G-E Electronic Tubes

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ABOUT POWER SUPPLIES

BETTER DYNAMIC CHARACTERISTICS MEAN BETTER OUTPUT ON CW, AM AND SSB

Here, for the first time, is a revealing discussion of how transient oscillations in the conventional power supply filter spoil the performance of an otherwise good rig—and what can be done to correct the difficulty.

The next issue of G-E HAM NEWS will contain design and construction specifications for 750-volt and 1500-volt supplies employing the principles discussed here.

Contents

better dynamic characteristics mean better output on CW, AM and SSB

What is dynamic regulation in a power supply? Because the literature in this field is exceedingly sparse, perhaps a good way to start is to take two common definitions and directly relate them to the subject at hand, thus:

Static—Relating to forces in equilibrium (as d-c plate voltage and current in a rig transmitting a continuous unmodulated carrier).

Dynamic—Relating to moving forces (as d-c plate voltage and current under typical operating conditions in the average amateur CW, AM or SSB rig).

Keeping these definitions in mind will help in understanding just what goes on inside the conventional plate power supply which ordinarily consists of a center-tapped step-up transformer, rectifier tubes, and a two-section choke-input filter to reduce ripple. Since such supplies have been used since the introduction of the mercury-vapor rectifier, one might think that just about all the "bugs" would have been smoked out by now. Well, many bugs have been eliminated and, as a consequence, manufacturers of transformers and chokes now proudly offer what they term "matched power supplies"—sets of components for which they publish ratings, voltage regulation curves, and ripple output to be expected. These "matched" components make up power supplies that do perform as the published data indicates.

LOSS OF VOLTAGE

However, poor *dynamic* regulation in these conventional power supplies means distortion of signal output—alteration of actual radiated intelligence—almost without exception in CW, AM and SSB rigs. These faults exist no matter how good a *static* regulation figure is indicated by d-c input instrumentation. This comes about in the conventional power supply because transient oscillations excited in the filter rob the rig of voltage during a sizable portion of the time it is sorely needed. Hams who light-heartedly pass this effect off as "instantaneous," thereby implying it is of no consequence, may want to examine their power supplies more critically after studying the test data presented below.

Consider the meaning of the voltage regulation curve usually given for the ordinary rectifier-filter combination. This is a "static" curve, obtained by loading the supply to certain currents, reading the voltages across each load, and then plotting the results. Such a curve is useful, but it tells us only what the ***average*** voltage will be at any ***average*** current value—***because the instruments used to measure these values respond only to average quantities.*** Figure 1 shows just such an acceptably good regulation curve in which the voltage drops about 10% or so from no load to full load on an ***average*** basis.

But is it the average load, voltage and current alone that we are interested in? What kind of loads do our amateur transmitters present to their respective power supplies? Do we transmit intelligence with average loads—or with a complex pattern of instantaneous loads?

VOLTMETERS MISLEADING

Consider the final stage of a CW transmitter. At key-up the load is zero, or, at most, a rather small one. When the key is closed, the maximum load current is drawn. Now does the power supply follow the same curve that was plotted under static or slowly varying loads? An ordinary voltmeter might lead one to think so.

But look at Figure 2! This is a photograph of a cathode-ray oscilloscope which shows how the voltage varies with time in the ordinary power supply when the load is suddenly applied as in keying a CW rig. The solid upper line shows the no-load output of the supply—820 volts; the lower solid line represents zero volts. The lower waving line is a 60-cycle timing wave which permits reading the actual load voltage (represented by the upper oscillating line) at any fraction of a second from the instant the load was applied. The spot on the oscilloscope was started as the key closed to a 200-milliampere load. (The steady current rating on the test supply is 250 milliamperes.)

Note how the load voltage dips suddenly to less than a third of the no-load voltage line, then wildly overshoots the line and oscillates about until it finally settles down to the average loaded voltage of 760 volts—which is the same as the static loaded output voltage shown in the curve of Figure 1 for a 200-milliampere load.

(Incidentally, the ripple under load is visible on the right-hand portion of the load voltage curve of Figure 2, but is fairly small compared with the extravagant excursion of the voltage in the period immediately following the application of the load.)

