MACHLETT

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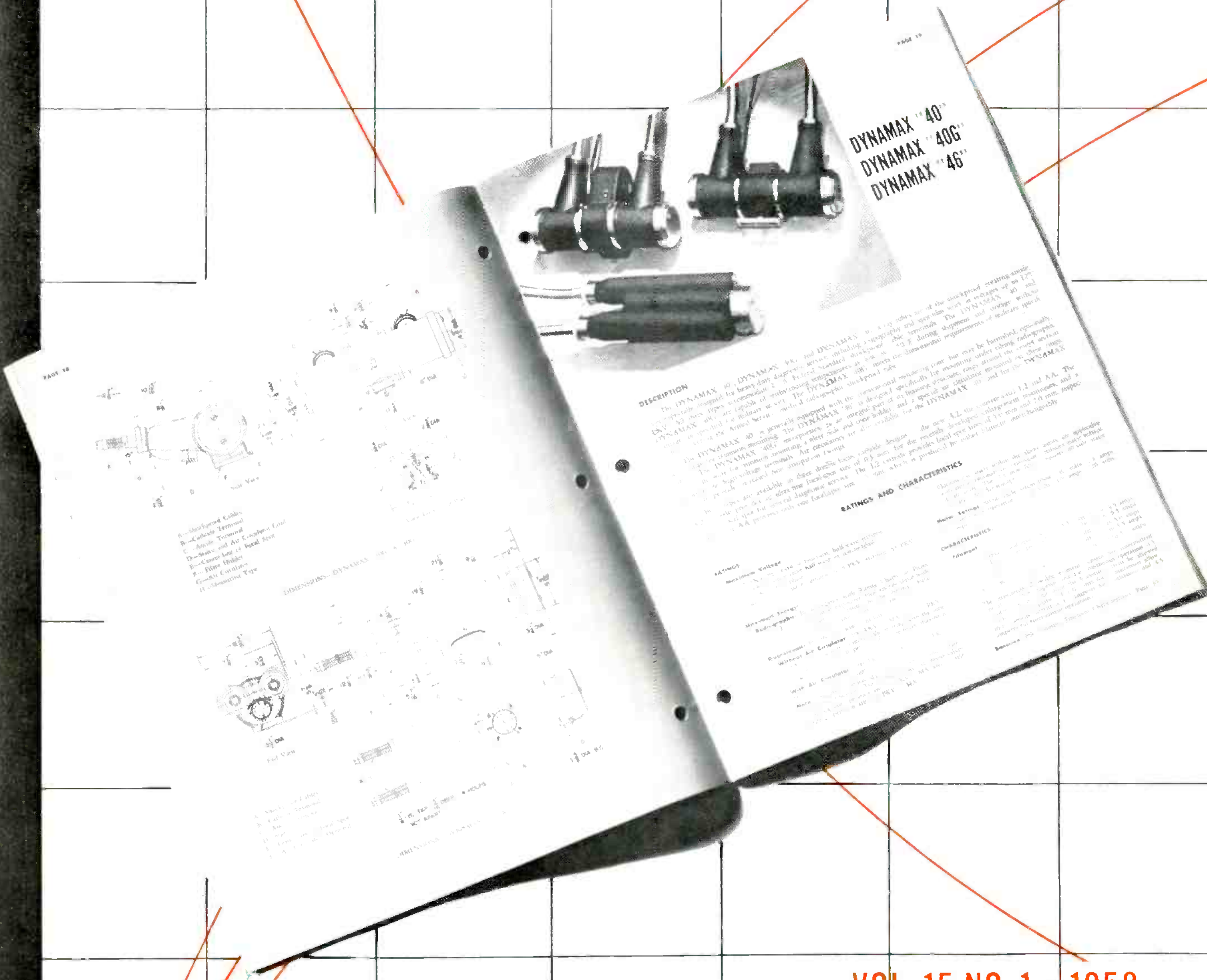


DYNAMAX "40"
DYNAMAX "40G"
DYNAMAX "46"

DESCRIPTION

RATINGS AND CHARACTERISTICS

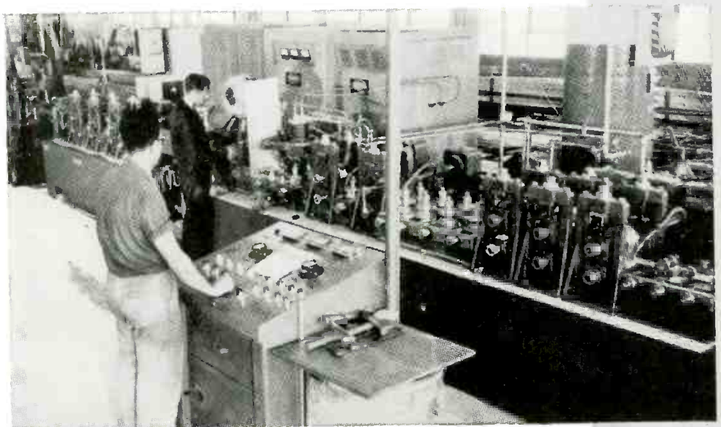
VOL. 15 NO. 1 • 1958

Aluminum Tube Welding with

MACHLETT ML-5658*

Industrial Oscillator Triodes

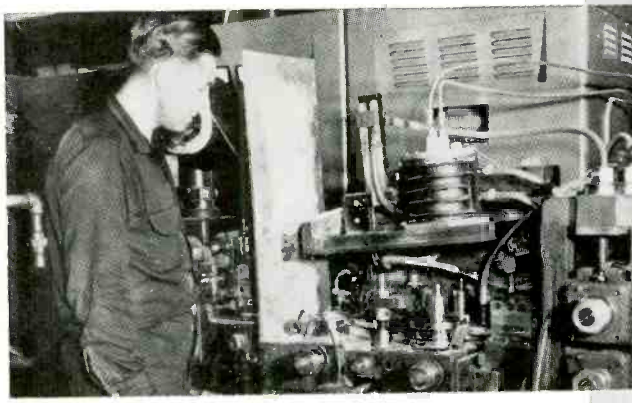
at JFD Electronics Corporation



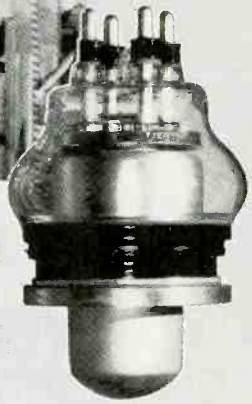
Thermatool High Frequency Resistance Welder at JFD Electronics, continuously welds round or square tubing at **300 feet per minute.**

Aluminum tubing for TV antennas and furniture is continuously welded at *300 feet per minute* at JFD Electronics with the new high frequency resistance welding Thermatool process perfected by the New Rochelle Tool Corporation. High frequency welding utilizes the "proximity effect" or tendency of high frequency current to flow in that part of the electrical circuit which is closest to the return circuit. By making the welding edge the return circuit, high current concentrations are easily achieved.

JFD reports that high strength tubing of highest quality is welded at unprecedented speeds and with great economy. Tubing is made so rapidly that it can be produced on demand. Tube inventory is no longer a problem. Overall cost savings of 25% have been realized.



Close view of electronic welding unit shows simplicity of operation. Machlett ML-5658 electron tubes provide welding power.



*Machlett ML-5658 industrial power oscillator triodes are widely used throughout the electronic industry. The ML-5658 is a heavy duty direct replacement for type 880 electron tube.

MACHLETT

FIRST IN INDUSTRIAL ELECTRON TUBES

MACHLETT LABORATORIES, INC.
Springdale, Connecticut

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IN THIS ISSUE

Cathode Press reports developments of interest to the Electronic Industry at large through its coverage of the latest advances in the design, manufacture and use of electron tubes—with specific reference to their use for x-ray, communication and industrial purposes. Particular emphasis is placed on the role of Machlett Laboratories in the development of new electron tube products, improvement in current types and in their application.

Cathode Press welcomes suggestions from its readers directed to the more effective presentation of such information to the rapidly expanding Electronics field.

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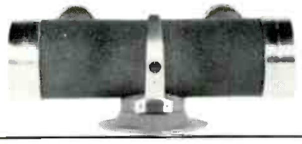
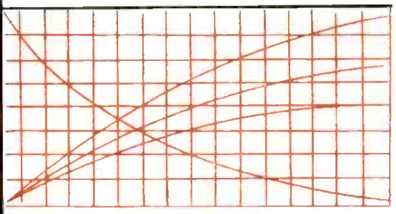
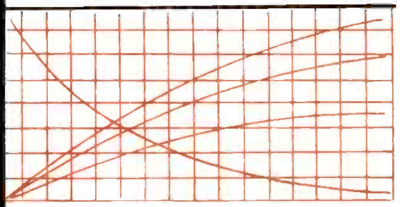
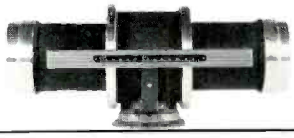
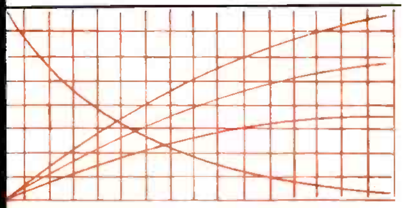
A Review of Methods used to Calculate Heat Loading of X-ray Tubes











by ***ARCHIBALD C. HALLOCK****, Manager,*
Distributor Sales & Services,
Machlett Laboratories, Incorporated

The first of a series of articles on the application of x-ray tube ratings

New and changing techniques, coupled with new developments and refinements in x-ray equipment, make the requirements that are necessary for good tube life a continually pertinent subject.

