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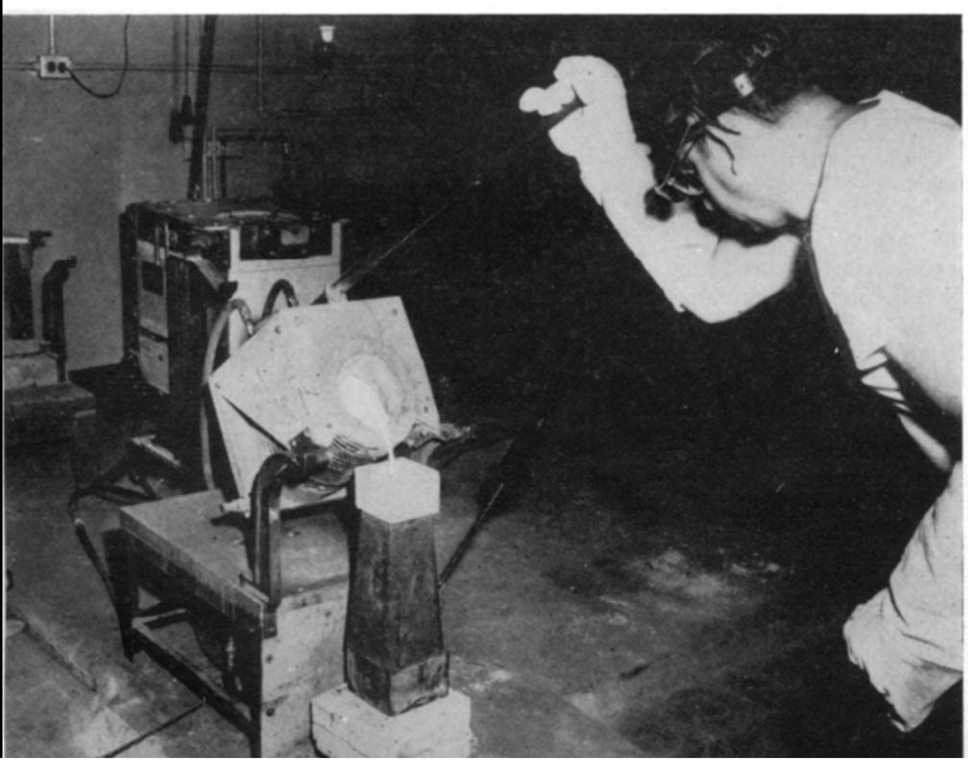
What Cathode is Best for the Job?

Types of construction available to the design engineer fall into two groupings—tubes and discs. For various applications seamless, welded and drawn, lapped-seam or locked-seam fabrication may offer certain advantages. Choice of active or passive base material will affect the hum characteristics and life of the tube.

TODAY the electron tube user has a wide assortment of materials and forms from which to select a cathode tailored to the requirements of the application. Standard cathode sleeves in 11 different materials and in four forms for receiving, power, industrial and other types of electron tubes and three different types of disc cathodes for cathode ray tube guns are available.

Indirectly heated cathodes are used in the majority of today's receiving tubes. The metal sleeves, coated with alkaline earth oxides as a source of electrons, are furnished commercially in four forms: seamless, Weldrawn (welded and drawn), Lockseam and lapseam. Three forms of another type of indirectly heated cathode—the disc cathode, with the cathode assembled in a round piece of ceramic—are supplied for cathode ray tube guns.

Fig. 1: Melts for drawing into experimental tubes are produced in this electric furnace.



Seamless cathodes are manufactured from tubing which is cold drawn from a 2-inch OD heavy-wall tube. Welded and drawn cathodes (Weldrawn) are fabricated from tubing which is cold drawn from a tube made from strip metal. The strip is rolled into a tube form, passed under a welding head to form a fusion weld, then drawn to size in the same way as seamless. The seam is undetectable except by etching and microscopic examination. Lapseam cathodes are made by simply lapping the edges of the metal strip and forming into the desired cathode configuration. Lockseam cathodes are made by mechanically locking the edges of the strip by a pressure fold.