A d-c voltmeter that was connected across the line at the same time merely dropped from 820 to 760 volts and gave no indication of the actual turmoil immediately after keying!

EFFECT ON CW OPERATION

Is this turmoil anything to worry about? Well, the final stage in a CW transmitter generally runs Class C, and the transient oscillation shown across the power supply modulates each character with that same wave form quite independently of any keying filter that may be provided for click reduction. This, then, is the signal envelope—somewhat poorer than ideal!

How long is a dot or a dash in seconds? That depends on the operator for the most part, of course. But this transient oscillation certainly lasts for a considerable portion of the average CW dot or dash, because as can be seen from the timing wave of Figure 2, the voltage does not settle down to a steady ripple until more than a tenth of a second has elapsed. And as anyone who has played with timing in radio or photography work knows, a tenth of a second is far from what is normally thought of as "instantaneous."

When the load is removed (key up), the power supply voltage behaves as photographed in Figure 3—another wild peak, with the oscillation finally settling down to the no-load line. Of course, in this case there is no "on the air" effect, but the filter condensers and all other connected equipment are subjected once

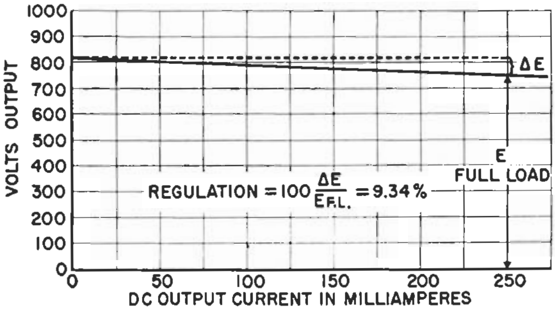


FIG. 1 *Static regulation curve (C_a, C_b any value)*

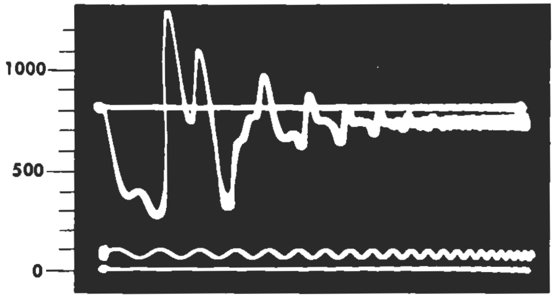


FIG. 2 *Load applied ($C_a = C_b = 2$ mfd)*

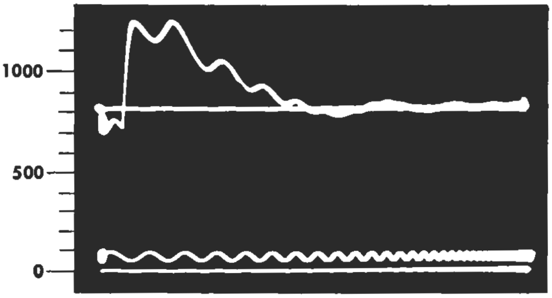


FIG. 3 *Load removed ($C_a = C_b = 2$ mfd)*

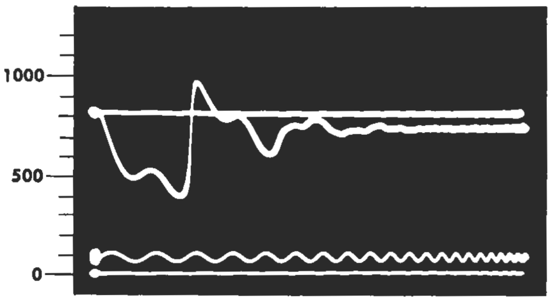


FIG. 4 *Load applied ($C_a = C_b = 5$ mfd)*

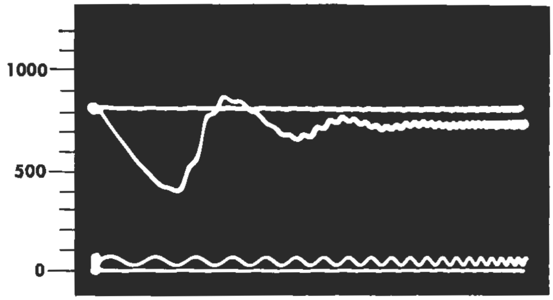


FIG. 5 *Load applied ($C_a = 0$; $C_b = 10$ mfd)*

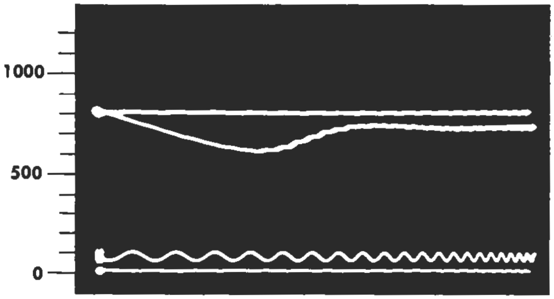


FIG. 6 *Load applied ($C_a = 0$; $C_b = 45$ mfd)*

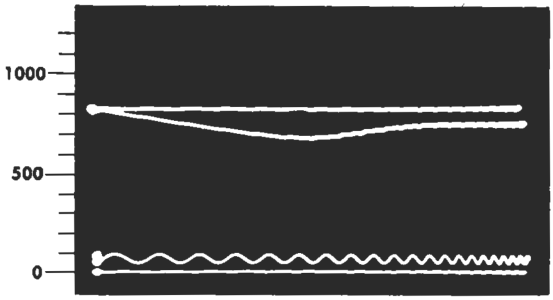
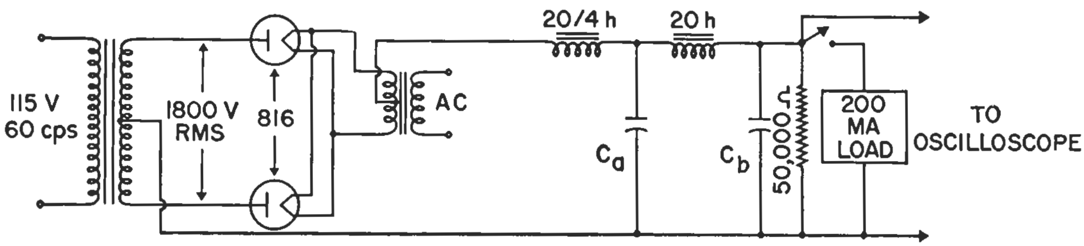


FIG. 7 *Load applied ($C_a = 0$; $C_b = 90$ mfd)*

FIG. 8 *Load removed ($C_a = 0$; $C_b = 90$ mfd)*

Above data taken with this 750 V/250 ma d-c supply (see text):



