Rectifier Tube Report File

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Title TUNGAR BULB CATALOG 199698 IN MODULATOR RECTIFIER, FACTORS INFLUENCING OUTPUT VOLTAGE

By

RECTIFIER TUBE ENGINEERING Dept.

Information prepared for J. J. FITZPATRICK

Tests made by C. MORSE, J. S. NELSON

Information prepared by J. S. NELSON

Countersigned by L. F. PEROTT

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TUNGAR BULB CATALOG 199698 IN MODULATOR RECTIFIER, FACTORS INFLUENCING OUTPUT VOLTAGE

References:

1. Letter of H. J. Mason to L. F. Perott, April 25, 1945.

2. Letter of J. S. Nelson to H. J. Mason, May 15, 1945, and reply of May 19.

3. Ware, "Operation of a Thyratron as a Rectifier" R134XR337, Proceedings of the I.R.E., November, 1942.

4. Specification JAN-1A for Radio Electron Tubes.

5. Electron Tube Type 199698, Signal Corps Tentative Specification No. 71-5270, 28 April 1945.

6. Tungar Bulb Data Manual, G-E Appliance and Merchandise Department, Bridgeport, Connecticut, 1945.

7. Letter of H. J. Mason to R. D. Amsden, April 27, 1945.

Purpose:

It was desired to determine the performance of Tungar Bulb Catalog 199698 in a proposed modulator rectifier, reference (1):

"A single-phase full-wave rectifier circuit is required which will deliver 2.8 amperes d-c maximum and 1.6 amperes d-c at light load. The output d-c voltage must fall within the limits of 26.5±3.5 volts under all operating conditions. The input voltage is 60 cycles in frequency."

"The input voltage will be 120 volts ±5%" (Ref. 7)

"Temperature (-40 C to +60 C)" (Ref. 1)

Apparatus Tested:

Five Cat. #199698 Tungar Bulbs.

Summary:

The most important cause of change in output is variation in line voltage. Next in order of importance are variations in output due to individual differences, including ageing effects, and regulation with change in load current. The effect of ambient temperature in the range considered is negligible.

Tube losses will gradually rise with age until the lower limit of output voltage is reached. The length of service can be increased several fold by providing taps in the plate transformer to be adjusted once or twice in the life of a tube or when tubes are changed to compensate for individual differences.

Unless taps are used, the range of characteristics required is narrower than our published limits. (See calculations)

Procedure:

The Catalog 199698 was selected for study because life tests show comparatively high stability of operating characteristics. This is a twin-anode rectifier and only one tube is required for full-wave rectification.

Because tube characteristics vary considerably with the manner of testing, it was decided to test these tubes in the equivalent of the proposed modulator rectifier.

Calculations based on the published average tube characteristics (reference 6) gave 76 Vac for the optimum closed circuit voltage between anodes. These calculations are included in the appendix to this report, together with a copy of the published characteristics.

Tests were made at this voltage with a simulated line variation of plus and minus 5% and at various ambient temperatures.

Calculations were made to determine the tube characteristics yielding maximum and minimum d-c output at extremes of line voltage (see appendix).

Results:

A complete description of the tests, with tabulated results, follows in the appendix.

Accuracy of Data: All indicating instruments were carefully calibrated laboratory portables, General Electric Types P-3, DP-2 and DP-2X.

Discussion of Data: As noted in the summary, the average effect of temperature is nil. The average regulation is one volt in output from light load to full load. The spread due to individual differences was 1.3 volts at light load in a random sample of 5 tubes, considered typical.

The maximum variation in output is due to change in line voltage. A glance at the data will show that with line voltage up 5% the maximum output of 30 volts is exceeded at light load (and, in the case of one tube, at full load). This is due to the fact that the tube drop is less at light loads. If this condition can be tolerated (despite the given limits), it would be wise not to lower the design voltage from the calculated optimum of 76 Vac, or the lower limit of output will be reached much sooner in the life of the tube. With a design voltage of 76, the limiting values of arc drop and pick-up are 10 and 13 volts d-c, respectively, to give 23 Vdc output when the line voltage is down 5%. (These values are not unique. The arc drop could be slightly higher and the pick-up slightly lower, or vice versa, with the same effect.) On accelerated life test, these values are reached in approximately 1700 hours. With a design voltage of 73 (which would drop the maximum output to the required 30 volts) the limiting values would become 8.5 and 12.2 volts, reached in 400 hours on the same accelerated test. In actual service the expected life would be about four times as great as on this accelerated test.