Seamless and Weldrawn Cathodes

Seamless and Weldrawn cathodes have a more uniform cross section, weigh less and have less mass, and their weight can be more easily controlled. These can be important considerations in certain applications. Perhaps the greatest advantage of seamless and Weldrawn cathodes is the greater dimensional control possible than is the case with Lockseams and lapseams. In the latter, the metal strip is formed in a machine with no other work done on it. Because both seamless and Weldrawn cathodes are made from *tubing* which is reduced in size by drawing, the tolerance spread can be held to much closer limits. The tolerance on the OD, for example, can be held to ±0.00025-in. on cathodes with 0.030-in. OD or smaller, compared to ±0.0005 for Lockseam and lapseam.

SEAMLESS CATHODE SHAPES

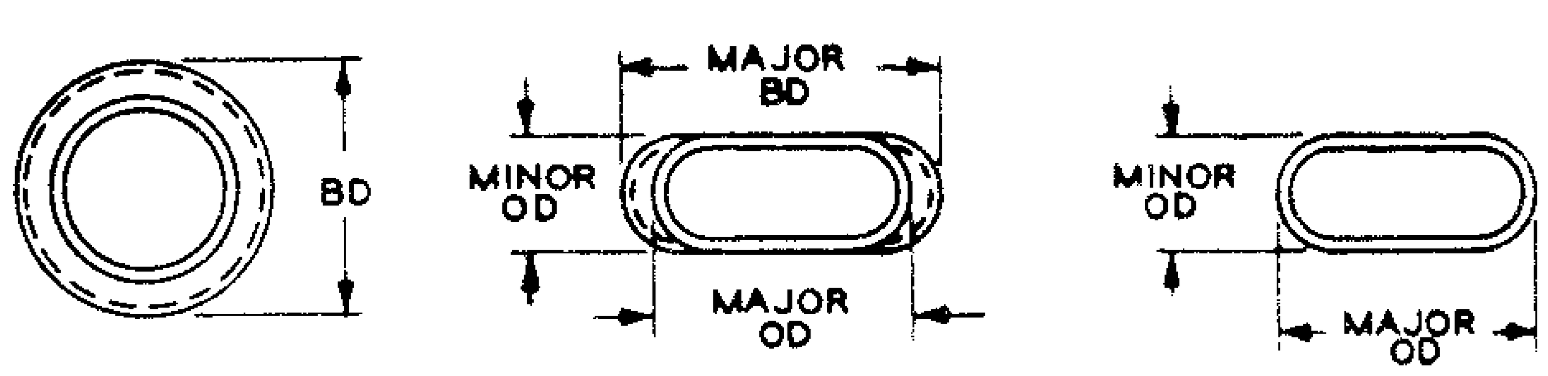
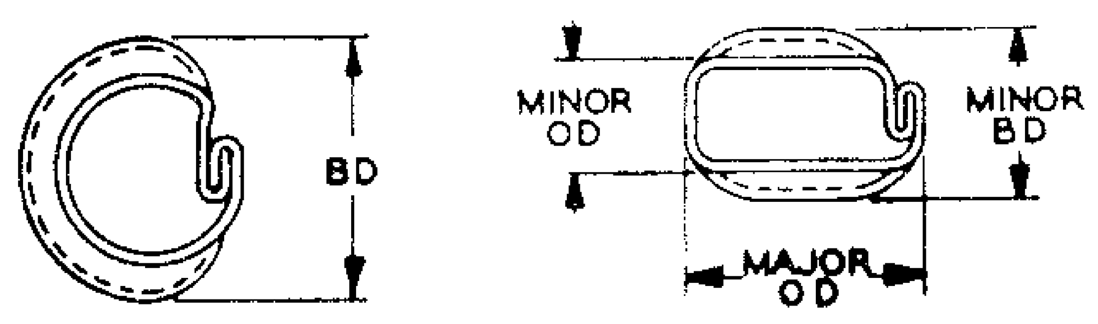
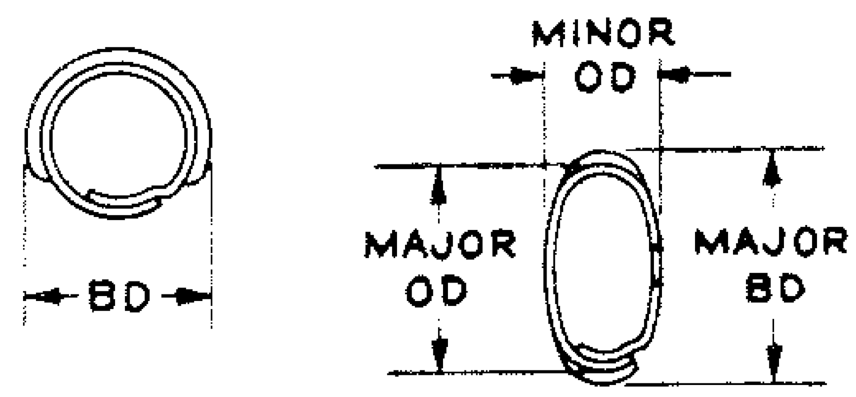