again to this voltage turmoil. This may explain why every once in a while a ham's whole rig is blown to kingdom come when he shuts it off.

The oscillograms shown apply only to single keying actions. Fast keying conditions intensify the transients shown in Figures 2 and 3.

EFFECT ON PHONE OPERATION

So much for CW loads on the common garden variety power supply. Now before the phone men start laughing up their sleeves at their brass-pounding brethren with "hand-modulated" rigs, let's take a close look at Class AB_1, AB_2, and B modulators operated with conventional power supplies.

It is characteristic of these modes of operation to draw average plate current which is a function of the modulating signal. Thus, the modulator load is similar to the on-off type of load experienced in a keyed CW transmitter, and the power supply transient so induced can be a real hazard to good quality. Because of the relatively sluggish action of a d-c plate current instrument (which tends to indicate current flow averaged over about half a second or so) the actual cyclic or syllabic transient load presented to the power supply is much greater than one would be led to believe by just reading the plate milliammeter.

What happens when the power supply behaves as in Figure 1? The answer is high distortion and loss of required peak power because most of the supply voltage just is not there part of the time it is needed by the modulator, and so the modulator tubes cannot draw the peaks of plate current that the grid drive on the modulator stage says should be drawn.

And remember, distortion tests made with steady tones will not show this "dynamic" distortion because the drain on a power supply induced by a steady tone is constant when averaged over one-half of the period of the test tone wave—relatively short compared to a filter transient which lasts more than a tenth of a second.

EFFECT ON SSB OPERATION

Single-sideband transmitters employing Class AB_1, AB_2, or B RF stages present the same type of load to their respective power supplies—and, as a result, also introduce considerable distortion in the radiated signal.

