Testing Cathode Materials in Factory Production*

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Summary—**The paper deals with the methods of testing radiotube cathode materials in factor production, and especially with a comparison of several specific lots of materials of variable content. It is believed that this is the first time the electron-tube industry has made mass tests on a well-controlled engineering basis of cathode materials which vary in singe component elements.**

THE CHAOTIC conditions under which the manufacturers of electron tubes have been testing cathode-nickel tubing for their use have been described by McCormack.[1] These costly tests, together with prove-in tests on other components of electron tubes, such as alkaline-earth carbonates, getters, and anodes, are performed to insure good manufacturing yields. The lack of fundamental knowledge concerning thermionic emission makes these acceptance tests necessary.

Each company in the industry accepts or rejects a new melt on the basis of the final test results and life performance of electron tubes containing cathodes made from the new melt, as compared with tubes being currently made using cathodes from the previously accepted melt. The type of tube used for this comparison is usually one of those in current production. The results of these tests, as reported by the entire industry to the suppliers of cathode tubing, were contradictory and full of inconsistencies. Through one of the supplier's efforts, a meeting of the representatives of the tube manufacturers was called in January, 1945, to discuss the situation and try to formulate better methods of evaluating cathode nickel tubing. A section of Subcommittee VIII of Committee B4 of the American Society for Testing Materials, was formed for this purpose, and possibly to improve the understanding of thermionic-emission phenomena and the type of nickel used.

The intent of this paper is to report on the progress made by the so-called "Data Subsection" in co-ordinating the methods of test and interpretation of results so that an industry-wide evaluation of each melt may be made to compare with evaluations based on the use of simple and much cheaper diode structures and ultimately chemical and/or metallurgical tests on the nickel.

One of the first steps taken to reduce the factory prove-in tests to a common denominator was to establish a standard melt of cathode nickel against which all tube manufacturers would rate new melts. One of the major suppliers of cathode tubing agreed to set aside for this purpose a 200-pound portion of melt 66, which is a 220-grade nickel melt of typical composition and normal 10,000-pound size, and which had given apparently normal test results in electron tubes. This quantity of material is sufficient to last for many years for melt-approval control purposes exclusively. Sample cathodes of appropriate size from this melt are sent along with the same size cathodes from a new melt to each factory when a new melt is to be tested for approval. The prove-in factory runs are made on cathodes from the new melt and melt 66 simultaneously and under identical processing conditions.

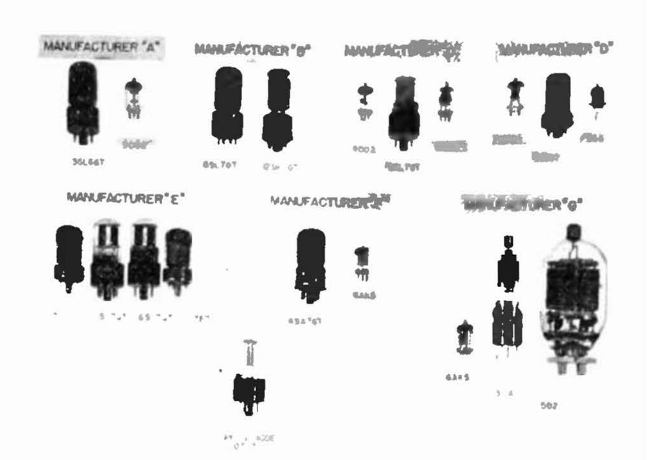

Fig. 1—Variety of electron tubes formerly used in cathode testing.

A second step in the direction of greater uniformity of test conditions was to strive to have the participating companies choose similar types of tubes for prove-in factory runs. It had been the practice to use any type of tube that happened to be in production at the time of the melt-approval test. The accompanying Fig. 1 shows the great variety of types of tubes formerly used by the industry for this purpose. Fig. 2 shows the pentodes that are currently used in these tests.

The committee found that the industry was evaluating the melts on the basis of initial shrinkage, initial tube characteristics, and life-performance tests. A study was made of the early test results in order to formulate a pattern or form that could be used by each company in reporting its test results, regardless of the parameters, for purposes of evaluation.

Factory prove-in runs of 50 to 200 tubes each are made using cathodes from the test melt and the standard melt 66. Variations in geometry and processing are

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[1] R. L. McCormack, "A standard diode for electron-tube oxide-coated cathode-core-material approval tests," Proc. I.R.E., this issue, pp. 683–687.