The influence of the trend to higher kilovoltages, modern efficient spot film devices, phototiming, angiocardiography, image amplification, milli-second radiography, to name a few, necessitates our re-examining closely those considerations which will insure adequate tube life. In many cases, existing tube types are adequate for these developments: however, in many other cases where an x-ray tube was adequate when sold a number of years ago, the evolution of heavier work loads and changing techniques have made the same tube inadequate for the task at hand, with resultant poorer tube life.

It is the purpose of this article to review some of the factors involved in rating x-ray tubes with the hope that a better understanding will contribute to better tube life.

Since most modern x-ray tubes are of the rotating anode type, this tube type will be used as an example. However, most of the factors considered apply to all x-ray tube types.

Any discussion of ratings must include the recommended safe operating factors for the anode, cathode, and housing assemblies. For the present we will concern ourselves with the thermal characteristics of the anode and housing.

The anode structure in the Machlett disc type rotating anode tube consists of a solid tungsten disc target, mounted on a relatively thin molybdenum stem. The stem in turn is joined to the rotor body, which is essentially the armature of a motor. The rotor body is free to rotate about a fixed member on specially coated bearings and races.

The major factors which affect this structure have to do entirely with heat and are as follows:

1. The maximum temperature that the surface of the tungsten target can tolerate, often referred to as skin temperature.
2. The maximum heat that the whole target can absorb. This is dependent upon the allowable heat input rate to the target, and its cooling rate.
3. The maximum temperature that the junction between stem and rotor body can tolerate.
4. The maximum temperature to which the bearing structure can be subjected.
5. Finally, since it is the result of target-generated heat, the maximum heat that the housing assembly can accumulate.

Since each of these factors, when exceeded, exhibits characteristic overload patterns, a better understanding of them will help make an "on the spot" determination of the cause of failure possible in many cases.

The rating chart that is published for each tube type and focal spot must be considered before attempting any individual exposure.

If we consider target mass as an ingot of lead, and a soldering iron as the source of heat, then the application of the soldering iron, even for an instant, would cause a localized melt on the surface of the lead with little or no change to the mass of lead itself. The same is true of the tungsten anode disc. Any exposure which generates excessive heat at the surface, or skin, of the disc will produce a localized melt in the focal spot area without overheating the entire disc. This can be noted by examining the disc, when possible, and will be evidenced by varying degrees of surface melt. These can vary from slightly glazed or shiny areas, to surface melt around the whole periphery of the target, or finally to the most severe condition of a deep localized melt produced with target stationary. It is to avoid such an overload that the rating chart must in all cases be given first consideration before making an exposure.

When referring to the rating chart it must be remembered that these are maximum energy limits for a single exposure.

EXAMPLE I

Desired Technique — PA chest on small focus (1.0mm) at 200ma. 95PKV and $\frac{1}{20}$ sec.

Tube Type — Machlett Dynamax "25," 1.2.

X-Ray Generator — Single phase, full wave.

Answer — The chart for the 1.0mm focal spot shows an allowable time in excess of $\frac{1}{20}$ sec. for the above factors, so the exposure is within ratings.

ARCHIBALD C. HALLOCK

Mr. Hallock attended Middlebury College in Vermont and Drexel Institute in Philadelphia. His professional interests have long been in the field of x-ray and include both sales and service for one of the foremost x-ray equipment manufacturers. Mr. Hallock joined Machlett Laboratories in June of 1956 as X-ray Field Engineer. He was appointed Manager, Distributor Sales and Services in July of 1957 which position entails responsibility for the company's renewal sales activity in all products. Mr. Hallock makes his headquarters at the company's sales office in Chicago, Illinois.

EXAMPLE II

Desired Technique — Lateral lumbar spine on small focus (1.0mm) at 100ma, 100PKV and 4 sec.

Tube Type — Machlett Dynamax "25," 1.2.

X-Ray Generator — Single phase, full wave.

Answer — The chart for 1.0mm focal spot shows an allowable time of 3 sec. for these factors; therefore such an exposure would exceed the rating and either the technique must be changed or the large focal spot must be used.

An important consideration is that amount of heat which the whole target mass can safely accumulate. This is the anode heat storage capacity which is listed for all Machlett tubes. This stored heat is defined in terms of units represented by the product of PKV x MA x seconds on single phase generators (this product must be multipled by 1.35 for three phase generators).

Again consider the mass as an ingot of lead, this time over a burner. We can add considerable heat to this lead without melting or deforming it if done slowly enough. Sufficient heat above this amount will immediately cause change in the structure of the lead. The same is true of the tungsten target mass. Any long time exposure, or more likely, a combination of exposures which generates a heat build up which exceeds the heat storage capacity of the tungsten disc will cause a change in the structure of the tungsten disc with resultant damage. An examination of this type of failure will show the disc to be heavily etched in the focal spot track with many small cracks and the appearance of a roughened area similar to the surface of a file. Often this will be severe enough to be accompanied by warping and even by cracking of the disc. This warping and cracking of the disc is a sure sign of total anode overheat and warrants an explanation. Tungsten discs are formed and react similarly to some common day plastics when subjected to excessive heat, in that the disc will try to straighten out. Since in this process the outer edge will try to achieve a larger diameter than is possible it will warp, or if the forces are great enough, will actually crack to the center.

More recently, with the increased use of high KV techniques, a side result of target damage has become a factor in tube failure to a greater degree. Any damage to any metal part in the tube, whether it is the target (most common) or other electrode parts, which causes the metal to vaporize will deposit a metal coating on the inside of the glass envelope. This coating can affect the high KV operation of the tube, mainly by the adverse effect it has on the proper establishment of wall charges on the tube envelope. In lesser degrees it will make the tube unstable at higher KV (often indicated by a slight ticking noise in the housing and instability of MA meter). In greater degrees this metallic deposit will cause puncture of the insert. This coating is rarely visible through the colored tube port, but is clearly evident when the insert is removed, and is the basis of our report that the tube failed due to puncture caused by overheating.

It is obvious that any consideration of the anode heat storage capacity must go beyond the individual exposure values obtained from the rating charts. We are here concerned with the number of individual exposures, occurring within a limited period of time, and must also consider the cooling rate of the tungsten as it applies. This information is obtained from the anode thermal characteristics chart published for all Dynamax tubes.

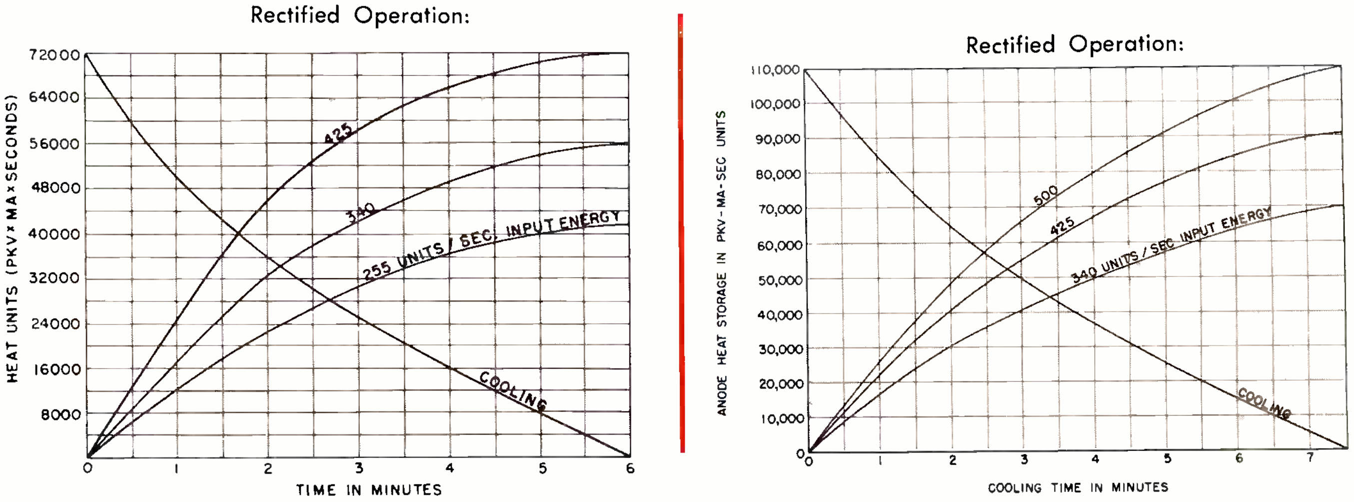


Figure 1 — Anode thermal characteristics charts for Dynamax "25" and Dynamax "40" respectively

The heat units listed represent the anode heat storage up to capacity. The cooling curve indicates the rate of cooling at any value of stored heat. The input energy curves indicate the rate at which the anode heat is accumulated at a given input rate and take into account the cooling that occurs during this period.

The following examples are based on the use of the chart.