About the only types of emission in common use which do not suffer "on the air" losses as a result of transient filter oscillations are NBFM and FSK. (No transients are excited in the filter because the load is steady.) Linear amplifiers used with AM signals overcome this dynamic power supply regulation problem, but the carrier efficiency of this mode of operation is so low that use of linear amplifiers in amateur AM transmitters is not common. Similarly, constant current (or Heising) modulation for AM is another case where dynamic power supply regulation is not of primary importance. Grid modulation systems—control, screen or suppressor—also side-step the dynamic regulation problem but are inherently low-efficiency systems at best. In all these modes of operation, the only important power supply considerations are adequacy of rating and ripple filtering.

What can be done to improve the dynamic regulation of the conventional power supply? Let us follow the steps that were taken in the shack of W2KUJ to attack the problem.

THE SOLUTION

It became apparent that merely improving the ripple attenuation by adding more filter sections affected the dynamic regulation very little. So the first step was to increase the capacity of the existing filter from 2 microfarads to 5 microfarads per capacitor. The result appears in Figure 4—which shows excellent ripple filtering but only slightly reduced voltage excursions as compared with the transient of Figure 2.

Next, the two 5-microfarad capacitors of the two-section filter were connected in parallel to make a single-section filter (with the two chokes left in series). As shown in Figure 5, the voltage excursions are not greatly changed in magnitude, but have a less complex pattern—comparable, in fact, to that of a simple damped oscillation. But here again, the oscillation is excited in the filter by the suddenly-applied load.

The next step in the test was to use 45 microfarads of capacity as the final element of the filter. The dynamic regulation performance responded nicely, as shown in Figure 6. Note the reduction of magnitude of voltage swing and lowering of the resonant frequency of the filter as compared with Figures 2, 4 and 5.

FINAL DESIGN

This encouraged a final design in which 90 microfarads of capacity rendered the curve shown in Figure 7. Here the dynamic regulation is just slightly greater than the static regulation, which, incidentally, measures 9.34%—quite good enough for almost any amateur transmitter. The "break" characteristics of this final design are pictured in Figure 8. Use of more capacity would improve the dynamic characteristics of the power supply correspondingly because the resonant frequency of the filter would be lowered even farther. (For more detailed theory on the dynamic characteristics of plate power supplies see "Designer's Corner," page 6.)

USING FLUORESCENT TUBE AS TUNING INDICATOR

A sure indicator of maximum RF in your antenna is a fluorescent tube placed in the antenna field. The tube can be taped right to the antenna at the voltage node. Thus in tuning the final or the antenna coupler maximum input is indicated when the light is brightest. This is particularly convenient when your antenna is located in such a position that it can be seen from the window of the shack. The stunt helps especially when using a pi-network in the tank circuit without a coupler.

—S. BAXTER, VE7HK

(*Ed. Note*—No doubt the neighbors will be confused no end to see an antenna winking at them at about 30 wpm—until they suddenly tumble to the fact there may be some relationship between that blinking light up in the sky and the tweedy look their TV picture tube takes on at certain times.)

TV CHANNEL FREQUENCIES

Hams frequently have occasion to refer to TV frequencies and the following list is reprinted for reference. The list includes both picture and sound carrier frequencies in each of the 12 VHF TV ranges and the 70 UHF TV ranges. More and more of these channels are coming into use in the smaller communities throughout the country.