Fig. 2: Cathodes are made in 3 different forms; each has its own unique application.

LOCKSEAM CATHODE SHAPES



LAPSEAM CATHODE SHAPES



Moreover, the drawing process gives better control of wall thickness of the metal. This is extremely important in the manufacture of shaped cathodes (Fig. 2), which are formed by squeezing around a mandrel in a press. Since the size of the mandrel remains constant, any variation in wall thickness of the round tube will end up as a variation in the outside dimensions of the shaped tube.

Even closer control of wall thickness in shaped cathodes is possible with a system of weight control. This consists of weighing tubing of exactly the same length. Variations in wall thickness show up as a variation in weight.

Rectangular cathodes are used in applications which require more power for a given frequency, such as radar, underwater telephone cables and TV. The rectangular shape makes possible a uniform

Table 1. Chemical analysis of cathode materials

CATHODE NICKEL

Alloy	ASTM Grade	Form	CHEMICAL ANALYSIS Cu max. %	Fe %	Mn max. %	C max. %	Mg %	Si %	S max. %	Ti max. %	Other	Ni + Co min. %
Active CATHALOY A-30		L, W Disc*	0.05	0.10 max.	0.05	0.03/0.10	0.01/0.06	0.02 max.	0.005	0.01	Al .03/.08	99.25
CATHALOY A-31	7	L, W Disc	0.10	0.10 max.	0.05	0.03/0.10	0.01/0.06	0.02/0.06	0.005	0.02	W 3.75/4.25	94.50
CATHALOY A-32		L, W Disc	0.05	0.10 max.	0.05	0.03/0.10	0.01/0.06	0.02 max.	0.005	0.01	Al 0.03/0.08 W 2.00/2.50	96.25
Passive CATHALOY P-50	22	L, W Disc	0.04	0.05 max.	0.02	0.05	0.01 max.	0.02 max.	0.005	0.01		99.50
CATHALOY P-51		L, W Disc	0.04	0.05 max.	0.02	0.05	0.01 max.	0.02 max.	0.005	0.01	W 3.75/4.25	95.25
Active D-H 799	2	L & Disc	0.04	0.05/0.10	0.05	0.08	0.01/0.10	0.12/0.20	0.005	0.01		99.25
INCO 225	3	L, S Disc	0.20	0.20 max.	0.20	0.08	Not Specified	0.15/0.25	0.008	Not Specified		99.00
D-H 599	4	L & Disc	0.04	0.05/0.10	0.10	0.08	0.01 max.	0.15/0.25	0.005	Not Specified		99.25
D-H 399	6	L	0.04	0.05 max.	0.02	0.08	0.01 max.	0.15/0.25	0.005	Not Specified		99.25
INCO 330	10	L, W Disc.	0.15	0.20 max.	0.30	0.08	Not Specified	0.10 max.	0.008	Not Specified		99.00
INCO 220	11	L, S Disc	0.20	0.20 max.	0.20	0.08	0.01/0.10	0.01/0.05	0.008	Not Specified		99.10

Forms: L—Lockseam and Lapseam, S—Seamless, W—Weldrawn (welded and drawn), D—Disc Cathodes.

close distance of cathode wall from the grid.