EXAMPLE III

The interval necessary between radiographic exposures.
Tube Type — Dynamax "40," 1,2.
X-Ray Generator — Single phase, full wave.
Desired Exposures — Stereo exposures of lumbar spine both lateral and AP (total 4 exposures).
AP Factors
—80KV-100MA-4 sec. x 2   64000 heat storage units
Lateral Factors
—65KV-100MA-2 sec. x 2   26000 heat storage units

90000 units for 4 exposures

Since the Dynamax "40" has an anode heat storage capacity of 110,000 units, these exposures are within rating and permissible. However, considering the above technique for use with Dynamax "25," which has an anode heat storage capacity of 72,000 units, shows that a cooling period between exposures must be considered. This is calculated from the Dynamax "25" chart as follows: If the lateral stereo pair were taken first, then the heat stored in the anode is 64000 units. This must be reduced to 46000 units before adding 26000 units for the AP stereo pair. Consulting the anode cooling curve shows that approximately one minute between the stereo pairs will reduce the stored heat from 64000 units to 46000 units. (Note: Any retake which is taken during this period due to patient moving, uncocked bucky, failure to remove cassette, etc., must be considered as an additional exposure and has to be added to this calculation.)

EXAMPLE IV

Combined fluoroscopy and spot film.
Tube Type — Dynamax "26," 1.2.
X-Ray Generator — Single phase, full wave.
Examination — Stomach. Fluoroscopy for 5 minutes at 85KV and 4ma combined with 8 spot films at 90KV. 200ma, $\frac{1}{5}$ sec.
8 spot films at 3600 units (90x200x$\frac{1}{5}$) per exposure = 28800 units.

The input energy curve corresponding to 85KV at 4ma is the 340 unit curve, which indicates that at the end of five minutes the fluoroscopic load has contributed stored heat in the amount of 54000 units, which when added to the radiographic load makes a total of 82800 units. This is in excess of Dynamax "26" ratings. While it is true that fluoroscopy may have been done intermittently, it should still be calculated on a continuous basis so as to have safe values established. The sample above represents a routine examination and shows how readily safe factors may be exceeded. It is interesting to note here that fluoroscopy at 85KV at 5ma for five minutes with a Dynamax "26" precludes the taking of spot films (425 input curve at 5 min. = 70000 units) while the factors of 90PKV at 3ma (270 input curve at 5 min. = 44000 units) allow the 8 spot films within rating. The Dynamax "46" with its heat storage capacity of 110,000 units naturally is the more capable tube for these examinations.

TUBE TYPE	TOTAL HEAT STORAGE CAPACITY	ANODE COOLING RATE
Dynamax "20"	**500,000 units**	**15,000 units/min.**
Dynamax "25"	**1,000,000 units**	**25,000 units/min.**
Dynamax "26"		
Dynamax "30"	**1,000,000 units**	**25,000 units/min.**
Dynamax "30G"		
Dynamax "36"		
Dynamax "40"	**1,250,000 units**	**30,000 units/min.**
Dynamax "40G"		
Dynamax "46"		
Dynamax "OR40"	**1,250,000 units**	**30,000 units/min.**
Super Dynamax	**1,250,000 units**	**45,000 units/min.**
Dynamax "150"	**1,250,000 units**	**45,000 units/min.**

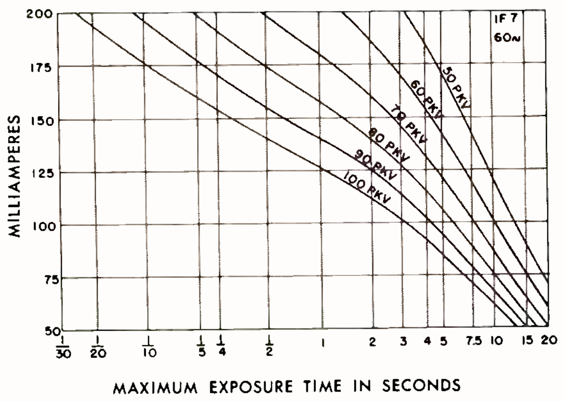
Before considering the next example, it is timely to discuss cooling that occurs during fluoroscopy. It is very important to understand that tungsten is a pure element and has an exact melting point. As far as the tungsten disc is concerned, for a given size, shape, weight, speed of rotation, focal spot area, etc., no manufacturer can claim a higher

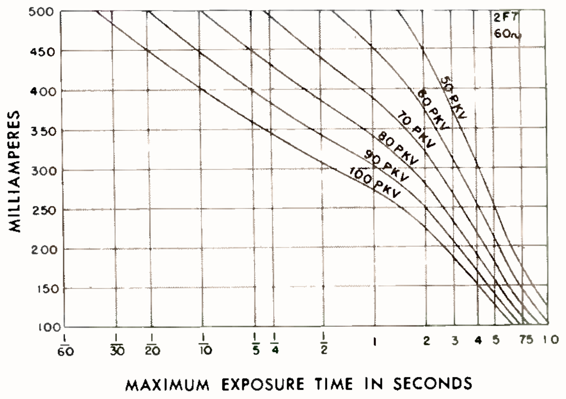
Figure 2 — Dynamax insert tubes — Dynamax "20," Dynamax "25" and Super Dynamax.

Effective Focal Spot Size—1.0 mm ▪

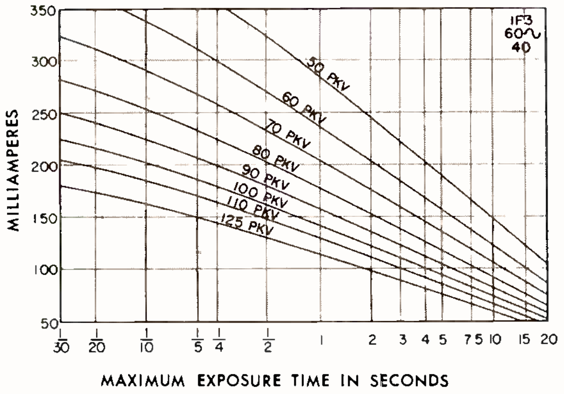
Effective Focal Spot Size—2.0 mm ■

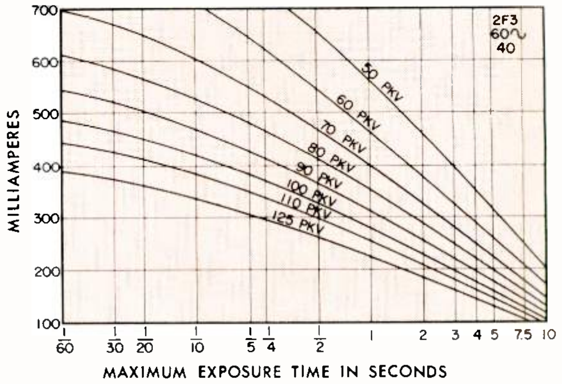
DYNAMAX "25" and DYNAMAX "26"
DYNAMAX "30", DYNAMAX "30G" and DYNAMAX "36"



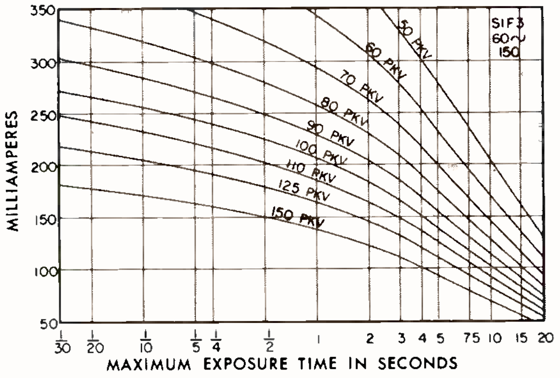


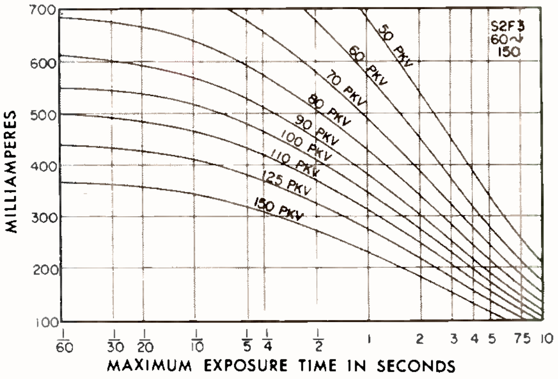
DYNAMAX "40", DYNAMAX "40G" and DYNAMAX "46"





SUPER DYNAMAX* and DYNAMAX "150"





**150 PKV curves do not apply to Super Dynamax.*

Figure 3 — Rotating anode tube rating charts for operation on single phase full-wave rectification.

loading ability than another if he applies the same safety factor. Consequently most rating charts and anode heat storage capacities are rated equally by different manufacturers. However tungsten can be treated so as to increase its emissivity or rate of heat dissipation.

This heat dissipation factor must be emphasized as it is very important in one of the most widely used techniques—that of fluoroscopy combined with spot films. Bear in mind here that the published anode thermal chart is the only accurate means of establishing the heat contribution of fluoroscopy. Multiplying KVxMAx sec. and subtracting cooling as obtained from a normal cooling curve is not accurate. Since the hotter a mass becomes the greater is its cooling rate, it follows that one would have to accurately know what part of the cooling curve to apply, and this cannot be accurately done in the field. The regular published cooling curve then becomes of maximum value to establish when the anode may be considered as a cold anode, while the anode thermal characteristic curves must be used to calculate heat build up due to fluoroscopy and this then establishes the maximum safe number of spot films that can be taken during the fluoroscopic examination. Tubes used for combination therapy and radiography must be calculated on the same basis.

