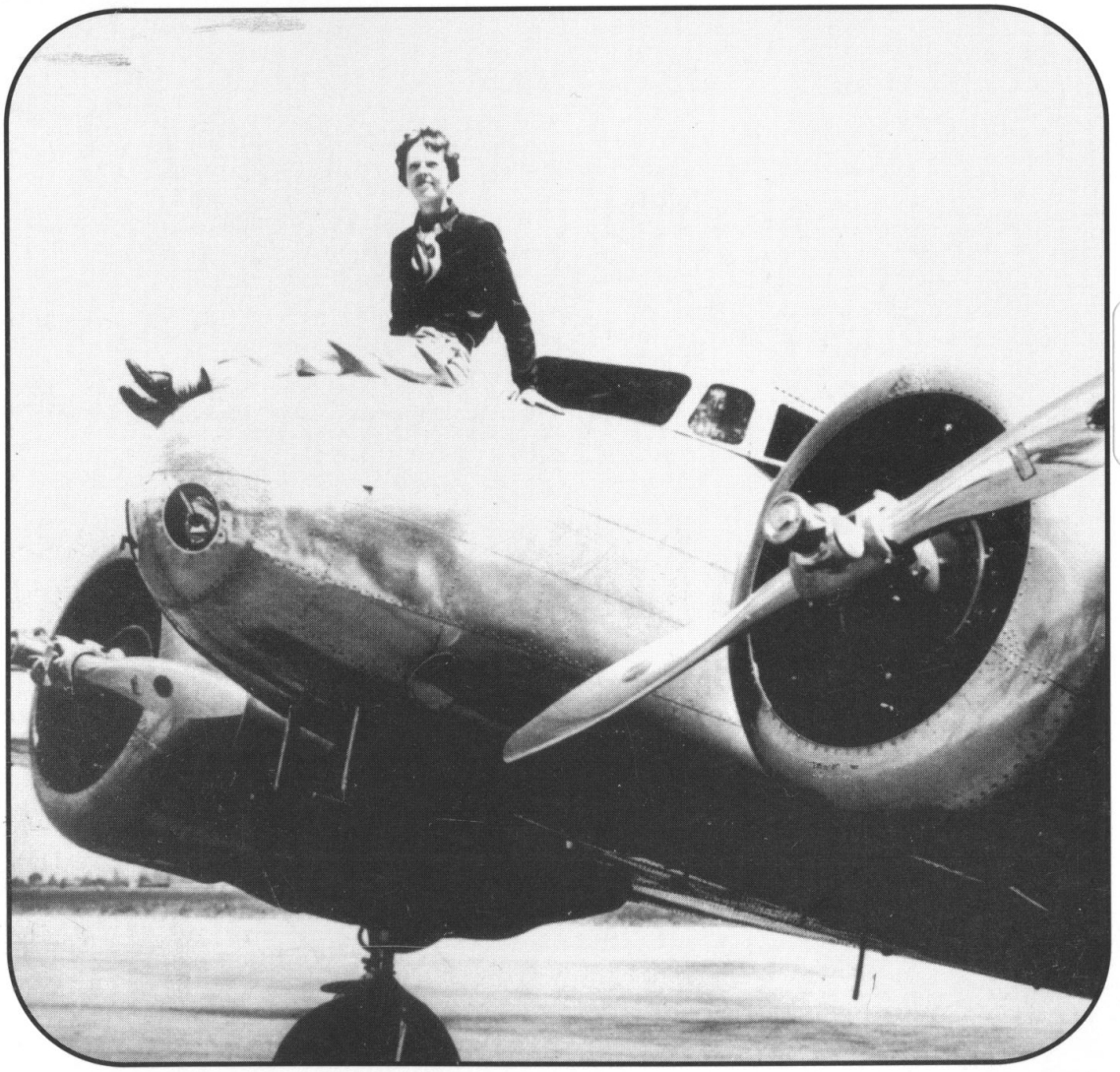
The Colorado Radio Collectors
Antique Radio Club

FLASH!

Volume 10 May ☺ June 1999 Issue 3



In this issue...

ABOUT THE COVER

It's been almost 62 years since the disappearance of Amelia Earhart. Yet, the mystery and mystique surrounding her continues to this very day. Turn to page 3 to read about some of the tantalizing evidence found by C. Bart Whitehouse and his group that may finally lead to some definitive answers to one of America's most intriguing manhunts.

The Colorado Radio Collectors Antique Radio Club

Meetings: Unless otherwise noted in this journal, regular meetings are held on the second Sunday of every other month starting in January (except: 3rd Sunday of May) at 1:00PM at the VectraBank Building, Community Room, 1380 S. Federal Bl. The meeting normally includes business items, discussions, "show and tell", a raffle and a swap meet.

Membership: All dues are $12.00 annually. Joining dues are prorated to June 1st. Contact club for foreign rates. Send dues and membership inquiries to the CRC Treasurer, Robert Baumann, 1985 S. Cape Way, Lakewood CO 80227 (303)988-2089

Article Contributions: Submission of articles are always appreciated. This would include historical and technical items as well as stories about individual collections. Articles may be written or e-mailed, and need not be in final form. Submissions and requests for information should be directed to the CRC "Flash!" Publisher, Larry Weide, 5270 E. Nassau Cir., Englewood CO 80110 (303)758-8382 - lweide@ibm.net.

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Publishing Deadlines: All submissions must be submitted by the 1st of Feb, Apr, Jun, Aug, Oct and Dec. for publishing in the following months.

Thanks to the **Pressworks** for printing the Flash! - **(303) 934-8600**

Upcoming 1999 CRC Events
CRC Annual Show/Sale April 17th-18th, Regular Meeting May 16th

14 MAY 1999

Colorado Radio Collectors Antique Radio Club

Founded October 1988

Dedicated to the Preservation and Education of Wireless, Radio, Television and Associated Equipment.

Volume 10, Issue 3 **May/Junel 1999**

TABLE OF CONTENTS

A CHAT WITH THE PRESIDENT

Spring Has Sprung ... ung ... ung, ... ung!

by Tom Kelley, CRC President

Hello again, fellow club members! Spring *has* sprung in the Front Range and maybe some good radio deals have sprung up as well. Be sure to check yard sales, flea markets, estate sales etc., because this is the time of year that individuals houseclean out their unwanted items. Perhaps a box of tubes or a radio or maybe a wireless coupler - am I dreaming, who knows?