CHANNEL NO.	FREQUENCY RANGE MC	PICTURE CARRIER MC	SOUND CARRIER MC
2	54–60	55.25	59.75
3	60–66	61.25	65.75
4	66–72	67.25	71.75
5	76–82	77.25	81.75
6	82–88	83.25	87.75
7	174–180	175.25	179.75
8	180–186	181.25	185.75
9	186–192	187.25	191.75
10	192–198	193.25	197.75
11	198–204	199.25	203.75
12	204–210	205.25	209.75
13	210–216	211.25	215.75
14	470–476	471.25	475.75
15	476–482	477.25	481.75
16	482–488	483.25	487.75
17	488–494	489.25	493.75
18	494–500	495.25	499.75
19	500–506	501.25	505.75
20	506–512	507.25	511.75
21	512–518	513.25	517.75
22	518–524	519.25	523.75
23	524–530	525.25	529.75
24	530–536	531.25	535.75
25	536–542	537.25	541.75
26	542–548	543.25	547.75
27	548–554	549.25	553.75
28	554–560	555.25	559.75
29	560–566	561.25	565.75
30	566–572	567.25	571.75
31	572–578	573.25	577.75
32	578–584	579.25	583.75
33	584–590	585.25	589.75
34	590–596	591.25	595.75
35	596–602	597.25	601.75
36	602–608	603.25	607.75
37	608–614	609.25	613.75
38	614–620	615.25	619.75
39	620–626	621.25	625.75
40	626–632	627.25	631.75
41	632–638	633.25	637.75
42	638–644	639.25	643.75

CHANNEL NO.	FREQUENCY RANGE MC	PICTURE CARRIER MC	SOUND CARRIER MC
43	644–650	645.25	649.75
44	650–656	651.25	655.75
45	656–662	657.25	661.75
46	662–668	663.25	667.75
47	668–674	669.25	673.75
48	674–680	675.25	679.75
49	680–686	681.25	685.75
50	686–692	687.25	691.75
51	692–698	693.25	697.75
52	698–704	699.25	703.75
53	704–710	705.25	709.75
54	710–716	711.25	715.75
55	716–722	717.25	721.75
56	722–728	723.25	727.75
57	728–734	729.25	733.75
58	734–740	735.25	739.75
59	740–746	741.25	745.75
60	746–752	747.25	751.75
61	752–758	753.25	757.75
62	758–764	759.25	763.75
63	764–770	765.25	769.75
64	770–776	771.25	775.75
65	776–782	777.25	781.75
66	782–788	783.25	787.75
67	788–794	789.25	793.75
68	794–800	795.25	799.75
69	800–806	801.25	805.75
70	806–812	807.25	811.75
71	812–818	813.25	817.75
72	818–824	819.25	823.75
73	824–830	825.25	829.75
74	830–836	831.25	835.75
75	836–842	837.25	841.75
76	842–848	843.25	847.75
77	848–854	849.25	853.75
78	854–860	855.25	859.75
79	860–866	861.25	865.75
80	866–872	867.25	871.75
81	872–878	873.25	877.75
82	878–884	879.25	883.75
83	884–890	885.25	889.75

Designer's CORNER

Some time ago when checking out my SSB transmitter I ran into a dismaying situation.

Checks with a steady audio tone showed the rig was putting out all that could be asked for. But voice peaks measured on the oscilloscope would not come anywhere near the same level. The cause was not easy to determine, but it finally turned out to be tremendous voltage drops in the power supply during a considerable portion of each syllable as a result of filter oscillations. In a more recent test I actually photographed these voltage drops, as pictured in the foregoing article.

The problem is one which involves effective damping of filter resonance or reducing the coupling between the load variations and the resonant system of filter chokes and capacitors—or both—without sacrificing efficiency or static regulation, and without overloading the rectifier tubes or any other power supply component. All this must be done without increasing the cost of the final design appreciably over that of the conventional power supply. It sounds a lot like "eating your cake and having it too," since what we have seen in the oscillograms of Figures 2, 3, 4 and 5 is commonly accepted although rarely suspected performance.

THE SOLUTION

The practical solution of the filter resonance problem involves these basic steps:

1. Reducing the Q of the filter without increasing its series resistance, and
2. Increasing the energy storage in the last filter element.

The first step could be achieved by shunting capacitors and chokes with resistors, but if this is done the peak current handled by the rectifiers would go up, the static regulation would be poorer, and a great deal of power would be wasted in the damping resistors—that is, the efficiency of the power supply would be low.

Since the Q of the choke is $\frac{X_L}{R}$, where X_L is the inductive reactance at a given frequency, and R is the effective series resistance of the choke at the frequency considered, and since the Q of the filter is equal to the Q of the choke (if the capacitor has relatively little effective series resistance), Q can be lowered by decreasing X_L or increasing R. If R is increased the static regulation will suffer as a consequence, so the approach should be through decreased X_L. Since $X_L = 2\pi fL$ a low product of $f \times L$ is desired. In the interest of efficiency and static regulation, practical limits are placed on the value of L, the inductance of the choke, so the factor f is the only one left to be altered.