Lockseam and Lapseam Cathodes

Lockseam and lapseam cathodes are formed from metal strip. The strip for Lockseam cathodes varies from 0.0021 to 0.005 in. thick. Lockseam cathodes can be furnished in all standard cathode materials; in round, oval, elliptical, rectangular and special shapes (Fig. 2), in sizes down to and including 0.040-in. OD. Smaller sizes are impractical because of the difficulty of locking the seam. They can be beaded at any location that is 0.040-in. or more from the end of the cathode and can be furnished with serrated lock, vertical rib or integral tab.

Lapseam cathodes have the advantage of providing a tighter fit in the hole of the mica. There is a small (0.0005-in. max.) opening between the overlapping surfaces, resulting in a slight spring action during processing. The tighter fit eliminates cathode vibration and thereby prevents micro-phonics. They are available in all standard cathode materials; in round, oval and elliptical shapes, and in all sizes from 0.040-in. outer diameter down to the smallest required. They can be beaded at any location that is 0.040-in. or more from the end of the cathode.

Disc Cathodes

Consisting essentially of a beaded metal tube assembled to a ceramic disc and with a metal cap welded on the top, disc cathodes derive their name from the fact that the oxide-coated emitting surface is the flat metal cap (disc) rather than the tubular sleeve.

One of the functions of the base metal in a cathode is to supply reducing agents for the activation of the oxide coating. Since only the cap in a disc cathode is coated with oxide, only it needs to have reducing elements in its composition. In disc cathodes, therefore, the caps can be made from an "active" cathode material—one that rapidly activates the oxide coating—while the metal sleeve can be of a "passive" material. This reduces sub-

Table 2. Mechanical and Physical Properties of Cathode Materials

CATHODE NICKEL

PHYSICAL PROPERTIES

Alloy	Thermal Expansion Coefficient ($x10^{-6}$ in./in./°F)	Electrical Resistivity (micro-ohms cm) 68 °F.	Electrical Resistivity (micro-ohms cm) 1000 °F.	Temperature Coefficient of Resistivity (ohm/ohm/°F.)	Density lb./in.^{3}	Special Features
Active CATHALOY A-30	8.97	9.14	26.41	0.00276	0.322	Aluminum alloy for long life.
CATHALOY A-31	8.74	16.04	24.12	0.00169	0.337	Tungsten alloy for strength.
CATHALOY A-32	Tentative 8.42	Tentative 12.78	Tentative 26.00	Tentative 0.00199	0.330	Tungsten and aluminum alloy for shock resistance and low interface impedance.
Passive CATHALOY P-50	8.69	7.65	26.55	0.00368	0.322	Very pure, for extremely long life.
CATHALOY P-51	Tentative 8.74	Tentative 16.04	Tentative 24.12	Tentative 0.00169	0.337	High strength alloy for extremely long life.
Active D-H 799	7.83			0.0025	0.321	High silicon alloy.
INCO 225					0.321	High silicon alloy.
D-H 599	7.40			0.0025	0.321	High silicon, very low magnesium alloy.
D-H 399	7.40			0.0026	0.321	High silicon, very low magnesium and manganese alloy.
INCO 330					0.321	Low silicon alloy.
INCO 220					0.321	Low silicon. Low magnesium alloy.

Forms: L—Lockseam and Lapseam, S—Seamless, W—Weldrawn (welded and drawn), D—Disc Cathodes.

limation, which results from the use of certain reducing elements.

Disc cathodes are supplied in three forms—standard, miniature and sub-miniature. They differ in the size of the shank and cap. (Fig. 3.)

The standard disc cathode is the one in widest use in cathode ray tubes of television and radar sets, electronic test instruments, computer storage tubes, and other special beam type tubes. The ceramic diameter is 0.490-in. and the cathode shank diameter 0.121-in.

A special adaption of the standard form is the narrow neck disc cathode. It has the same size cathode shank as the standard cathode but the diameter of the ceramic has been reduced about 25% to 0.365-in. This permits production of cathode ray tubes with a narrower glass neck so that the deflection angle of the cathode ray tube can be considerably increased and the length of the tube thereby shortened.

The miniature disc cathode has not only the smaller .365-in. OD ceramic but also a smaller shank. Both shank diameter and shank length have been reduced about 25%. Shank diameter is .090-in. and length of shank including cap is .220 to .280-in.