The safest thing to do would be to provide taps in the plate transformer to be adjusted once or twice in the life of a tube or when tubes are changed to compensate for individual differences. This is the practice followed by the designers of Signal Corps Rectifier, RA34B, which uses the Cat. 199698 tube. If taps are provided in the primary, a separate filament transformer must, of course, be used.

This same rectifier, RA34B, has established a precedent for the use of the Catalog 199698 at loads in excess of the present published maximum of two amperes. Extensive life tests have been conducted at 3.3 amperes load current with satisfactory results.

TEST ON CAT. #199698 TUNGAR BULB FOR THE PITTSFIELD MODULATOR

Circuit: Full-wave center tapped, with resistance load connecting the center taps of the plate and filament transformers.

Tubes Tested: Random samples unpacked from stock in Bldg. H.

Tests:

1. D-c characteristics: Run tubes 2 minutes at two amperes d-c, anodes clipped together. Take arc drop at 1.6, 2.0 and 2.8 amperes. Remove clip and take pick-up by raising d-c voltage till tube fires.

   At 2.0 amperes remove clip and record drop for one anode alone. Filament voltage 1.8 Vac.

2. Place in F.W. circuit described above and read E_o:

(a)	Epp 76.0 Vac (Plate to plate)	E_f 1.8 Vac	I_o 1.6	I.02.8
(b)	79.8	1.89	1.6	2.8
(c)	72.2	1.71	1.6	2.8

3. Repeat (2) at -40C. Pack dry ice around tube and reduce temperature well below -40C. Start tube and take reading when temperature at the juncture of the envelope and base reaches -40C as indicated by a thermocouple potentiometer.

4. Repeat (2) at +60C. Record base temperature and E_o (T.C. potentiometer) when air temperature in the enclosure reads 60C (mercury thermometer).

5. Strip the filaments of two tubes and measure output.

TEST DATA

Test 1

Tube #	Arc drop, Vdc 1.6A	2.8A	2.0A	One anode 2.0A	Pick up, Vdc Vdc
1	4.3	5.9	5.4	6.0	11.5
2	4.5	6.0	5.7	6.2	11.5
3	4.4	6.1	5.3	5.8	11.8
4	6.0	6.4	5.7	6.4	11.5
5	4.2	5.6	5.3	6.0	11.9
Average	4.68	6.0	5.48	6.08	11.65

Tube #	E_o at 1.6A		E_o at 2.8A	
		Test 2a.		Room temperature, normal voltage
1	28.8		28.0	
2	28.6		28.1	
3	28.6		28.0	
4	28.5		27.7	
5	29.2		28.5	
Avg.	28.8 Vdc		28.1 Vdc	
		Test 2b.		Room temperature, voltage up 5%
1	30.6		29.6	
2	30.9		30.0	
3	31.0		29.8	
4	30.1		29.6	
5	31.4		30.2	
Avg.	30.8 Vdc		29.8 Vdc	
		Test 2c.		Room temperature, voltage down 5%
1	26.5		25.9	
2	26.7		26.2	
3	26.4		25.9	
4	26.4		25.7	
5	27.3		26.5	
Avg.	26.7 Vdc		26.0 Vdc	
		Test 3a.		-40C Normal voltage
1	28.8		27.8	
2	28.5		27.9	
3	28.7		28.0	
4	28.1		27.4	
5	29.0		28.3	
Avg.	28.65 Vdc		27.9 Vdc	
		Test 3b.		-40C Voltage up 5%
1	31.0		29.6	
2	30.7		29.6	
3	31.2		29.9	
4	29.8		29.4	
5	31.2		30.1	
Avg.	30.8 Vdc		29.7 Vdc	

Test 3c. -40C voltage down 5%

Tube #	E_o at 1.6A	E_o at 2.8A
1	26.6	25.8
2	26.6	26.0
3	26.4	26.2
4	25.7	25.8
5	27.0	26.3
Avg.	26.5 Vdc	26.0 Vdc