The new medium for finding that wanted radio is of course the Internet. Be sure to check out E-Bay, the premiere auction site on the "web". I have had good luck on the Internet, and you never know when a surprise might turn up. I have recently found four radios that were never marketed in our area. The radios I collect are regionalized, i.e., certain colors and models were sold in specific areas of the country.

On the subject of spring; it's not too early to start thinking about our upcoming summer picnic. It will be held at Lakewood's Historical Center (formerly "Belmar") on the 4th Sunday of July - 4/25. Let's have a good turnout and share some good food and radios. More on this later.

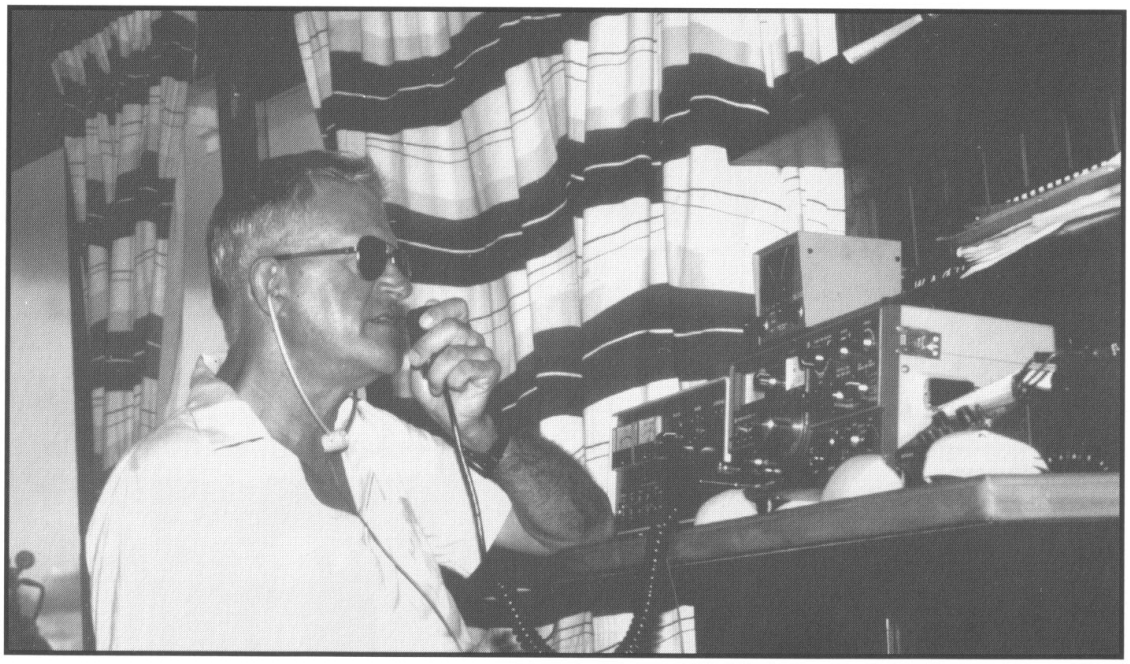
Also, I have noticed that the raffles, show 'n tells and swap meets have gotten markedly better lately. This really adds interest to our club meetings and helps out the club a lot - Thanks, and let's keep it up!

Tom

The Search for Amelia Earhart
The Radio Operator's Story

By C. Bart Whitehouse, CRC Member

We are indeed fortunate to have Bart as a member of the CRC, and be able to "collar" him for this first hand account about the TIGHAR 1989 and other expeditions. Bart was the 1989 radio operator aboard the Pacific Nomad, and was responsible for all expedition long and short range communications - Ed.

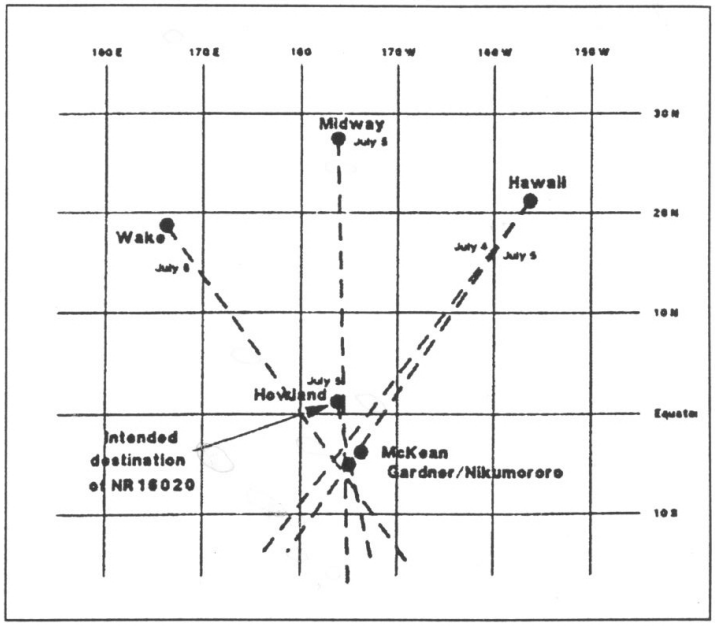


Bart Whitehouse at the radio station aboard the "Pacific Nomad"

"Suva, Fiji Islands. Observers at the harbor today cheered the departure of the motor-ship Pacific Nomad, as she cast off for an unusual voyage. The 115-foot converted fishing boat is under charter to The International Group for Historic Aircraft Recovery (TIGHAR, pronounced tiger). A contingent of professional and volunteer aviation archaeologists is aboard. The objective is to locate and recover parts of the Amelia Earhart Lockheed 10 Electra.