An advantage of miniature disc cathodes over standard and narrow neck types is the lower heater power required. Miniature disc cathodes can use heaters with ratings of 6.3 v-450 ma and 6.3 v-300 ma compared to 6.3 v-600 ma usually required.

For even greater savings in space and heater power, a subminiature disc cathode has been developed. It has a shank of 0.065-in.

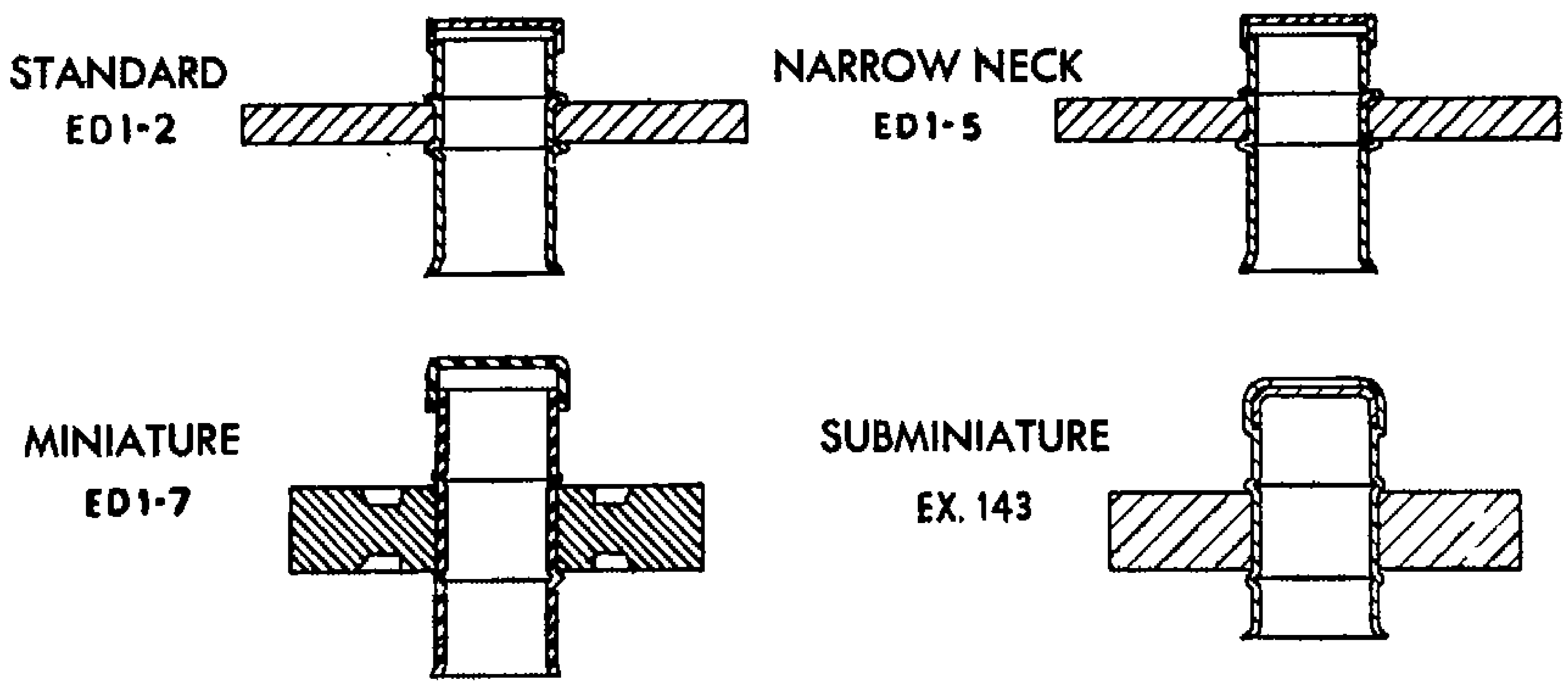


Fig. 3: Disc cathodes differ mainly in the size of shank and cap.