Test 4a. High temperature normal voltage

Tube #	E_o at 1.6A (Vdc)	E_o at 2.8A (Vdc)	Base Temp. (°C)	Air Temp. (° C)
1	28.8	27.9	94	64
2	28.6	28.2	108	67
3	28.6	28.1	114	60
4	28.5	27.8	120	65
5	29.3	28.4	110	61
Avg.	28.8 Vdc	28.1 Vdc		

Test 4b. High temperature, voltage up 5%

Tube #	E_o at 1.6A (Vdc)	E_o at 2.8A (Vdc)	Base Temp. (°C)	Air Temp. (° C)
1	30.8	29.8	94	60
2	31.2	30.0	109	63
3	30.8	29.9	117	60
4	30.3	29.4	121	62.5
5	31.4	30.4	103	60.5
Avg.	30.9 Vdc	29.9 Vdc		

Test 4c. High temperature, voltage down 5%

Tube #	E_o at 1.6A (Vdc)	E_o at 2.8A (Vdc)	Base Temp. (°C)	Air Temp. (° C)
1	26.6	26.0	97	65
2	26.8	26.3	107	67.5
3	26.3	26.0	118	62
4	26.3	26.8	114	63
5	27.1	26.5	108	60
Avg.	26.7 Vdc	26.3 Vdc		

Test 5

By stripping the filaments, two tubes were rendered "low readers" with output 4% under the passing limit of the factory test. With 72.2 Vac plate to plate, 1.7 Vac on the filament (line voltage down 5%) these tubes each delivered 24.6 volts at 2.8 amperes resistance load.

Tungar Bulb Catalog #199698 - Description and Rating

The Catalog #199698 Tungar Bulb is a twin-anode rectifier for use in low-voltage "full wave" (biphase half-wave) circuits. The discharge medium is argon gas, and the tube is designed for quick starting.

General Design:

Number of electrodes	3
Socket required	Standard Edison
Cathode - thoriated tungsten filament:	
Voltage	1.8±5%
Current, amperes, approx.	12
Pre-heating time, typical seconds	0*
Tube voltage drop, volts d-c:	
Maximum	10.0
Minimum	5.5
Average during life	8.0
Starting (pick-up) voltage, volts d-c:	
Maximum	14.0
Minimum	10.0
Average during life	12.0
Net weight, ounces, approx.	2
Shipping weight, ounces, approx.	6
Length, inches, approx.	5 5/8
Diameter, inches, approx.	2

Ratings:

Maximum peak voltage between anodes	105	120
Maximum current:		
Average per anode, amperes	1.0	0.25
Average full-wave, output per tube, amperes	2.0	0.5
Instantaneous (peak) amperes, recurrent	6.0	1.5
Maximum d-c output, average volts	25	30

This tube will deliver 90% of full output within three seconds after the simultaneous application of anode and filament voltages to a cold tube. Longer life may be obtained by applying the anode voltage one to three seconds later than the filament voltage.

Summary of Calculations

The range of characteristics permitted by the conditions prescribed is (approximately):

	Min.	Max.
Arc drop*	6	10
Pick-up*	11	13

Published range:

A.D.	5.5	10
P.U.	10.0	14

*A lower value of arc drop may be permitted in conjunction with a higher value of pick-up and vice versa.

Calculations Cat.# 199698 in Modulator Rectifier

Assumptions and definitions:

Notation follows JAN practice (Ref. 4). Capitals indicate rms or average values. Lower case letters indicate instantaneous values.

E_o = Output voltage of full-wave rectifier, Vdc

E_f = filament voltage, Vac

P.U. = pick-up voltage, Vdc, with ac on filament, no center-tap.

A.D. = arc drop voltage, Vdc, one anode carrying 2 amperes. (Conventional test for arc drop)

e_α = dynamic starting voltage, assumed = P.U. + $\sqrt{2}\,E_f$

E_{td} = arc drop in rectifying service, assumed = A.D. and constant during conduction.

E_{pp} = Plate transformer secondary voltage, Vac

$E = \frac{E_{pp}}{2}$, Vac

e_m = sine peak of $E = \frac{E_{pp}}{2}\sqrt{2}$

θ = load power factor angle, assumed 0° (U.P.F.)