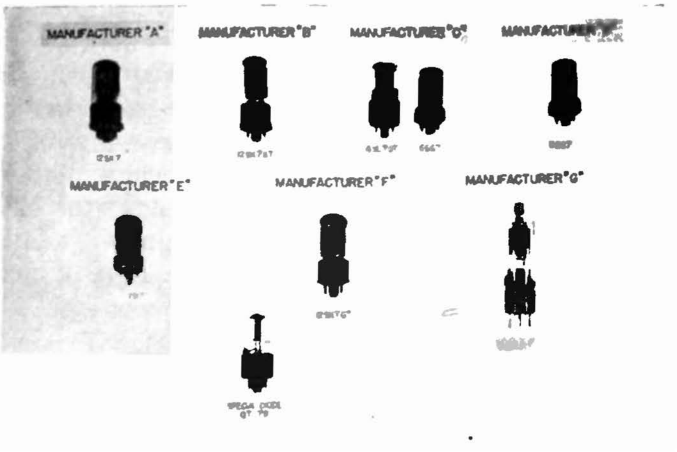
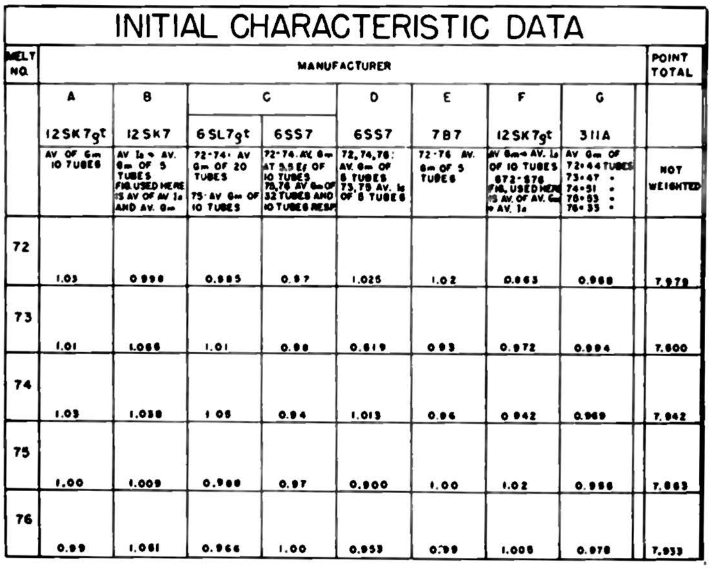


Fig. 2—Electron tubes used in recent cathode testing.

minimized by simultaneous manufacture under shop conditions. The shrinkage is counted only for causes related to the cathode. The initial tube characteristics are taken either on all of the tubes or on a representative sample of the run. Life tests are carried out for 500 hours on 5 to 10 tubes selected at random from the lots. In each category the comparison is expressed as a ratio of results for the test melt to the control melt. In order to avoid zero values in the shrinkage ratios, the per cent yield rather than the per cent shrinkage is used. It has been agreed that shrinkage and life are more important than initial characteristics, so that, in arriving at the over-all figure of merit, they are rated as twice as important. The sum of all the ratios so adjusted gives the over-all figure of merit for the industry. Figs. 3, 4, and 5 show the results obtained by eight plants, on melts 72 to 76 inclusive, when compared with melt 66. Melt 72 is a normal 220-grade melt of seamless tubing, while melts 73 to 76, inclusive, were made from a single 10,000-pound melt of nickel, half of which was poured normally with additional silicon added to the second half before pouring. Each half was split between seamless and weldrawn tubing as shown in Table I.



INITIAL CHARACTERISTIC DATA

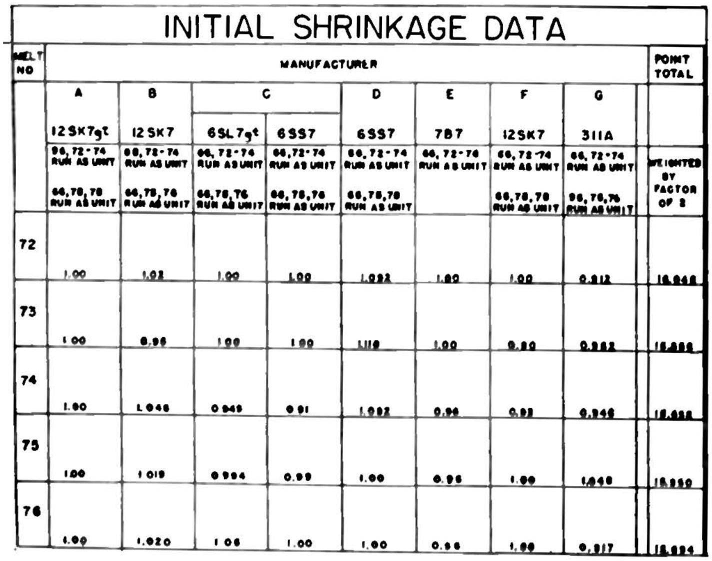
MELT NO.	MANUFACTURER								POINT TOTAL
	A	B	C		D	E	F	G	
	12SK7gt	12SK7	6SL7gt	6SS7	6SS7	7B7	12SK7gt	311A	
	AV OF G_m 10 TUBES	AV I_a + AV. G_m OF 5 TUBES FIG. USED HERE IS AV OF AV I_a AND AV. G_m	72-74: AV G_m OF 20 TUBES 75: AV G_m OF 10 TUBES	72-74. AV. G_m AT 5.5 E_f OF 10 TUBES 75,76 AV G_m OF 32 TUBES AND 10 TUBES RESP.	72,74,76: AV. G_m OF 8 TUBES 73,75 AV. I_a OF 8 TUBES	72-76 AV. G_m OF 5 TUBES	AV G_m + AV. I_a OF 10 TUBES 872-876 FIG. USED HERE IS AV. OF AV. G_m + AV. I_a	AV G_m OF 72: 44 TUBES 73: 47 " 74: 51 " 75: 53 " 76: 35 "	NOT WEIGHTED
72	1.03	0.998	0.985	0.97	1.025	1.02	0.963	0.988	7.979
73	1.01	1.066	1.01	0.98	0.819	0.93	0.972	0.994	7.800
74	1.03	1.038	1.08	0.94	1.013	0.96	0.942	0.969	7.942
75	1.00	1.009	0.988	0.97	0.900	1.00	1.02	0.988	7.883
76	0.99	1.081	0.966	1.00	0.953	0.99	1.008	0.978	7.933