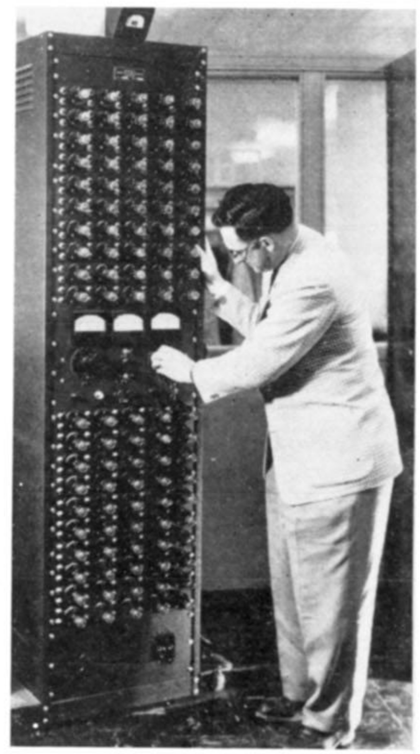
MECHANICAL PROPERTIES

Alloy	Temper	Tensile Strength (x 1000 psi)	Yield Strength (x 1000 psi) 0.2% Offset	% Elongation in 2 in.	Rockwell Hardness
Active CATHALOY A-30	1	75 max.	15/30	50/30	B 70 max.
	2	75/95	40/70	25/12	B 75/90
	3	95/120	75/110	10/4	B 90/105
CATHALOY A-31	1	85 max.	15/40	50/30	B 80 max.
	2	85/105	50/80	25/12	B 80/95
	3	105/140	85/125	10/4	B 95/C 35
CATHALOY A-32	1	85 max.	15/40	50/30	B 80 max.
	2	85/105	50/80	25/12	B 80/95
	3	105/140	85/125	10/4	B 95/C 35
Passive CATHALOY P-50	1	75 max.	15/35	50/30	B 70 max.
	2	75/95	40/70	25/12	B 70/90
	3	95/120	75/110	10/4	B 90/105
CATHALOY P-51	1	85 max.	15/40	50/30	B 80 max.
	2	85/105	50/80	25/12	B 80/95
	3	105/140	85/125	10/4	B 95/C 35
Active D-H 799	1	85 max.	15/40	50/30	B 80 max.
	2	85/105	50/80	25/12	B 80/95
	3	105/130	85/125	10/4	B 95/C 35
INCO 225	1	85 max.	15/40	50/30	B 80
	2	85/105	50/80	25/12	B 80/95
	3	105/130	85/125	10/4	B 95/C 35
D-H 599	1	85 max.	15/40	50/30	B 80 max.
	2	85/105	50/80	25/12	B 80/95
	3	105/130	85/125	10/4	B 95/C 35
D-H 399	1	85 max.	15/40	50/30	B 80 max.
	2	85/105	50/80	25/12	B 80/95
	3	105/130	85/125	10/4	B 95/C 35
INCO 330	1	75 max.	15/30	50/30	B 70 max.
	2	75/95	40/70	25/12	B 75/90
	3	95/120	75/110	10/4	B 90/105
INCO 220	1	75 max.	15/30	50/30	B 70 max.
	2	75/95	40/70	25/12	B 75/90
	3	95/120	75/110	10/4	B 90/105

Forms: L—Lockseam and Lapseam, S—Seamless, W—Weldrawn (welded and drawn), D—Disc Cathodes.

First step: Spraying the cathodes with a coat of barium-strontium-calcium-carbonate.