The ship's manifest indicates that it will be in the waters of Kiribati

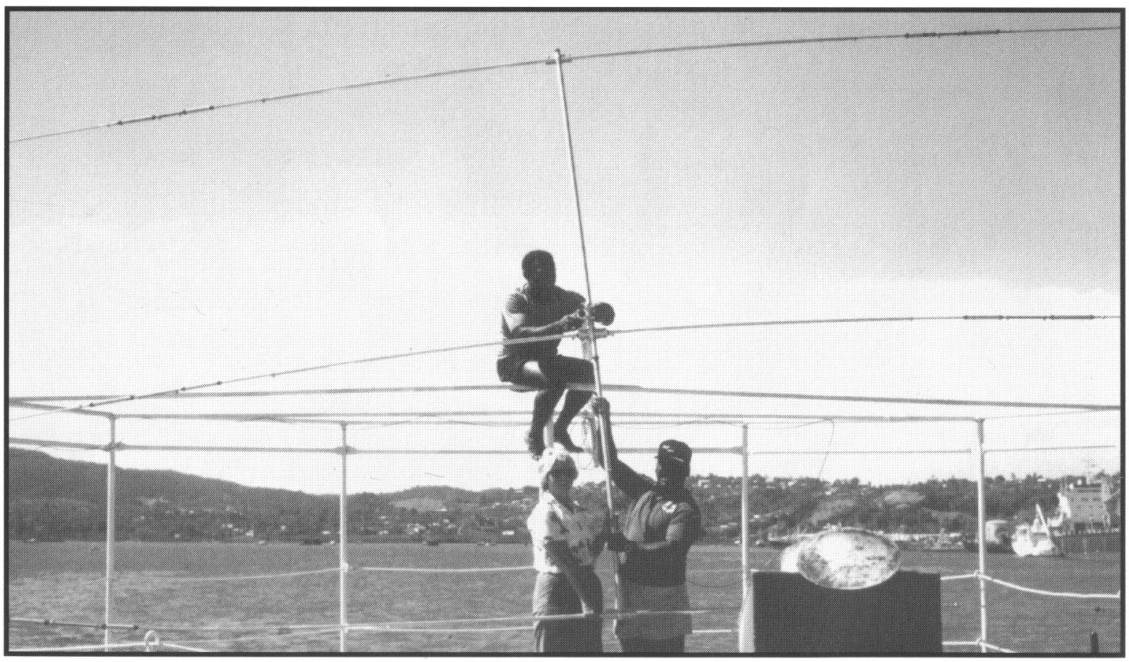
(pronounced kiri-bas), among the Phoenix Islands. The land and waters around McKean Island, Gardner Island and possibly Hull Island will be systematically explored for solid evidence that Earhart's Lockheed was abandoned there."



The radio DF plots of Earhart's tranmissions

This somewhat contrived newspaper story actually came to pass when the TIGHAR group launched a fact-finding field expedition to the Phoenix Islands in an attempt to add verifiable knowledge to the 52-year old question of "What happened to Earhart and Noonan on July 2, 1937?" The Earhart Project is the most recent in a series of aviation archaeological efforts by TIGHAR.

One of the most fascinating aspects of this particular search for an historic aircraft is that the only certain information of where to look is 52-year old radio data. This is the first and only quest to locate



Installing the long range radio antenna on the ship's rear deck

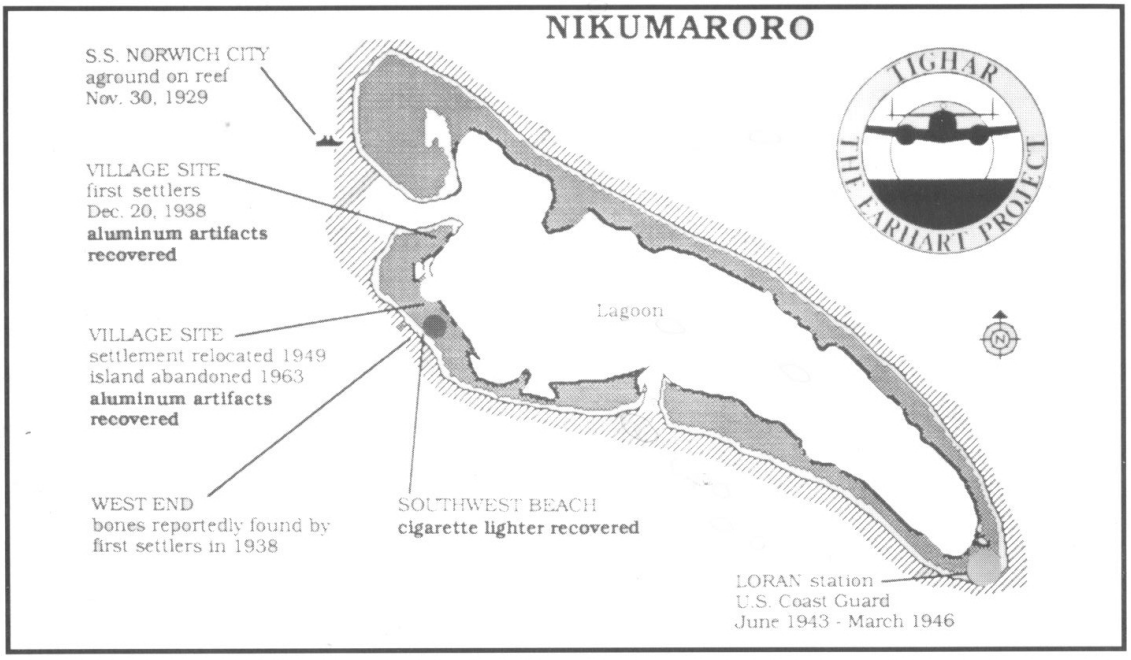
by radio data alone an aircraft that is so long overdue.

The Earhart Lockheed 10 Electra was equipped with a Western Electric model 20B receiver, tunable in the 200-400 Khz 550-1500 Khz, 1.5-4.0 Mhz, 4.0-10.0 Mhz bands. Also installed was a Western Electric model 13C 50 watt HF transmitter crystal controlled on 6.21- Mhz and 3.105 Mhz, and later modified to operate on the 500Khz high seas marine distress radiotelegraph frequency as well.

One of the ironies of these radio considerations is that Earhart and Noonan obtained no real navigation or position-finding assistance from their radio equipment. They were not receiving the ground/ship stations that were trying to assist them.