EXAMPLE V

Photoroentgen factors in mass chest surveys.

Tube Type — Dynamax "25," A,A without air circulator.

X-Ray Generator — Single phase, full wave.

Average Exposure of 100PKV, 15ma, ½ sec. at a rate of 4 per minute.

The individual exposure is well within the rating of the tube rating chart. The total anode heat storage is 7500 (100x150x½) units per exposure at the rate of 4/minute = 30000 units. The maximum cooling rate or anode dissipation rate listed for a Dynamax "25" is 25000 units per minute, so these factors are not permissible at this rate. This means that the rate must be lowered to 3 per minute (3x7500 = 22500 units). There is a further consideration here of the total housing storage capacity and the use of air circulators which will be discussed later.

It is obvious from the above example why there are a large number of premature failures on mass chest equipment. Those failures occur not because the individual exposure is excessive, or again not because the total number of exposures per day are excessive, but rather because at some time during the day too many exposures were taken in too short a period.

As mentioned earlier in this article special techniques such as ciné examinations and angio work with rapid film changers are governed by special ratings. It follows that the energy in an individual exposure can be within the limits established by the tube rating chart, and that the total number of exposures be less than the heat storage capacity of the anode, but that the rate at which these exposures are made could be fast enough that the bombarded side of the target would get excessively hot because the heat generated at the surface would be greater than the heat transmission through the disc. This results again in heavy focal spot etching and melt accompanied by metallic deposit on the tube glass wall. Shown on page 8 are the angiographic rating charts for the Dynamax "40," and Super Dynamax, and similar charts are in preparation for ciné applications. The reader is referred to a former Cathode Press article* for the determination of these curves. The important considerations here, again, are to determine first that the individual exposure is within tube ratings, and then that the number per second is within the limits of the tungsten disc as per the angiographic chart.

EXAMPLE VI

Tube Type — Super Dynamax, 1.2.

X-Ray Generator — Single phase, full wave.

Technique — 500MA, 95KV, 1/20 sec., at 6 exposures per sec.

The heat units per exposure = 2375 units. At the rate of 6 exposures per second a maximum of 38 exposures could be made using the 2.0mm spot. While the rate of 2375 units per exposure would seemingly allow 10 exposures on a 1.0mm spot the individual exposure factor far exceeds its allowable rating so only the large focal spot could be used.

Of obvious importance is the maximum temperature that the bond between target stem and rotor body can withstand. In a rotating anode tube, good design makes every effort to minimize the heat transferred to the rotor structure. As a consequence the stem is very thin to act as a heat barrier, the rotor body is darkened so as to increase its heat dissipation. The bearings and races have as little contact with the rotor body as is practical. As a consequence, as much as possible, the energy converted to heat in a Machlett tungsten disc is dissipated by radiation with minimum amount conducted to the rotor body.

Another related factor which must be considered is excessive heat that is conducted to the bearings. This can have two common results. First the bearings and races can soften and deform with resultant increase in vibration and noise and diminished coasting time. Expansion can occur between races and balls in excess of allowable tolerances. This can stop the rotation with resultant destruction to the tungsten anode disc indicated by a heavy localized melt and heat storage and dissipation ratings are adjusted to insure that these temperatures remain within safe limits.

The total housing heat storage capacity rating listed for all Machlett tubes, serves a twofold purpose, first to insure an environment for the tube insert which is not too hot and thus remove the heat radiated from the disc, and second to maintain a housing temperature that is consistent with the

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*Cooke, H. S. "Rotating Anode Tube Ratings for Unusual Applications." Cathode Press, Winter 1951-52.

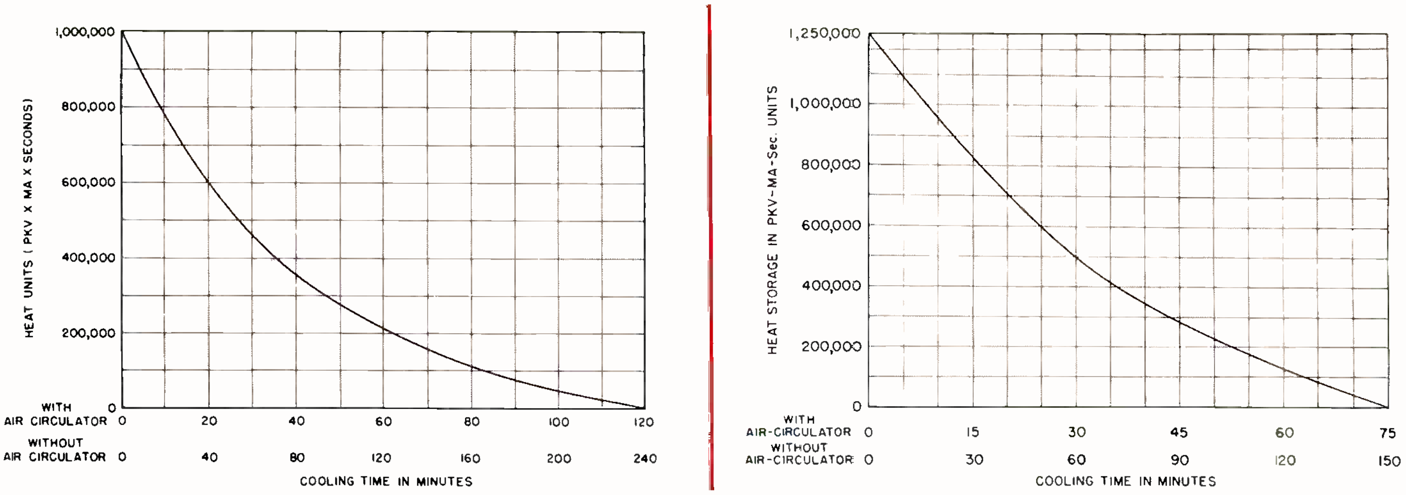
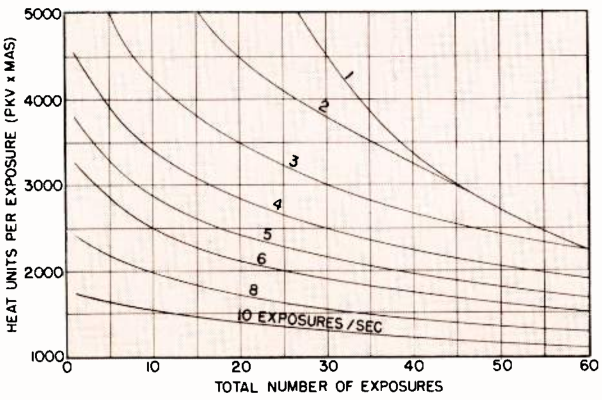


Figure 4 — (Top) Housing cooling charts for Dynamax "25" and Dynamax "40" — (Bottom) Angiographic rating charts for Dynamax "40" and Super Dynamax tubes.

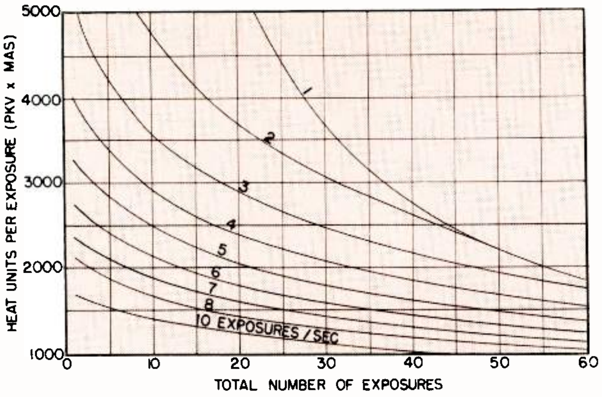
Ratings For Operation On Full-Wave Rectification:
SINGLE PHASE

Effective Focal Spot Size—1.0 mm ▪

SUPER DYNAMAX

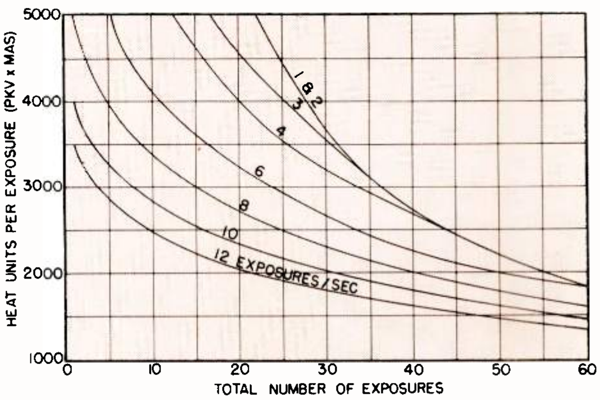


DYNAMAX "40"

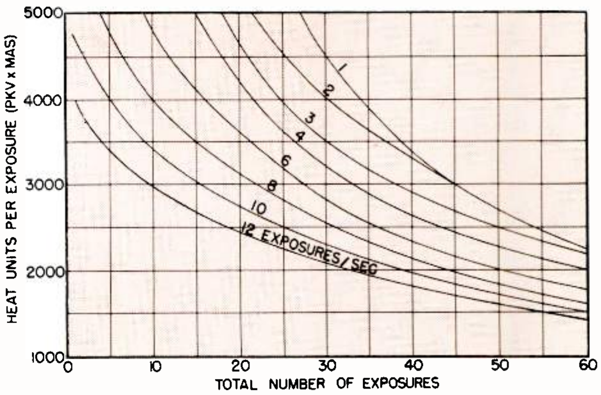


Effective Focal Spot Size—2.0 mm ■

DYNAMAX "40"



SUPER DYNAMAX



allowable temperatures and expansion that the housing parts can tolerate. The plastic port, for instance, must be kept below a temperature at which it will deform. The cable socket insulators must not exceed a temperature consistent with good dielectric strength. Finally temperatures must be consistent with bellows expansion and metal expansion so as to prevent oil leaks. The housing heat storage capacity is based on a maximum allowable housing temperature near 200°F, so it is obvious that feeling a tube housing is no criterion of how near it has approached capacity, but rather that heat storage capacity is a factor which must be calculated.