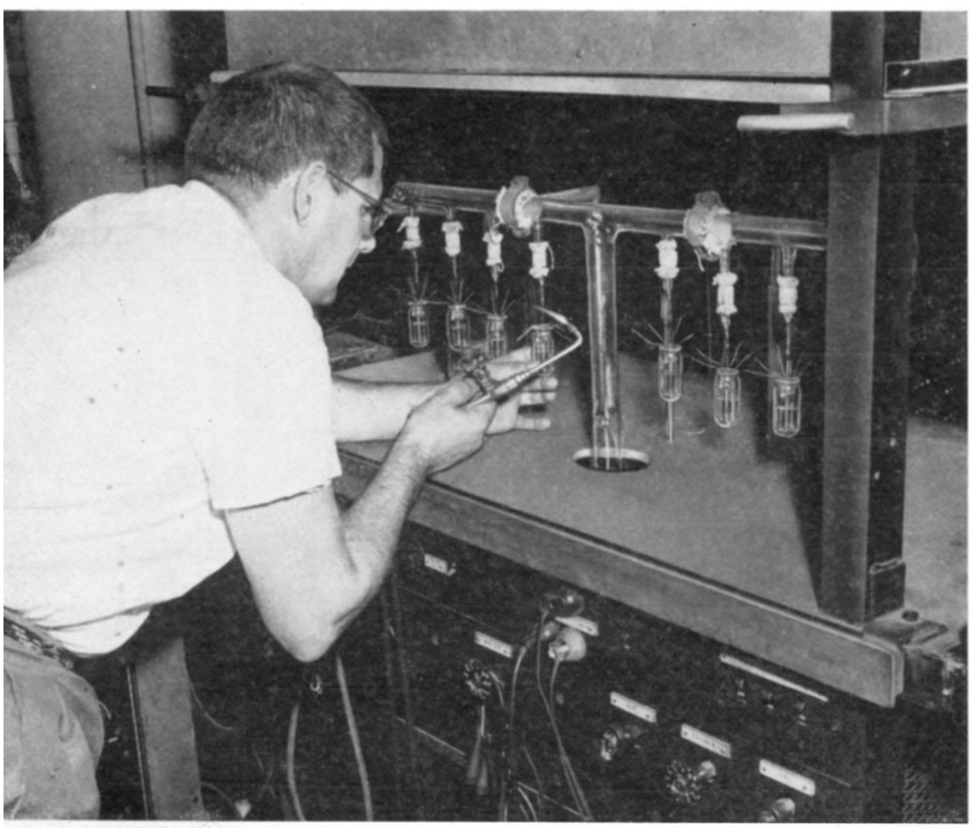
Second step: (above) Assembling the cathodes in vacuum tubes.



Tubes are tested for cathode life, rate of activation, emission level and sublimation characteristics.

Testing Cathode Materials

Third step: Close the tube, evacuate the air, and activate the cathodes.



diameter compared to 0.090-in. for the miniature cathode. Length of shank, including the cap, is 0.220-in. It can be furnished with any size ceramic.

The commercial application of the subminiature disc cathode awaits the development of a suitable small-size heater by the tube industry. When this has been done, the new cathode will help greatly to extend miniaturization in the design of electron tubes.

Both miniature and subminiature disc cathodes can also be supplied with the standard 0.490-in. ceramic for easy insertion in standard cathode ray gun structures.

In all three forms of disc cathodes, the "E" dimensions—the distance from the ceramic to the top of the emission cap—is 0.098 in. to 0.101 in. and is held to a tolerance of ±0.0005 inch.

Close control of the "E" dimension is important in order to assure uniform distance from the top of the coating to the aperture in the No. 1 cut-off grid, a cup which encloses the cathode. Uniform cut-off of electron flow from the cap through the aperture is possible only when the grid has uniform cut-off characteristics, and this in turn depends upon maintaining an exact distance from coating to aperture. Without exact control of electron cut-off, black areas in the television picture can become gray, and white areas muddied.

Cathode Materials

In sleeves for indirectly heated cathodes, the base metal serves as a mechanical support for the emitting coating, transfers heat energy to the coating, and supplies reducing agents for activation of the coating.

The base metal is almost always pure nickel or nickel with small additions of other elements. Selection of a cathode base metal, is usually a matter of compromise among various performance characteristics desired. Active cathode alloys are recommended where the greatest speed of activation is desired. Passive alloys offer low rate of barium evolution, minimum sublimation and freedom from interface impedance.