NEED LOWER FILTER Q

What determines f? The resonant frequency of the filter is the quantity f in question. To a first approximation, $f = \frac{1}{2\pi LC}$, where C is the capacity of the filter condenser with which L resonates. Therefore, the Q of the filter can be lowered by increasing C, and this helps in attainment of the second basic step listed above.

What would have happened if L had been increased by a factor of 9, instead of increasing C by the same factor? The resonant frequency would have been lowered as much, but the series resistance probably would increase by about the same factor (it certainly would if 9 times the number of identical chokes had been used) and the static regulation would be nine times that indicated by Figures 1, 2, 4, 5, 6, and 7, or 84%, a drop from 820 volts, no load, to 131 volts at 200 MA load! The Q would be the same in the filter, but the total performance would be so sadly degraded that such a supply would be valueless except for salvage of parts.

In some cases, the best design would be one in which both the chokes and the condensers were increased in value until suitable dynamic performance was obtained. In high-voltage supplies this begins to pay dividends since the "critical"[1] inductance increases with voltage for a given minimum or bleeder current drain, and high-voltage capacitors begin to get expensive. Static regulation depends on the DC resistance of the chokes (together with the equivalent series resistance due to the plate transformer) but a given total equivalent resistance in the chokes and transformer yields less *percentage* voltage drop as the operating voltage is increased.

TWO POWER SUPPLY DESIGNS

We have designed two power supplies which promise to provide excellent dynamic regulation, good static regulation and good ripple filtering. Best of all, these supplies are not expensive ones. The first supply has a continuous rating of 750 volts/250 MA output for moderate and low power applications, while the second is rated at 1500 volts/250 MA. One nice thing about it all is that the builder may utilize the principle we have explained and proven in order to build other supplies which exhibit equally good (or better) dynamic regulation. Either power supply is ideally suited for CW transmitters, Class B modulators, linear amplifiers (such as the Lazy Linear[2] or the Power Peaker[3]), or any application where the voltage and average current requirements are within the ratings given. The final samples of these two power supplies were not completed by the time this issue of G-E HAM NEWS went to press, but construction details will be given in the March-April issue.

—*W2KUJ*

[1] See G-E HAM NEWS Volume 7, No. 2, page 6; also, the ARRL Handbook. In these treatments only static regulation is considered. Good background material, though.

[2] G-E HAM NEWS Volume 4, No. 4

[3] G-E HAM NEWS Volume 7, No. 5

HOW TO GET G-E HAM NEWS

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SWEEPING *the* SPECTRUM

Seems like one thing that plagues most hams is a perpetual list of unfinished projects. Perhaps it's partly a general failing of the human race to bite off more than can be chewed. But as far as hams go, a lot of the trouble comes from what we might call "over-enthusiasm." In the field of ham radio there are so many things to do, so many types of equipment that can be built.

But one of the fellows here dropped a comment a while ago which can help keep down the number of unfinished projects—by keeping down the list of projects. We had asked him if he would like to see an article published on a certain piece of equipment and he shot right back at us: "What would I use it for? I don't keep anything in the shack I don't use."

That's an admirable policy, we thought. We made a New Year's resolution and that night cleaned house. And we found that we get along very nicely without the old junk.

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One of the nicest things about ham radio is the readiness of the fraternity to jump in and help whenever and wherever help is needed. And we don't mean just physical emergencies—we mean spiritual emergencies, too. As an example, the editor was telling us the other day how each member of the Northern N. J. Radio Association (W2DAY) sent a QSL card to a local lad who was afflicted with cerebral palsy. The interest that these total strangers seemed to show in his life perked the boy up, and his folks got him a communications receiver. Then the hams began to mention the lad's name frequently in their local rag chews. He became an avid SWL, a silent member of the local networks—and still hopes some day to be able to get his ticket. Incidentally, he's still collecting QSL cards and if anyone wants to send him one, he'd sure appreciate it. Here's the QTH: Richard Ernst, 242 Wales Avenue, River Edge, New Jersey.