Secondly, Earhart would not make sufficiently long bursts of transmissions on 6.210 or 3.105 Mhz for the ground stations to obtain good direction finding. Earhart made short voice transmissions on three consecutive nights following what is presumed to have been her last flyable day - due to running out of fuel. The good DF information that is on record was obtained after the plane went down, and then the DF information was ignored during the two weeks of the search. It is just recently (1988-89) being reexamined. It is part of the primary evidence prompting the TIGHAR team to launch the Earhart Project.

The boot heel that was discovered on Nikumaroro Island



Nikumaroro Island showing points of interest

Thirdly, Earhart apparently negated her 500 Khz marine distress capability by removing the trailing-wire antenna necessary for its operation. Neither Earhart nor Noonan was proficient in radiotelegraph and disdained its use as primitive and unnecessary.

The radio DF plot chart depicts the known bearings taken on NR16020's signals on three successive nights after its disappearance about midday on July 2nd. The radio DF hearings were done by experienced radio operators of Pan American Airways and the U.S. Coast Guard. Radio was their trade and they plied that trade in expert fashion.

The HF DF plots from distant points as Wake, Midway and Hawaii do not yield pinpoint accuracy - As shown on the previous page inset map. They define an area about the size of Connecticut. But in that area, there are only a half-dozen or so islands that are near Earhart's last reported line-of-position. The total dry land area of those islands all added together is only a few square miles. The Lockheed engineers who built and equipped the plane have stated with great certainty that the plane's radios could not be used if it were ditched in the sea and afloat. The location of batteries and dynamotors precluded such operation.

The previous paragraphs were "lifted", with permission, from a 1989 article written by Bart for a Colorado Aviation periodical. I had a chance to sit down with Bart

to hear more of the story and review many of the pictures that he brought back with him from the expedition - along with other pictures from a subsequent TIGHAR project.

Let me relate to you what I've learned from Bart about some of the evidence that has been amassed through the TIGHAR efforts:

✈ As stated previously, the fact that there was any post-flight transmission from Earhart at all suggests that she was calling from an airplane that must have been reasonably intact and on dry land. Lockheed personnel have long confirmed that she could not have been transmitting unless at least one of her engines were running (there could easily have been enough residual fuel to do this.). In addition, one of her garbled messages included words that "suggest" she may have landed somewhere that she thinks of as consisting of coral.

✈ A subsequent TIGHAR expedition found two very interesting artifacts that you may have heard about. The first is a rubber heal from a shoe (see picture). The maker of that heel, Cat's Paw, confirms that it was the type and style of a heel that was used to repair a shoe that Earhart wore. There is even a picture taken just days prior to her disappearance showing show her wearing that very shoe. In addition, they have found an aluminum plate similar in type and rivet pattern to that which was used to repair Earhart's plane when she had an accident during a previous but aborted attempt to fly around the world.

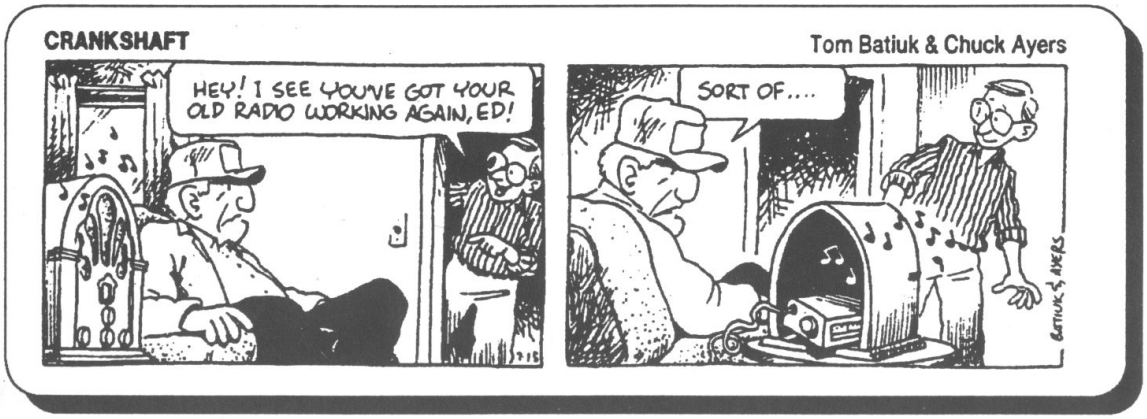
✈ Another interesting artifact that TIGHAR discovered was the cap from a bottle exactly like the one that Earhart carried with her that contained medicine for a stomach condition that she was suffering with at the time.

✈ These artifacts were located on the small island/atoll now called Nikumaroro. Another intriguing bit of evidence is that there is a prominent ship wreak at the N/W corner of this island (see map). Earhart reported, while still flying, that she saw a ship in this quadrant of whatever land she was flying over at that moment. In addition, during the two week search for Earhart and Noonan, there was a report by one of the search aircraft of evidence of inhabitants on this island. This was at a time when the island was known to be uninhabited. But, because of unfortunate circumstances, this report did not come to light until years after the search was over.

A significant point that Bart wanted to be made absolutely clear

is that, ***although there is very compelling evidence to suggest where Earhart and Noonan may have landed, it is all circumstantial evidence at best.*** *Until there is physical material found that contains an identifying number or perhaps even a bone fragment from which DNA matching can be done, the Earhart story will remain one of America's most enduring enigmas. - Ed.*

Olde Tyme Radio Humor



Capacitors and Old Radios

A Series of Articles

by

Dave Boyle in collaboration with Barney Wooters, CRC members

In the previous Flash article entitled "Capacitors and Old Radios", I discussed what a capacitor is, and some of their uses in old radios. I also provided some basic technical information regarding their common electrical characteristics. So, we had the theory course and now it's time to go into the "ole radio laboratory" and start applying this newly acquired knowledge.

Failure Modes of Capacitors

In the course of our hobby, we are dominated by age induced failure modes. Age degradation combined with poor construction material choices of yesteryear, produces a condition where most caps found in old radios are considered suspect for failure or reduced operation. Standard caps of the 1920's to the 1950's used in coupling, bypass or filtering applications were generally constructed using rolled up aluminum foil as the plates with waxed or oiled paper as the dielectric. Attachment leads were then added to the cap before the cap was impregnated or dipped in wax. Often times they were potted in tar (the better ones). Some were aluminum foil with mica dielectric then molded into a bakelite plastic. These were often of lessor capacitance, and were used the radio frequency (RF) stages of a radio.