Fig. 4—Factory prove-in tests on cathode nickel melts.

TABLE I

	Normal Half—0.02 per cent Si	*Special Half—0.09 per cent Si*
Seamless	Melt 73	Melt 74
Weldrawn	Melt 75	Melt 76

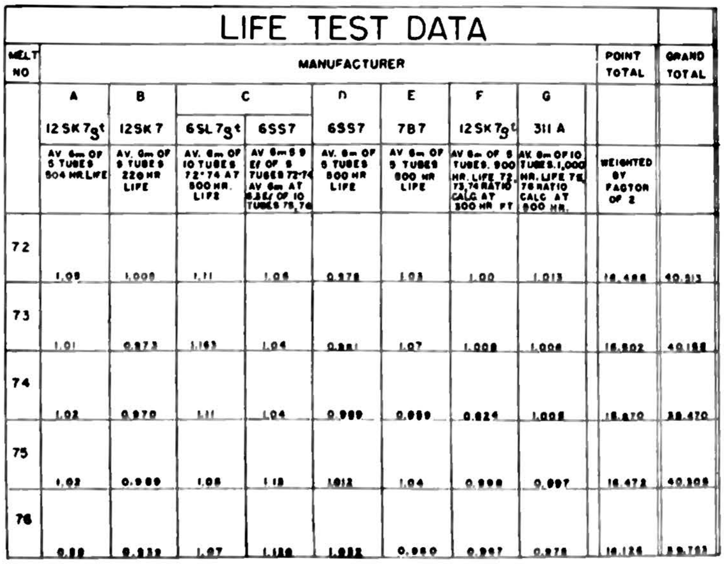
It will be noted from Fig. 5 that the over-all figure of merit would be 40 for a melt of identical test results with melt 66. The spread of these five melts is not very large—only 2.9 per cent. This is not surprising, in view of the fact that these melts are all essentially identical with the exception of the variation in silicon content.



INITIAL SHRINKAGE DATA

MELT NO	MANUFACTURER								POINT TOTAL
	A	B	C		D	E	F	G	
	12SK7gt	12SK7	6SL7gt	6SS7	6SS7	7B7	12SK7	311A	
	66, 72-74 RUN AS UNIT 66,75,76 RUN AS UNIT	66, 72-74 RUN AS UNIT 66,75,76 RUN AS UNIT	66, 72-74 RUN AS UNIT 66,75,76 RUN AS UNIT	66,72-74 RUN AS UNIT 66,75,76 RUN AS UNIT	66, 72-74 RUN AS UNIT 66,75,76 RUN AS UNIT	66, 72-76 RUN AS UNIT	66, 72-74 RUN AS UNIT 66,75,76 RUN AS UNIT	66, 72-74 RUN AS UNIT 66,75,76 RUN AS UNIT	WEIGHTED BY FACTOR OF 2
72	1.00	1.02	1.00	1.00	1.022	1.00	1.00	0.912	15.848
73	1.00	0.96	1.00	1.00	1.118	1.00	0.90	0.982	15.888
74	1.00	1.046	0.949	0.91	1.082	0.96	0.92	0.946	15.688
75	1.00	1.019	0.994	0.99	1.00	0.96	1.00	1.040	15.950
76	1.00	1.020	1.06	1.00	1.00	0.96	1.00	0.917	15.924

Fig. 3—Factory prove-in tests on cathode nickel melts.