One more subject must be touched on here and this is the matter of effectiveness of the use of an air circulator. Since the main factor to be considered is the anode dissipation rate of the target, a blower is effective only when the anode dissipation rate of a tube is greater than the housing rate. This means then that an air circulator which increases the housing cooling rate so that it is equal to the anode cooling rate does as much cooling as is possible. No increase in the size of the air circulator will gain anything in tube rating. A secondary advantage of an air circulator is to provide a better ambient temperature in an enclosed table where the air can stagnate.

Caution should be used in recommending an air circulator as definite responsibilities are incurred. First is it not a cure-all; as pointed out above, it can only increase the rating to that of the anode dissipation rate and this must be considered on a long time basis as considerable time elapses before the anode can dissipate its heat to the housing. Second, and very important, is the necessity of servicing the air circulator to insure its operating at peak efficiency. Under table air circulators in particular can become clogged with lint and dirt, and air circulators of the type which push air through a duct or shroud around the tube when clogged actually decrease the original efficiency of the housing cooling rate. This may be considered to have the same effect as wrapping a blanket around the tube which would reduce the cooling rate. So it becomes very important that air circulators have periodic cleaning.

EXAMPLE VII

> Using the heat storage capacity as shown in the housing cooling chart let us consider further the example used in #5. Here we determined 3 exposures per minute at an average exposure of 100PKV, 150MA, and ½ sec. (or 3x7500 units = 22500 units) were permissible since this was less than the maximum cooling rate of the anode (25000 units) per minute. However, in this example at the end of 45 minutes (1000000 ÷ 22500) a total housing heat storage in excess of 1,000,000 units would be reached. Since a Dynamax "25" without an air circulator has a maximum housing cooling rate of 12500 units per minute the rate of heat input would then have to be reduced so as not to exceed these 12500 units per minute or to 3 exposures every two minutes.
>
> The addition of the air circulator would increase the housing cooling rate to 25000 units per minute which would then be equal to the anode cooling rate and then the 3 exposures per minute could be safely maintained.

It is our hope that the foregoing explanations coupled with close examination of tube failures at the scene in the future will help in diagnosing some of the common overload failures which give shortened tube life.

This discussion has pointed out the factors that must be considered in determining the loading capacity of the tungsten disc. On the basis of this knowledge we would like to point out a specific case where present day techniques are requiring a more adequate tube type. The Dynamax "26" has for the past several years been the standard of the profession as a combination fluoroscopic-radiographic tube. During this period we have seen the emphasis on spot film diagnosis change from one or two films to an average of eight or more for a routine stomach examination. This is a direct result of the many fine improvements made in spot film devices, tables, grids, and control circuitry such as phototiming. This change has put demands on the Dynamax "26" which are borderline in some cases, and, which in others, are beyond the capacity of the tube. The result produces some premature failures due to the anode storage capacity being exceeded. Returned tubes show damaged targets, heavy metallic deposit, warped and cracked targets, and wobbly stems in these cases.

Any premature failure of this class of tube should call attention to the fact that this tube should be replaced with the more adequate Dynamax "46." Machlett Laboratories in line with its policy of protecting the customers investment gives full allowance for the Dynamax "26" housing when replacing it with a Dynamax "46."

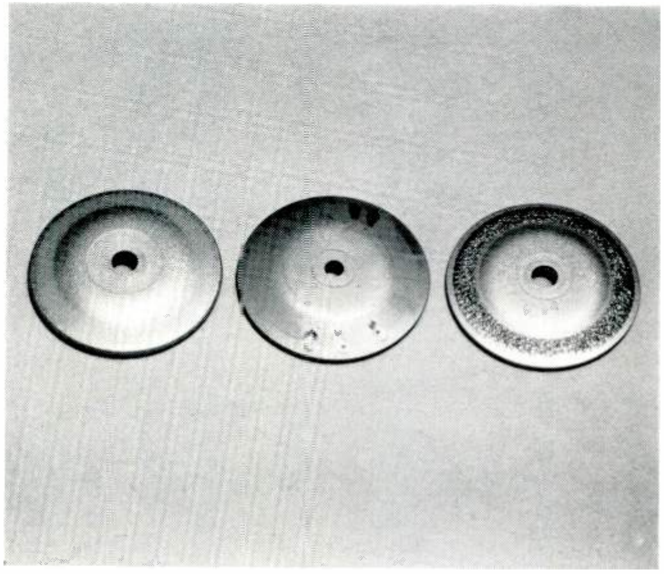
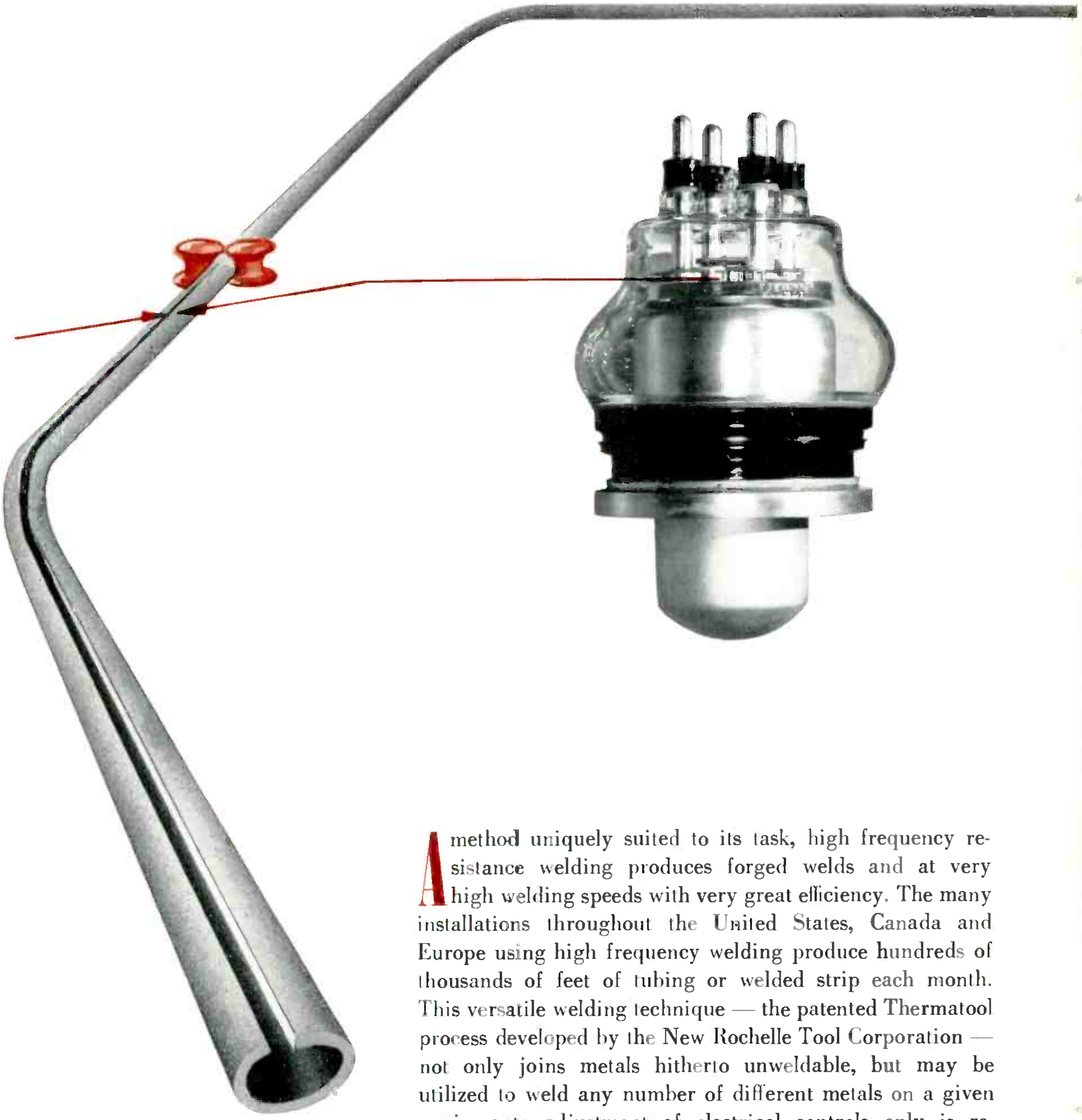


Figure 5 — Targets removed from rotating anode tubes after use. (Left to right) Appearance of target when used within ratings — melting of tungsten by exposures on stationary target — focal track damaged by excessive loads.