In the process of repairing an old radio, we should always replace electrolytic caps. I suggest this cap replacement before any powering up. In early AC radios, apx. 1928 - 1932, filter caps were of the aluminum foil/wax paper construction, and may have been typically potted inside a can or small paper box. My experience tells me that these low capacitance filter caps (usually 2 - 5 mfd) can remain relatively good for years. It's best to replace caps exhibiting physical damage, such as cracking, leaking, loose leads, discoloration, etc. It is also prudent to replace any caps that see high voltage potential across them. This is particularly valid in audio output stage circuits.

In order to provide reasonably straight forward cap usage and their associated failure mode or failure characterization, I thought it would be beneficial to look at caps in a "real" radio and explain their use and service information. Fig. 1 is a schematic of an All American 5 AM radio circuit, circa 1940 to 1949, and certainly representative of most radios that would find their way to our bench tops. I've listed all the ***fixed***, as opposed to

adjustable, and ***variable*** style caps. Variable caps are the tuning capacitor sections (37). The adjustable caps are the "trimmers" used to align/tune the RF and IF stages (A1, A2, A3, A4, A5, A6). Variable and adjustable caps are not part of this article.

Capacitor Diagram References

(1), (8) - These caps are used to filter/ground out interference that might have found it's way into the 115V AC line source. Replace if physically suspect. Keep working voltage at 250V or higher.

(6A), (6B) - The "infamous" filter caps that are notorious for failure in older sets. I usually replace these before powering up. Why waste time and cause problem with excessive current draw through the rectifier tube and related circuitry. Be sure to carefully observe polarity and adequate working voltage for the replacement caps.

(9) - This cap is a "cheap" tone control. The larger the capacitance the more the treble is attenuated. It's not usually a failure problem unless the tone quality is poor or the audio output is very low.

(24) - This cathode bypass cap may be an electrolytic type. In older radios, this cap may "reform" during power-up. The working voltage is usually 25 - 50VDC. If the cap has a high leakage then this will affect audio clarity and output as the result of poor cathode biasing.

(18) - This is one of the most stressed caps in the radio - second only to the filter caps. It sees full B+ voltage across it. It's purpose is to couple the faint audio signal from the detector and 1st audio stage to the final audio output stage. It blocks the plate voltage of the 12SQ7 and allows the AC component to reach the grid of the 50L6 tube. Any leakage, albeit low, directly affects the control grid voltage of the audio output tube. Any positive bias will result in overheating and distortion. I replace this particular cap as a precautionary measure.

(14), (15A), (15B) - These are radio frequency (RF) bypass caps. Generally of molded mica construction. Their purpose is to provide RF circuit or continuity to ground. They are not subject to a high failure rate. The voltage across them is several orders of magnitude below their working voltage. If (14) shorted there would be no audio signal. If (15B) shorted the automatic volume control (AVC) voltage would go to zero and effectively clamp off the gain of the intermediate frequency (IF) amplifier - 12SK7. Likewise for (15A), it would short the IF signal to ground - "radio no workee!".

(12) - This .05mfd paper style cap is known as the AVC bias filter. If it is leaky, the RF sensitivity would be reduced and the radio would only pick up strong radio stations. I've seen these caps actually short out the AVC

voltage. AVC voltage should vary approximately -3 to -5 VDC.

(16) - This cap couples the local oscillator signal to the converter tube and is also part of the RF tuned circuit. If it failed open, no IF signal would be generated and hence, no signal could pass on the to the IF amplifier. It's extremely rare for a failure here. This cap probably is a mica capacitor.

(13) - This is probably a tubular or paper cap, and is part of the loop antenna, most likely fastened directly to the loop. A lightning strike or a voltage surge in the antenna may make it fail. On reasonably strong signal inputs you will probably not miss this cap.

Miscellaneous hints and stuff relative to capacitors

✶ Test coupling caps by measuring the voltage at the grid of the next stage. It should be in specification to the typical operating characteristics for that particular tube as noted in schematic information or tube manual. Leakage may be a function of temperature and time so be patient. Be sure to use a VTVM or DMM with a high input impedance.

✶ Test screen grid bypass caps with the B+ applied and the tube pulled from the set. The voltage at the screen, again measured with a high impedance volt meter, should be the full B+ or value at the other end of the dropping resistor. If not, the cap is leaking.