LIFE TEST DATA

MELT NO	MANUFACTURER								POINT TOTAL	GRAND TOTAL
	A	B	C		D	E	F	G		
	12SK7gt	12SK7	6SL7gt	6SS7	6SS7	7B7	12SK7gt	311A		
	AV G_m OF 5 TUBES 504 HR. LIFE	AV. G_m OF 9 TUBES 220 HR LIFE	AV. G_m OF 10 TUBES 72-74 AT 500 HR. LIFE	AV G_m 5.9 E_f OF 9 TUBES 72-74 AV G_m AT 5.5 E_f OF 10 TUBES 75,76	AV. G_m OF 5 TUBES 500 HR LIFE	AV G_m OF 5 TUBES 500 HR LIFE	AV G_m OF 5 TUBES. 900 HR. LIFE 72, 73,74 RATIO CALC AT 500 HR FT	AV. G_m OF 10 TUBES. 1,000 HR. LIFE 75, 76 RATIO CALC AT 900 HR.	WEIGHTED BY FACTOR OF 2	
72	1.09	1.008	1.11	1.06	0.978	1.03	1.00	1.013	16.486	40.313
73	1.01	0.973	1.163	1.04	0.981	1.07	1.008	1.006	16.502	40.188
74	1.02	0.970	1.11	1.04	0.989	0.989	0.824	1.008	16.870	38.470
75	1.02	0.989	1.08	1.18	1.012	1.04	0.998	0.997	16.472	40.309
76	0.99	0.939	1.07	1.180	1.082	0.980	0.997	0.978	16.126	39.793

Fig. 5—Factory prove-in tests on cathode nickel melts.

However, the individual variations in each melt among the various companies are still very large. The shrinkage results are +11.6 per cent and −18.3 per cent from the standard, the tube characteristics vary +8.5 per cent and −18.1 per cent from the standard, and the life results are +16.3 per cent and −17.6 per cent from the standard. There still are instances, as there were formerly, before this work started, where one company gets the best results for a given melt in a particular comparison, and another company finds it poorest. The maximum variations for a given melt are of the order of 25 per cent. Despite these difficulties, the over-all figure of merit seems to give a true picture of the quality of the cathode nickel. This is substantiated by the fact that the melt which shows up to be the worst was the only one of this series rejected by more than one company.

It is recognized that the cathode sleeve is, perhaps, of secondary importance to the coating applied to the cathode and the processing of the tube. That is why it is so important to keep these and other factors constant when making cathode-nickel tests. In the course of th work it has been found also that surface contamination of the cathode sleeve may mask the effect of the base-metal composition on thermionic emission.

It is felt that this work has put melt-approval tests on at least a semiquantitative basis, and that a melt substantially different from the usual variety will show a figure of merit higher or lower by several per cent. An instruction manual for factory testing by this method is being prepared in considerable detail so that even better control of factory tests will be made in the future, and the results are expected to be more reliable.

A Method of Measurement of the Internal Series Resistance of a Capacitor Under Surge Conditions*

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Summary—**Recent application of capacitors as energy-storage devices for low-impedance loads, such as short-duration light sources and electric detonators, has emphasized the importance of examination of capacitor efficiency from this standpoint. Ballistic measurements, using a vacuum thermocouple and galvanometer, are shown to afford the desired evaluation.**

THEORY

RECENT APPLICATION of capacitors to spark photography, radar, and the firing of low-resistance electric detonators has involved their use as energy-storage devices in connection with circuits of very low impedance. Consequently, it becomes pertinent to inquire about the effectiveness of the capacitor in delivering its stored energy under these conditions.

Evaluation of the low internal series resistance in question, not readily made by the usual bridge methods, is important in application of the capacitor to some low-impedance surge circuit, as will be shown below.

The energy stored in a capacitor is

$$J = \frac{CE^2}{2}$$

where J is the work or energy in joules, C is the capacitance in farads, and E the potential in volts. It is convenient to discuss the percentage of this energy made available to the external load as a function of the load resistance and the internal series resistance of the capacitor. If we assume that the capacitor and load are represented by the simple circuit of Fig. 1, showing the capacitor

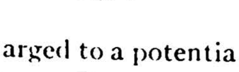

Fig. 1

of capacitance C, charged to a potential E and having an internal series resistance R_S, connected to a load resistance R_L, the expression for the energy transfer must be

$$J = \frac{CE^2}{2} = R_S \int_0^\infty i^2 dt + R_L \int_0^\infty i^2 dt. \qquad (1)$$

The first and second terms on the right-hand side of this expression represent the work converted into heat in the resistors R_S and R_L, which can be represented by J_S and J_L, respectively, so that

$$J = \tfrac{1}{2} CE^2 = J_S + J_L. \qquad (2)$$

As the energy in the series circuit divided proportionally to the resistances,

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