High Frequency Resistance Welding



A method uniquely suited to its task, high frequency resistance welding produces forged welds and at very high welding speeds with very great efficiency. The many installations throughout the United States, Canada and Europe using high frequency welding produce hundreds of thousands of feet of tubing or welded strip each month. This versatile welding technique — the patented Thermatool process developed by the New Rochelle Tool Corporation — not only joins metals hitherto unweldable, but may be utilized to weld any number of different metals on a given equipment; adjustment of electrical controls only is required for a shift from one metal type and thickness to another. This aspect of the process is particularly attractive to the user inasmuch as it reduces the capitalization costs, since one mill can do many different tasks.

Electrical contact at high frequency is significantly different from contact at low frequency. Basically, the "contact" isn't a contact at all; it is, partly, a capacitive coupling with the oxide coating on the metal, which acts as a dielectric. In low frequency resistance welding oxides form a high resistance barrier which must be broken down (by cleaning and high pressure) for current flow and heating. The ramifications of this difference are many and important; in the

— with High Power Electron Tubes

by R. N. ROSE, Machlett Laboratories, Incorporated

following table these two welding techniques are explored and compared.

	High Frequency Resistance Welding 450,000 cps.	Conventional Low Frequency Resistance Welding 60 to 360 cps.
Heat Concentration at Weld	HIGH	LOW
Power Required for Weld	MEDIUM	HIGH
Method of Introducing Current to Workpiece	Watercooled, sliding or rolling contacts. (Low amperage at high frequency has no sparking.)	High pressure electrode rolls.
Heating Characteristics		
Current Magnitude	200 to 5000 amperes.	15,000 to 250,000 amperes.
I^2R	High R results from surface flow of HF current; value of I is reduced drastically for a given power.	Low R, depends on metal and contact resistance; value of I is proportionately high.
Effect of Type of Heat	"Skin" heating of high intensity; minimum metal heated; efficient use of power.	Wide metal heating; inefficient use of power.
Direction of Current Flow	Parallel to axis of weld, heats surfaces prior to weld; independent of surface condition of metal.	Perpendicular to weld. Makes weld a function of current, surface condition, interface pressure, and contact resistance.
Concentration of Current and Depth of Current	A. Ferrous Metals. Below Curie Point — depth of current is 0.003″ to 0.004″. Above Curie Point (above 1300°F)—resistance also rises because of temperature of metal; since the metal is no longer magnetic, penetration increases, up to 0.03″. As current flow approaches the actual welding point, it is increasingly affected by the return flow in the opposite conductor. Depth of penetration decreases, bringing maximum heat to the surface at the weld point.	A. Ferrous Metals. No particular concentration is involved at any temperature.
	B. Non-Ferrous Metals. Depth of current depends on resistivity of the metal. Heating depth decreases, intensity increases, toward the weld point due to increased resistance because of heat and the effect of the current flowing in the opposite side of the tube.	B. Non-Ferrous Metals. Not done.

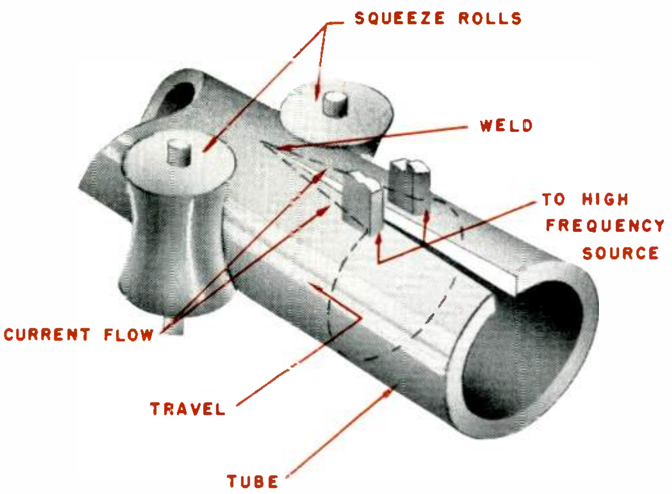


Figure 1 — High frequency resistance tube welding.
(Courtesy New Rochelle Tool Corp.)

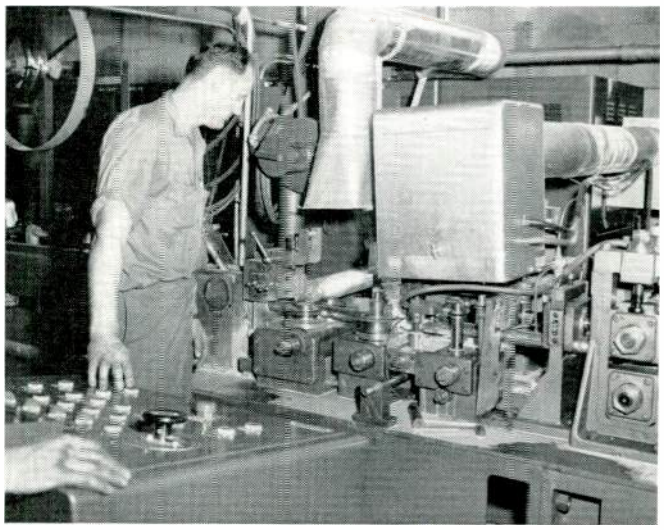


Figure 2 — Closeup of Thermatool equipment welding galvanized steel.
(Courtesy James Steel & Tube Co.)

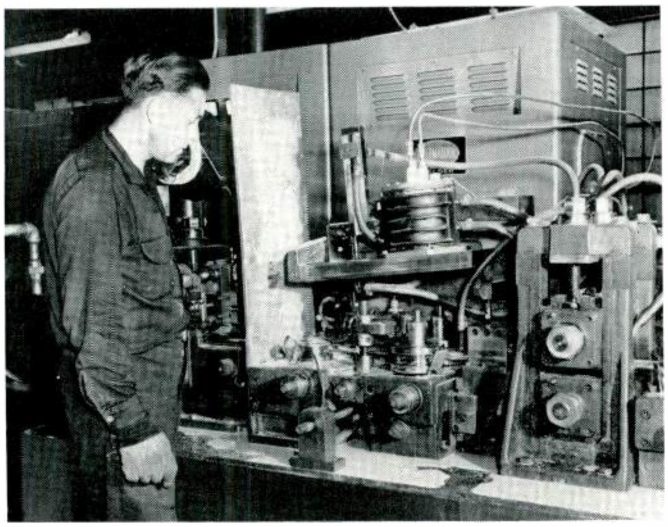


Figure 3 — Closeup of Thermatool head welding aluminum tubing.
(Courtesy JFD Electronics Corp.)

General Considerations

Condition of Outer Metal at Welding Zone

Oxide coating not objectionable for operation of circuit: it forms dielectric for capacitive coupling of contact to load.	Oxides must be removed prior to operation; heavy scales must be blasted and cleaned off.

Life of Contact

200,000 to 400,000 feet on Aluminum or similar tubing. 50,000 to 100,000 feet on Steel.	Electrode rolls refaced every 30,000 to 70,000 feet.

Diameter of Workpiece

Any diameter tubing. On small tubing (⅜″ to ½″) additional elements are used to concentrate heat at weld.	Normally down to ⅜″ tube.

Wall Thickness of Tubing

A. Thin wall tubing. Low pressure contacts permit welding of materials having wall thickness as small as 0.004″.	A. High pressure of electrode rolls prevents use on thin tubing.
B. Heavy wall tubing. With use of pre-heating device to bring weld area to 1000°F, metals of ⅜″ to ½″ wall thickness may be welded. ¼″ thick metals may be welded without pre-heating.	B. Heavy wall tubing can be welded.

Speed of Weld

TYPICAL RATES

	OD	Wall Thick.	Rate	OD	Wall Thick.	Rate
Aluminum	1″	0.049	300 fpm	1″	0.049	Cannot Weld
Aluminum	6″	0.062	113 fpm	6″	0.062	Cannot Weld
Copper	1″	0.049	150 fpm	1″	0.049	Cannot Weld
Mild Rolled Steel	⅜″	0.028	300 fpm	⅜″	0.028	200 fpm
Hot Rolled Scaled Steel	6⅝″	0.160	30 fpm	Cannot be welded as such.		

Type of Weld

"Forged" weld. Two surfaces joined, under pressure, when plastic. Butt weld or lap weld.	Forged weld — normally butt only.

Upset

Can be controlled in amount and position. Upset can be directed, for instance to exterior of tube to minimize need of internal scarfing.	Depends on roll pressure alone. Can be positioned to limited extent.

Strip Welding

Butt or lap welding of strips is possible.	Not normally used on strip.

Dissimilar Strip Welding

Reactance devices change current flow on one side and therefore temperature of weld point. Permits expensive high speed steel to be bonded to inexpensive carbon steel.	Not normally practical.