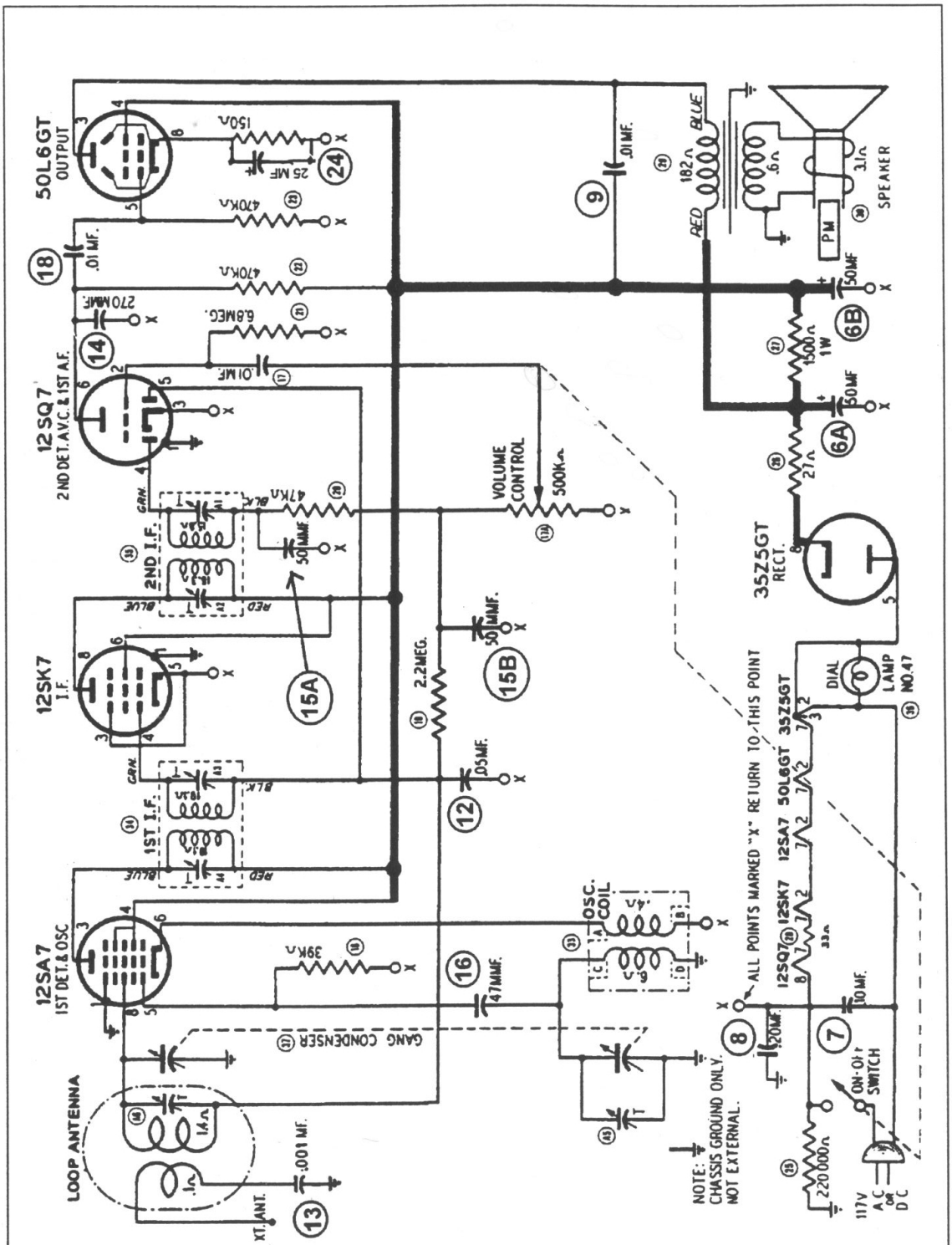
✶ I've seen B+ bus circuits pulled down in voltage on the load side the voltage dropping power resistors due to excessively leaking B+ bus filter caps (typical values of .01 - .1mfd).

✶ When replacing fixed caps, always completely remove the offending one. This is particularly valid when dealing with Philco capacitor blocks.

✶ You can crudely test loose caps (not connected at one end) by using a high impedance analog voltmeter in series with a B+ power supply adjusted to the DC working voltage of the cap under test. By applying voltage to all items connected in series, the meter will jump up then slowly settle down toward zero - if the cap is good. Once the meter settles, any residual voltage measurement indicates the cap has some leakage.

I hope these two articles provided you - the radio collector and restorer, a little appreciation for and knowledge of capacitors used in old radios. These articles were intentionally written to provide basic understanding and practical information.

My appreciation goes out to Barney Wooters for a technical cross-check and input. I also thank Larry Weide, your untiring Flash editor, for typing up the words and formatting the article presentation. Future articles may include transformers and inductors and tuned circuits..



Typical "All American 5" table radio, starting from the 1940's with octal based tubes

The United Fruit Company A.K.A. The Tropical Radio/Telegraph Co.

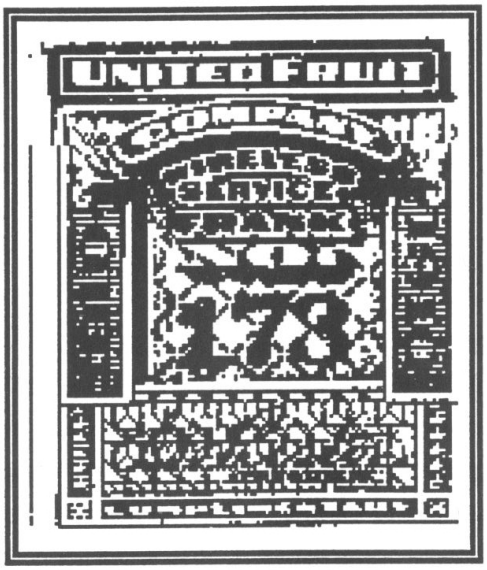
by Wayne Gilbert, CRC Member

What the devil has an article about the United Fruit Company to do with radios? Maybe it's because they were one of the largest and earliest wireless networks up and broadcasting by 1908. Arguably they can claim to being involved with more radio developments and Latin American revolutions than almost any other company in this hemisphere. The first claim will be briefly covered by this article, the second tactfully ignored in deference to those who like tropical fruit and/or imperialism.

When the United Fruit Company began its wireless system, it was out of necessity. Coordinating shiploads of fruits with U.S. markets was essential if the produce was to arrive at the consumers' table in an edible condition, and the management apparently thought that if you wanted a job done right, "do it yourself" so they invested in their own system. This decision may have also been influenced by their heavy investment in land telegraph systems, which could provide the new wireless radio technology a good starting basis. Soon they were also transmitting radiograms for other companies as a part of their business, becoming a competitor of Marconi's and DeForest's Central and South American wireless systems and the established transoceanic cable businesses servicing that area. In this era, when one competitor wouldn't carry another's wireless traffic, United Fruit was quickly left with a large part of the hemisphere in which to provide its own systems. Ever vigilant for competitors, by 1910 they developed client loyalty among theplantation owners by issuing free or low cost wireless telegraph franks (prepaid stamps) that entitled the user to have messages broadcast

exclusively throughout their system for free or at a reduced rate.

By 1922 the system was so sophisticated that the United Fruit Company contracted with RCA to provide five 100 kilowatt stations to allow them to transmit more effectively between Honduras, Nicaragua, Panama, New Orleans, and Miami, Florida and all of the United Fruit Company's freighters plying the seas in that triangle. The new system was to encompass an area of more than 54,000 square miles in Central America and was hailed as a giant leap in opening communications between the Americas. It was assigned the right to broadcast on a band of between 2,500 and 4,500 meters and was to be equipped by RCA's latest and most powerful tubes and technology.