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A handy tip for both mobilers and fixed stations to keep in mind comes via "Zero Beat," bulletin of the Providence (R. I.) Radio Association: If called upon to report an accident along an unfamiliar stretch of highway, the location can be pinpointed by reporting the number on the nearest utility pole. . . . "Zero Beat" also expresses amazement at the things you hear on 2 meters. One Sunday a.m. this mail was read: "take 3 cups loose cranberries, 1½ cups raisins, 1 cup sugar, 2 tbls flour, ½ cup water, and a pinch of salt for good luck. Boil until cranberries pop, pour into pie shell, cover with strips of dough and bake." Neither "Zero Beat" nor G-E HAM NEWS assumes any responsibility. . . . "Sparks," published by the Tri-State ARA at Evansville, Indiana, reports a 3-kw generator has been ***donated*** to the club by a local electric company.

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"Ham Hum," bulletin of the Ak-Sar-Ben RC of Omaha (W0EQU), passes on this idea: Shim up the front of the receiver and transmitter with a length of 2 x 4 shaped and painted to match the equipment. They say it makes the dials and meters more readable and gives the equipment a novel appearance. . . . The mobile section of the Michiana ARC (W9AB) has been engaging in a community service which may be of interest to others—parade duty. They patrol local parades, aiding in keeping the parade units spaced and providing LL hook-ups when emergencies or other unforeseen problems arise, according to the club bulletin, "Marc Sparks."

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W5KNY passes on a mobile noise reduction idea which he apparently got from W5DAS: Provide both the auto BC set and the converter with a hot A lead direct from the battery—a lead with a well-grounded shield. They say this can take off a good thick layer of mobile noise. . . . A TV serviceman in California has come up with a stunt that helps in tracking down an intermittent failure. He uses an infrared heat lamp to bring a benched chassis up to its normal in-the-cabinet operating temperature. This stunt is reported in the current issue of "Techni-Talk," our Tube Department publication for TV servicemen—available to them through authorized G-E tube distributors.

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It's reported K0WBF is maintaining a constant daytime watch on 3983 kc for any "CQ Omaha" in anticipation of communications emergencies in these months of snow, sleet and ice. . . . The Detroit Amateur Radio Association (W8ZZ) has been hashing over the problems involved in delivering traffic from boys overseas asking their folks to send some money. When the citizen who doesn't know much, if anything, about ham radio, gets a message that his or her boy wants money—well, it often leads to misunderstanding and suspicion. Some hams now refuse to handle such traffic; others feel that all traffic must be handled. In any event, delivering such a message by phone is a ticklish problem. Those called upon to telephone such messages are cautioned to think out carefully beforehand just how to answer the inevitable questioning of the addressee. The boys who have had trouble say it can be worse than handling a TVI complaint!

—Lighthouse Larry

Trapping Transients

HOW TO PHOTOGRAPH VOLTAGE DROPS

The oscillograms shown on page 3 of this issue of G-E HAM NEWS were taken with a 5-inch cathode-ray oscilloscope fitted with an oscillograph camera. In this photograph Don Norgaard, W2KUJ, is shown just before he opens the shutter of the camera and applies the load to a power supply he is testing for dynamic regulation.

The power supply output voltage is fed to the vertical deflection plates of the oscilloscope through a voltage divider while a single horizontal sweep is started by the same switch that applies the load to the power supply. The load, incidentally, was a vacuum tube biased to cut off for no-load conditions and made to take load by controlling the grid voltage with the switch. This type of load simulated the load applied to a power supply feeding a keyed stage in a transmitter.

On one occasion the transient voltage developed in the power supply was so high that the multiplier resistor of a voltmeter reading the output voltage of the supply under test arced across and burned out the meter. That time the voltmeter *did* give some indication of the turmoil in the power supply following a suddenly applied load!

Don has been a regular contributor to G-E HAM NEWS and has been responsible for the design of the *Harmoniker,* the *Lazy Linear,* the *Signal Slicer,* the *SSB, Jr.,* and other pieces of ham gear described in G-E HAM NEWS.

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