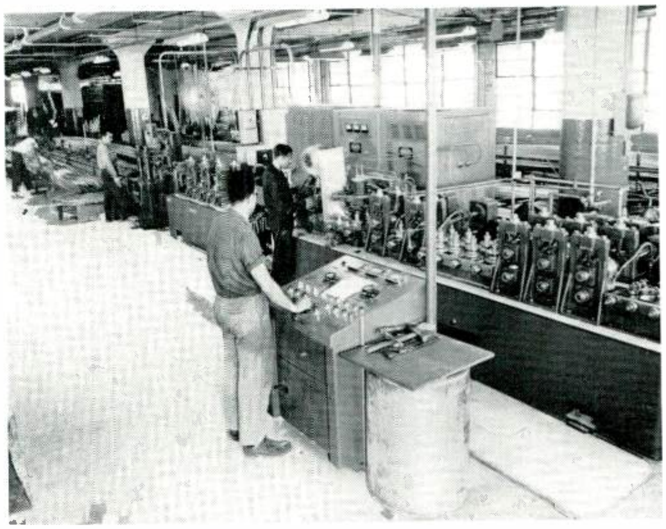


Figure 4 — Complete tube mill with Thermatool high frequency resistance welder.
(Courtesy JFD Electronics Corp.)

Typical Metals

Aluminum

Very rapidly welded. Heat localization excellent despite good conductivity and low resistance of aluminum.	Not practical.

Steel

Many applications of H.F. resistance welding, which works on nearly all metals including hot rolled steel with scale. No internal spatter is produced.	Conventional means are used. Requires cleaning of metal. Subject to weld variations resulting from segregation in metal and thickness differences.

Copper

Very rapidly welded. Heat localization excellent. 100% conductivity copper can be welded by this method. Uniform grain of weld shows no differentiation from parent metal in most coppers.	Not practical.

Brass

Very rapidly welded. Heat localization excellent.	Not practical.

Zirconium

Very rapidly welded by H.F. resistance. With argon atmosphere — good corrosion resistance of joints.	Not practical.

Other Metals

Many metals may be welded by H.F. resistance techniques. These metals include: Bronze, Silicon Bronze, German Silver and Incoloy, etc.	Normally not practical.

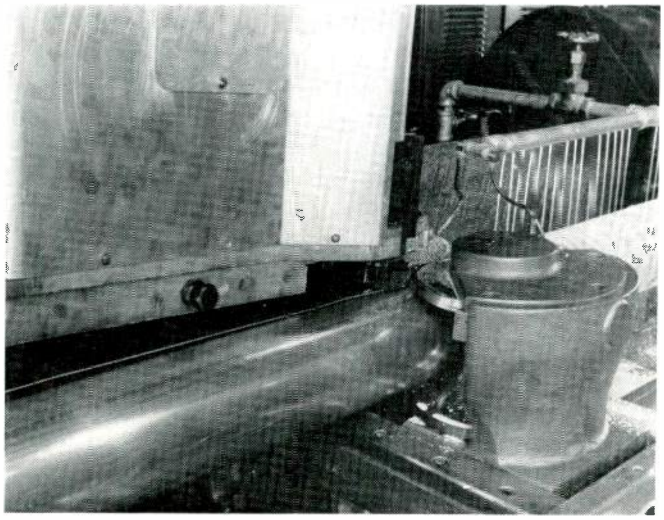


Figure 5 — Closeup of welding contacts and squeeze rolls on large diameter irrigation tubing.
(Courtesy Aluminum Co. of Canada)

Power for New Rochelle Tool Company's high frequency resistance installations is supplied by oscillators using Machlett ML-5658's. Each oscillator is basically the same as those long used by them for their induction and dielectric heaters. However, resistance welding requires a ripple free output (not necessary in the other types of heating) and this is obtained by the addition of a filter in the plate supply.

The ML-5658 heavy duty triode is designed to withstand the mechanical and electrical rigors of industrial usage. Particularly noteworthy in its design is the stress-free filament and the construction which permits an r-f final seal-in. The stress-free filament consists of parallel tungsten wires connected at the base by a simple weld. No extraneous supports, springs or other devices are required to keep the strands in position. Filament wire processing, which includes prestretching at high temperature, assures proper filament

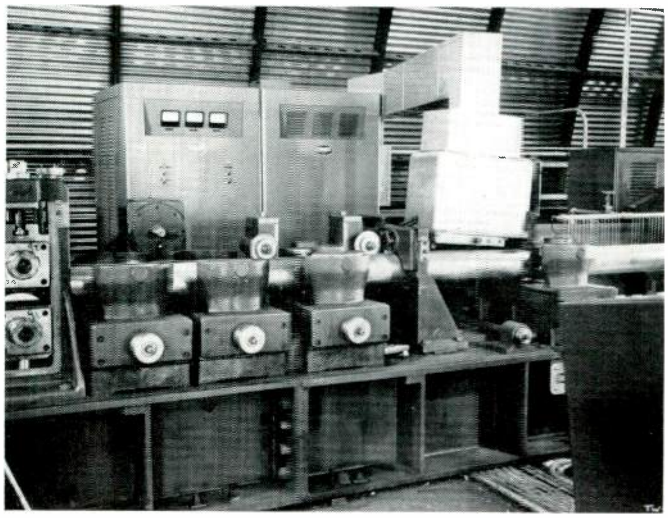


Figure 6 — Center section of tube mill with Thermatool high frequency generator and welding head.
(Courtesy Aluminum Co. of Canada)

stability. The final seal-in of the tube is made, metal-to metal, under a protective atmosphere, using r-f heat. The seal-in, which takes only a few seconds, leaves no residual stress in the glass envelope and causes virtually no heating of the internal components. As a result the tube is sturdy and possessed of a vacuum which will stay "hard" under rigorous industrial conditions.

The ML-5658 anode permits the use of the water saving helix in the water jacket. Water savings of approximately 30% at 20kw dissipation and over 40% at 10kw dissipation are realized through the use of this helix. Such a device cannot be used with thin wall tubes because hot spotting and scaling result.

To the many contributions made by high power electronics to industry High Frequency Resistance Welding makes a valuable addition. As automated production becomes more widely used, the rapid, highly controllable processes permitted by electronic equipments will become increasingly important. It may well be that the typical tube mill of the future, its production schedules programmed by tape, its processes controlled by electronic instruments, will employ only electronic high frequency power for its tube welding equipments.

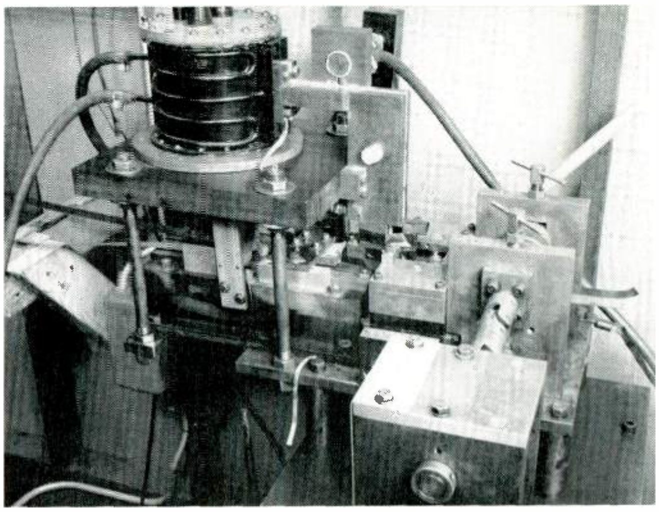


Figure 7 — Continuous strip welding showing two different steels in process of being welded together at discharge side of mill.
(Courtesy New Rochelle Tool Corp.)

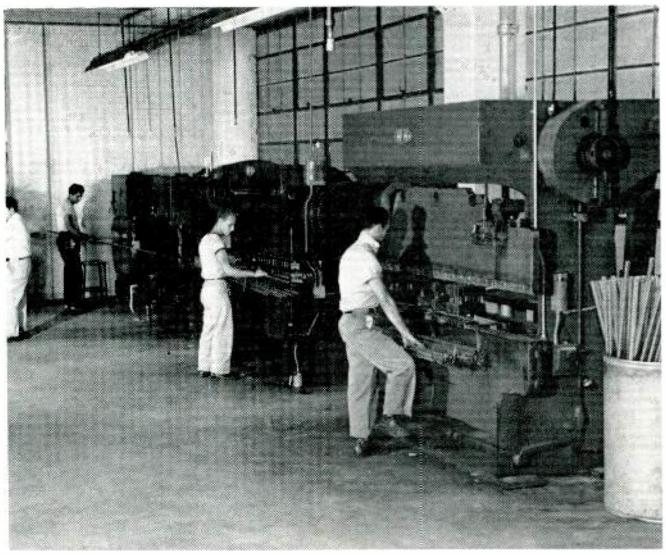


Figure 8—Production operation on high frequency welded tubing.
(Courtesy JFD Electronics Corp.)

Figure 9—Only one of the many end products of high frequency resistance welded aluminum tubing.
(Courtesy JFD Electronics Corp.)