As a side light, the contracts were actually signed by the Tropical Radio Telegraph Company, a wholly owned subsidiary of United Fruit, and some of the sites of the new installations were already being used by the Tropical Radio Telegraph Company. Other sites were purchased from the United Wireless Telegraph Company, one of Dr. Lee DeForest's companies who sold too much stock and sent too few messages, resulting in its management being indicted for stock- selling fraud. There are reports of radio reception verification stamps being issued by the Tropical Radio stations, to compete with the EKKO stamps issued in the United States, although this author has been unable to personally locate any. Both the United Fruit franks and at least some of the reported EKKO-like stamps were lithographed by the same company who produced theEKKO stamps.

Although the United Fruit company is often remembered as the supplier of your grocer's bananas, they also provided North Americans with a variety of other fruits and was one of the largest suppliers of sugar in our hemisphere.

Their diversity also included providing passenger and freight shipping services with their "Great White Fleet," distinctively identified by their yellow smoke stacks, which with 110 ships was one of the

largest steamship enterprises in the world during the 1920s. Their ships were pressed into the national war effort during World War II, and they reportedly lost 30 ships during the war.

They also justly deserve to be acknowledged for being the major pioneer in providing radio and telegraph communication between the Americas, albeit for their own benefit. They surmounted many very substantial obstacles with their determination to establish wireless stations in areas where company and countries with lesser resources and perseverance failed.

It should be remembered that when they set their goal of wireless communication from Central and South America being transmitted to the U.S. every hour, the goal was purely visionary since the technology was not yet available to achieve this goal. They had to develop methods to deal with hurricanes, long periods of natural radio frequency interference (static), and powering stations in areas where merely having reliable electrical power was virtually unknown. They installed and reinstalled transmission towers and stations that were repeatedly destroyed by stormsand bought and designed equipment that could withstand the riggers of tropical climates.

They were one of the first to use Fessenden's rotary spark transmitters whose 500 cycle notes could be more easily distinguished from the background static, and set up ship to shore weather broadcasts that enabled the U.S. national weather service to more accurately predict the weather across the entire North American continent. They invested in the latest radio and wireless technology from both RCA and General Electric, many times only to find it obsoleted before it could be installed in their more isolated locations.

Although their early stations would not compare even to any of today's smaller commercial stations, they had invested millions of dollars by the early 1920s, installing a network of stations with the latest of technology. Meanwhile their subsidiary, the Wireless Specialty Apparatus Company, was becoming one of the acknowledged leaders as

providers and designers of wireless components in the industry.

Also to their credit, they provided a better standard of living for many of the natives of the third world countries they exploited. By 1922 they had provided more than 1,300 miles of rail lines, 500 miles of tramways, and more than 3500 miles of land telegraph and telephone lines as well as building nearly a quarter of a million dollars worth of hospitals and medical aid stations throughout the area.

Coincidentally they also contributed directly to the economy of Denver, Colorado. Most, if notall, of their container labels printed in the 1920s were printed by the Continental Printing Company of Denver.

The United Fruit Company with all its faults and virtues, was forced to divest its holdings in 1954, and the remaining parent company was renamed to the Chiquita Fruit Company. The fate of the Tropical Radio Company is not fully understood. It continues to exist openly as the Tropical Telephone Company in some Central American countries, but it is not so open about owning radio stations. Telephone calls to their corporate offices were not returned and attempts to establish their ownership of any current radio stations have not been conclusive.

Their involvement in the development of very early wireless telegraphy and telephony is one of the more overlooked aspects of radio history, and they surely should be credited for their contribution to radio history.

Sources:

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Thanks to all the staff and volunteers of The Rocky Mountain Philatelic Library for all their assistance and advice.

Replacing A Resistance Line Cord with a Capacitor Revisited

by

Ed Brady, CRC Member - cebrady@esscom.com

After reading Larry Weide's replacing voltage dropping line cords in the January/February Flash, I thought I might add to it by sending in a portion of an article I wrote for the New Mexico Radio Club some time ago. At that time I wrote an article very similar to the one that appeared in this past issue. At the next club meeting following the publication of my article I must have had a dozen members ask me how to protect against a capacitor failure. I felt this was a very unlikely event but given the potential for loss I decided to see if I could come up with something to protect against it. Unlike a resistance line cord whose only failure mode is an open circuit, a capacitor can fail via this means or by shorting out. Must modern capacitors are very reliable. However that does not imply that they will never fail. Given the unlikely event that the capacitor shorted, the entire line voltage would appear across the tube filaments. If this happened, it is a sure guarantee that one or more of the tubes would be lost. After a great deal of thought I believe I have a solution.

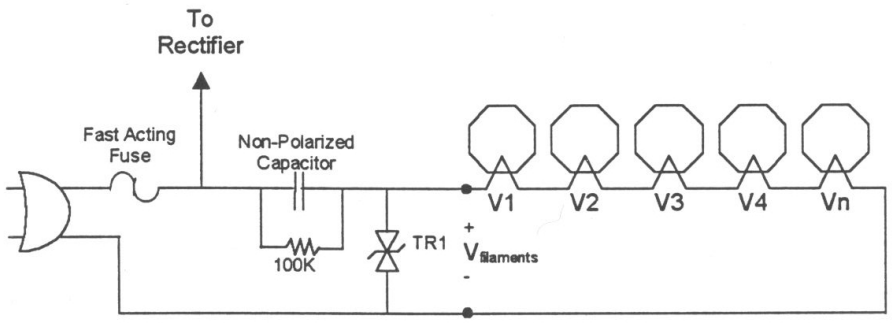

Figure 1. Revised AC/DC Filament Circuit using Capacitor.

Figure 1 shows a modification to the standard series capacitor replacement method.

In this circuit a 100Kohm resistor is placed across the capacitor. This resistor does not help protect against a capacitor failure, but it does provide a discharge path when the radio is turned off. This prevents the capacitor from remaining charged for a long period of time after power is removed. Primarily it is a safety precaution and changes

the impedance of the capacitor only slightly.