The close relation between cathode performance characteristics and the type of base metals is seen in the following (Fig. 4):

1. Rate of Activation. This is controlled to a great extent by the quantity of uncompounded reducing agents present in the nickel alloy. Some of these agents are aluminum, magnesium, silicon, titanium and carbon. Where the greatest speed of activation is desired, the use of active cathode alloys is recommended.
2. Rate of Free Barium Evolution. This depends upon the type and quantity of reducing agents present in the cathode alloy. A high rate of barium evolution is associated with active alloys. An active cathode alloy is required where high-speed tube production is paramount. A passive cathode alloy is recommended where freedom from undesired grid emission is essential.
3. Rate of Sublimation. Cathode alloys are formulated and controlled to produce the least amount of volatile metallic materials. Operating and processing temperatures and cathode design are extremely important in controlling the rate of sublimation. Magnesium is quite volatile and for this reason Mg content is carefully limited.
4. Interface Impedance. Cathode alloys not depending upon silicon for activating the coating are usually favored for VHF and pulsed applications. The impedance of the interface has been shown to be due to the resistance and capacitance effects of compounds formed by reactions of base metal reducing agents with coating materials. Silicon-nickel cathode alloys produce undesirable blocking layers in tubes operated at high frequency or under cut-off conditions. Similar effects have been observed when the bond between coating and base metal is not perfect, even though coating peel is not visible. This gives rise to reports of interface impedance even where the base metal does not contain silicon.
5. Heater-Cathode Leakage. This is of importance where unusually low hum levels are required. The passive type of cathode is beneficial for this characteristic.
6. Life. This is the most complex cathode problem of all, since it is dependent upon a great number of cathode alloy, coating and processing variables. Individual manufacturing techniques in the production of electron tubes determine the optimum choice of cathode material for this characteristic. High current density and extreme cathode temperature reduce the effective life of the cathode. Passive alloys are generally recommended for applications requiring extremely long life.

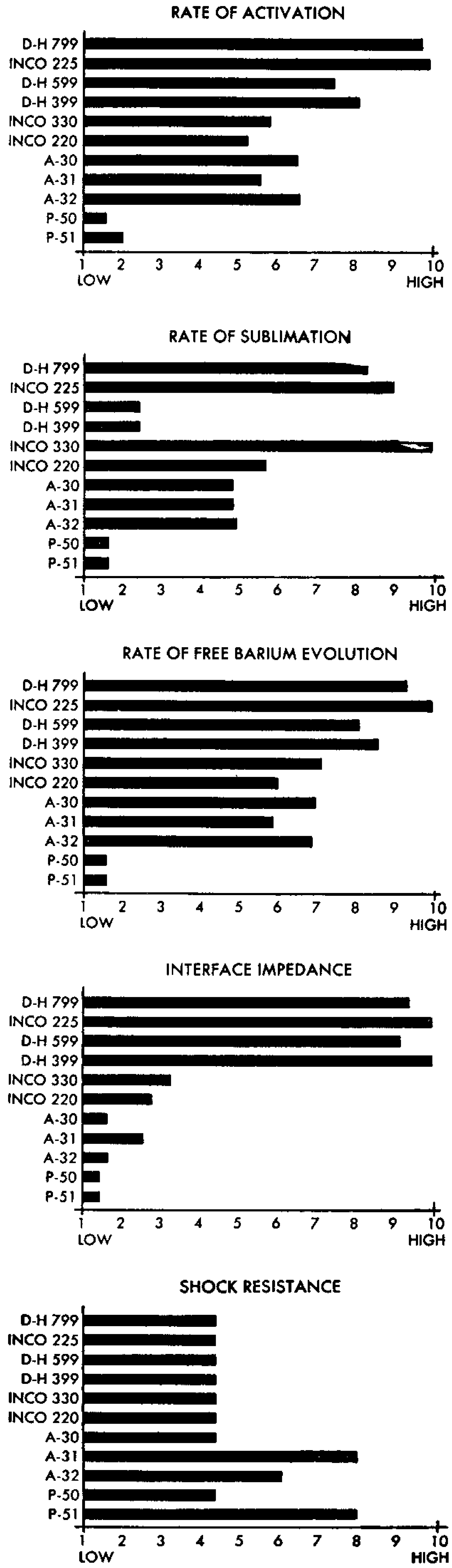


Fig. 4. Cathode characteristics have a close relationship to base materials.

The accompanying tables list the chemical analysis, mechanical and physical properties and performance characteristics of 11 cathode materials offered by Superior Tube Company. These comprise most of the materials used in cathode production today. The Cathaloy materials have been developed and trade-marked by Superior.