ϕ = angle of cut-off = arc sin $\frac{E_{td}}{e_m} - \alpha$

α = ignition angle = arc sin $\frac{e_\alpha}{e_m}$

(1.) $$E_o = \frac{e_m}{\pi}\left[\cos\alpha - \cos(\phi+\alpha) - \frac{E_{td}\,\phi}{e_m}\right]$$ (reference 3)

1. Optimum design voltage, plate transformer secondary:

$A.D. = 8.0$ }
$P.U. = 12.0$ } Average during life (ref. 6)

$E_o = 26.5$ (ref. 1)

$E_{td} = 8.0$, $e_d = 12.0 + \sqrt{2}\,(1.8) = 14.55$

By successive solutions of Equation (1), $E_{pp} = 76$ Vac ←

Sample calculation:

Try $E_{pp} = 76$; $E = 38$, $e_m = 53.8$

$\phi = \arcsin \frac{8.0}{53.8} - \arcsin \frac{14.55}{53.8} = 171.43° - 15.7 = 155.73°$
$= 2.72$ radians

$\cos(\phi + \alpha) = -.989 \quad \cos\alpha = .963$

$$E_o = \frac{53.8}{\pi}\left[1.952 - \frac{21.8}{53.8}\right] = \frac{53.8}{\pi}1.547 = 26.5 \text{ Vdc (check)}$$

2. Minimum characteristics permissable when line voltage is maximum:

$E_{pp} = 76 + 5\% = 79.8$ Vac $\qquad e_m = \frac{79.8}{2}\sqrt{2} = 56.4$

$E_o = 26.5 + 3.5 = 30$ Vdc

Try $A.D. = 6$, $P.U. = 11.0$:

$E_{td} = 6 \qquad e_d = 11.0 + \sqrt{2}\,(1.8) = 13.55$

$\alpha = \arcsin \frac{13.55}{56.4} = 13.9°$; $\cos\alpha = .971$

$\phi = \arcsin \frac{6.0}{56.4} - \alpha = 173.9 - 13.9 = 160° = 2.79$ radians

$\cos(\phi + \alpha) = -.994$

$$E_o = \frac{56.4}{\pi}\left[.971 + .994 - \frac{2.79(6)}{56.4}\right] = 29.93 \simeq 30 \text{ Vdc} \leftarrow$$
(check)

3. Maximum characteristics permissable at minimum line voltage:

$E_{pp} = 76 - 5\% = 72.2 \text{ Vac}$ $\qquad e_m = \frac{72.2}{2}\sqrt{2} = 51.0$

$E_o = 26.5 - 3.5 = 23 \text{ Vdc}$

Try A.D. = 10, P.U. = 13:

$E_{td} = 10 \qquad e_d = 13 + \sqrt{2}(1.8) = 15.55$

$\alpha = \text{arc sin} \frac{15.55}{51} = 17.8°; \quad \cos\alpha = .953$

$\phi = \text{arc sin} \frac{10}{51} - \alpha = 168.7 - 17.8 = 150.9° = 2.63 \text{ rad}$

$\cos(\phi + \alpha) = -.981$

$E_o = \frac{51}{\pi}[.953 + .981 - .515] = 23.0 \text{ Vdc}$ ← (check)

4. Comparison of calculated and measured output values:

Avg. of 5 tubes: A.D. = 6.08, P.U. = 11.65 } Test #1

Set $E_{pp} = 76.0$, $e_m = 53.8$

$E_{td} = 6.08 \qquad e_d = 11.65 + \sqrt{2}(1.8) = 14.20$

$\alpha = \text{arc sin} \frac{14.2}{53.8} = 15.31°; \quad \cos\alpha = .964$

$\phi = \text{arc sin} \frac{6.08}{53.8} - \alpha = 173.51 - 15.31 = 158.2° = 2.76 \text{ rad}$

$\cos \phi + \alpha = -.994$

$E_o = \frac{53.8}{\pi}\left(.964 + .994 - \frac{2.76(6.08)}{53.8}\right) = 28.2 \text{ Vdc}$

Avg. measured output at 2.8 amp. = 28.1 Vdc (Test 2a)

Using A.D. values obtained with 2 amperes flowing in paralleled anodes, the output at 1.6 amperes is calculated with equal accuracy. The justification for choice of arc drop values is empirical in either case.

JSm