A fast acting fuse and a bi-directional Zener Transient Voltage Suppresser (TR1 in Figure 1) are used to protect the circuit against a catastrophic capacitor failure. Individually neither provides adequate protection but together they provide full protection for the tube filaments. The fuse is employed to break the flow of current in the event that something in the radio fails and excessive current begins to flow. Unfortunately even fast acting fuses can not react instantaneously. The amount of time that is required to blow a fuse is dependent on the amount of excess current flowing through it. For example, for a radio I repaired, the combined resistance of the 5 tubes (25Z3, 43, 75, 6D6 and 6A7) is 230 ohms and the radio uses 0.36 amperes during normal operation. When selecting a fuse, the normal operating current should never exceed 75 percent of the fuse's rating. This avoids nuisance blowing due to transients and other conditions. Applying this de-rating criterion, to the radio, required the use of a 0.5-ampere or greater fuse. In the event of a capacitor failure, the entire line voltage will appear across the tube filaments. Using ohms law (V = IR) the resulting current would be 0.51 amperes. The relationship of fuse blow time to current is given in Table 1. These are general numbers for 2AG Fast Acting fuses. These numbers will vary slightly by fuse type and manufacturer.

For this particular radio, the failure current is only about 102% of the rated current of the fuse. Based on the numbers in Table 1, it will probably never blow. As a result one or more of the filaments will burn out. Thus by itself, the fuse will not solve the problem.

Table 1. Time/Current Relationship for Fast Acting Fuses.

Time (Seconds)	Current (Percent of Rating)
100	120%
10	150%
1	190%
.1	300%
.01	1000%
.001	4000%

This is where the transient voltage suppresser comes in. These devices are high-current surge capacity Zener diodes. They have excellent clamping capability, fast response time and provide excellent protection against over-voltage A/C fault conditions. The idea behind using this device is to clamp the voltage across the tube filaments at a safe level until the fuse has time to blow. In the event of a capacitor failure the over voltage will exceed the chosen zener voltage causing a large current to flow through the diode and fuse. The increased current reduces the fuse reaction time causing it to open much faster. The zener action of the diode prevents the voltage across the tubes from exceeding their ratings until the fuse has time to blow. Be advised that since

this is an AC application uni-directional suppressors will not work here.

Assuming that the average source impedance of an A/C outlet is on the order of a few ohms the approximate fault current, again using ohm's law, will be in the order of 15-30 amps. Given this current level, the fuse should blow in less than 1 milli-second. A 1500-watt bi-directional suppressor should be able to handle this magnitude of current over this time interval.

Table 2 shows the ECG part numbers for various voltage bi-directional suppressors. Referring to this table, the first parameter is the Reverse Standoff Voltage. This parameter specifies the start of the zener knee. The zener will not conduct significant current until this voltage is exceeded. This parameter is used to select the proper device. For the device selected, this value should be greater than or equal to the sum of the peak tube voltages. I would suggest using a device with a reverse standoff voltage at least 1 or 2 volts higher then the series filament voltage. Where higher voltages or higher current capacity is needed, two or more of these devices can be placed in series. The breakdown voltage indicates the voltage level at which the device enters its avalanche region of operation. It gives an indication of the initial clamping voltage. The final two columns indicate the maximum current handling capacity of each device and the clamp voltage that will be reached at that current. Be sure to use a device whose maximum current rating is within the range of expected current, in this case 15-30 amps.

For my particular application I choose to use three ECG4943s. Their combined standoff voltage is 70.5 Vrms. This selection yielded approximately 1.5 volts of margin over the 69 Vrms of the filament string. The string has a 117 V peak or 82 Vrms initial clamping voltage and a peak clamping voltage of 114 Vrms at a peak current of 28 amps. Whereas I would like to see a lower peak clamping voltage, this is the best of any other available transient suppressor device. This value, if obtained, puts the total filament string approximately 65 percent above its nominal rating. I believe that the filaments should be able to accommodate this over voltage for the fraction of a second required to blow the fuse.

Be advised that I did not have the time, proper equipment or excess tube inventory to fully test and fine-tune this protection circuitry. It is however based on sound proven designs used in commercial electronic applications. I have no way of guaranteeing that it will yield protection under all circumstances. There is still a possibility that you may damage one or more tubes if for some reason the capacitor used in this application should fail. However I do believe it does provide a mechanism for increasing the likely hood of saving your tubes in the event the capacitor should fail. I think it is well worth the added $2 or so cost in parts. Be aware

however that modern capacitors are very reliable and have very long mean time between failure rates (MTBF). My guess is that the tubes will fail long before the capacitor does. If anyone has any other ideas on how to protect against capacitor failure please let me know. I am always looking for better ways of doing things.

Table 2. 1500-Watt Transient Suppressor Part Numbers.

ECG Type	Reverse Standoff Voltage (RMS)	Breakdown Voltage Nom	Breakdown Voltage Max	Peak Current Amps	Clamp Voltage
ECG4911	6.0	10	10.5	103	14.5
ECG4915	7.2	12	12.6	90	16.7
ECG4919	7.8	13	13.7	82	18.2
ECG4921	9.0	15	15.8	71	21.2
ECG4923	9.6	16	16.8	67	22.5
ECG4927	10.8	18	18.9	59.5	25.2
ECG4929	12	20	21	54	27.7
ECG4933	14.5	24	25.2	45	33.2
ECG4935	16	27	28.4	40	37.5
ECG4937	18	30	31.5	36	41.5
ECG4939	19.9	33	34.7	33	45.7
ECG4941	21.8	36	37.8	30	49.9
ECG4943	23.5	39	41	28	53.9
ECG4945	25.8	43	45.2	25.3	59.3
ECG4947	28.4	47	51.7	23.2	64.8
ECG4951	30	51	53.6	21.4	70.1
ECG4953	33.8	56	58.8	19.5	77
ECG4955	37.5	62	65.1	17.7	85
ECG4959	41	68	71.4	16.3	92
ECG4961	45.3	75	78.8	14.6	103
ECG4963	49.5	82	86.1	13.3	113
ECG4965	55	91	95.5	12	125
ECG4967	60.4	100	105	11	137
ECG4969	66.4	110	116	9.9	152

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