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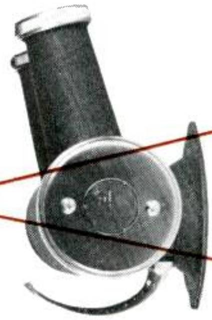

Optimum
Projections
with
0.3 MM
Focus

Optimum Projections with 0.3 MM Focus

by OLLIE J. SPARKS, R.T.A.R.X.T.
X-Ray Department
Good Samaritan Hospital
Lexington, Ky.

This paper will deal entirely with the evolution of a practical technique to take fuller advantage of a particular equipment refinement. It is the radiographic tube with an effective focal spot of 0.3 mm. When motion can be strictly stopped, it has sufficient capacity to do a wide range of useful work. While of finite size, the effective focal spot is small enough to allow considerable direct magnification without loss of detail. The majority of reports dealing with this fractional focus tube have been favorable enough to regard it as a valuable accessory to any department with more than one general radiographic unit[1,2,3].

In our department, we have a specially designed mobile table, a picture of which is shown in Figure 1. Originally, this was a war surplus portable radiographic table. It has a micarta top, similar to many other x-ray tables. The legs have been braced to improve structural strength. They have been equipped with rubber casters and on the side of the brace, there are threaded bolts with a crank to lower them to the floor to anchor the table.

To assure precise centering of film and focal spot, a cassette holder has been designed and is seen in all photographic illustrations. This device is detachable and has a total weight of nine pounds. It has a maximum adjustable length of 16 inches, thus permitting a variation of target film distance from 60 to 44 inches. The design is such that the film is always centered to the beam. In practice, the tube is angled the desired degree and the cassette

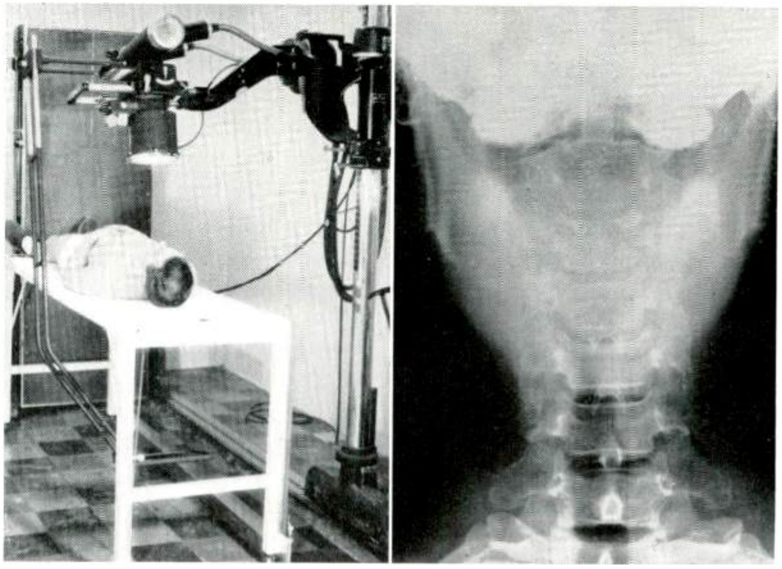

Figure 1

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[1] Lofstrom, James E., Warren, Clark R.: Magnification Techniques in Radiography, The X-ray Technician, 26:161-165 (Nov.) 1954.

[2] Wood, E. H.: Preliminary Observations Regarding the Value of a Very Fine Focus Tube in Radiologic Diagnosis, Radiology, 61:382-390 (Sept.) 1953.

[3] Stevenson, W. E.: The Value of an Ultra-Fine Focal Spot in Radiology, Cathode Press, (Spring) 9:16-17, 1952.

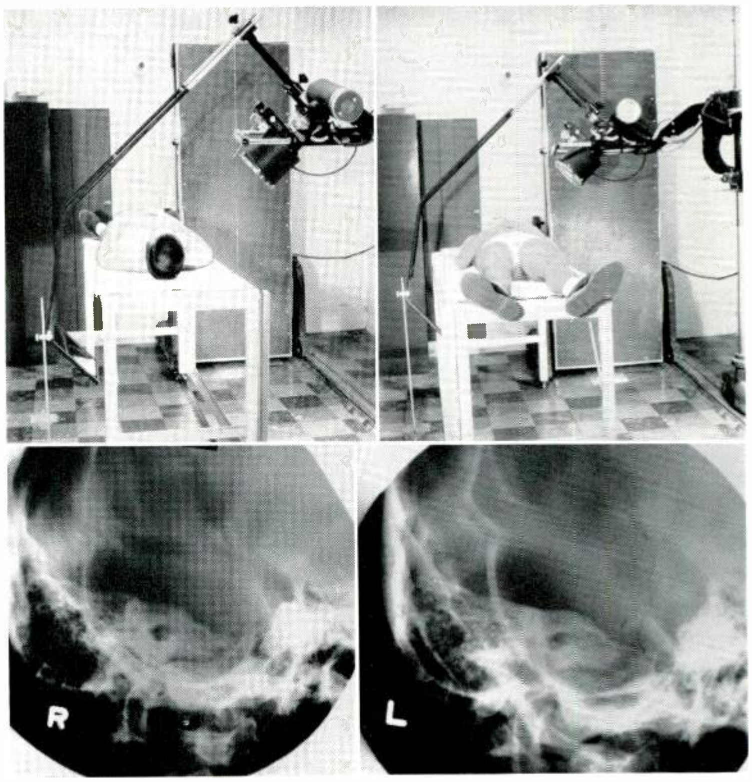

Figure 2

holder is then stabilized by resting its weight on an aluminum tube, which slides in a pivot pin arrangement that can be manually tightened at the desired height.

We use a cone of the type with a light built inside to show the size and center of the area we are to radiograph. Our regular table in that particular room is capable of being rolled on a track a short distance. By tilting it upright, sufficient floor space is gained for the magnification table to be rolled into the room and fastened in place. These adaptions were made, of course, to save time to assure accurate centering. The increased skin exposure due to using a closer distance makes it imperative to avoid repeats due to faulty centering. An added safety factor here is the use of 2.5 mm aluminum, or a total filtration of 3 mm aluminum.

Most of the reports to date have indicated that the use of bucky or grid in direct magnification was not needed. Since the film is far removed from the object, contrast is improved enough to alow excellent visualization of detail. Reasons for this are somewhat vague, but we can conclude that it is the result of at least two known facts.

1. Filtration in air of those secondary rays which are characteristic radiations of organic substances which have a longer wave length than the attenuated primary radiation. These are said to be absorbed by a few centimeters of air[4].

2. The spherical origin of secondary rays is such that they have a spatial distribution. The divergence of these rays obey the principles of primary radiation, with one exception. The primary radiation is limited at the tube port to an arc of approximately 40°. Whereas, the secondary or

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[4] Rhinehart, D. A.: Roentgenographic Techniques, 87: 1954.

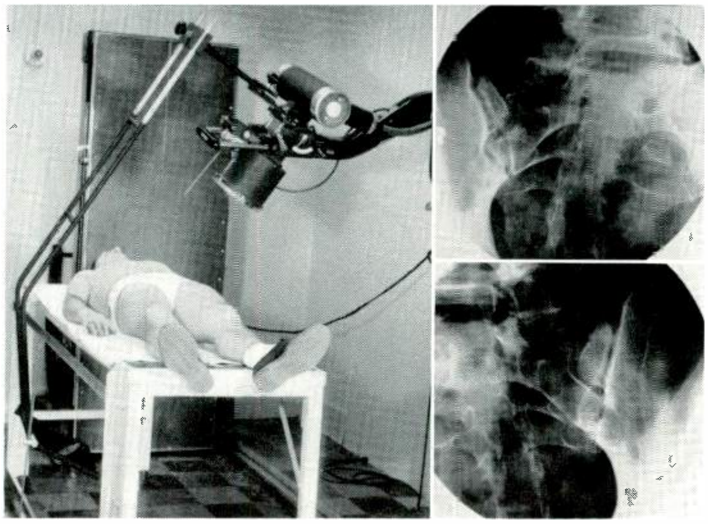

Figure 3

scatter arises in such a manner that it emanates with an unlimited arc of 360° in all planes. By extending the radius of this sphere (that is a longer object film dist.), an increasing percentage of scatter from a given point would miss the film. Neglecting air absorption, this apparent diminution of scatter can be likened to the inverse square law, where the intensity is inversely proportional to the square of the distance.

Of the two theories listed above, the spatial distribution and consequent divergence of secondary is by far the most prevalent, and is thought to contribute more to the heightened contrast, thereby precluding the use of a grid.

This loss of secondary when using magnification technique has been investigated and reported by Lofstrom and Warren[5], and later widely quoted (to my knowledge, it is the only published investigation of this phenomena). They showed that the effect of scatter was negligible in ordinary techniques when the film was 30″ from the object. Since the efficiency of grids, 8.1 and 16.1 have been shown to remove 90% and 95% of scatter[6] — this method is the equal, if not the superior method of reducing scatter, providing we consider the lessened scale of gradation which accompanies the use of a grid.

Another limitation of the grid is the inability to angle the x-ray focus in any direction other than parallel with its longitudinal axis. In conventional routines where a grid is indicated with angulation other than in the longitudinal direction, this handicap is for the most part overcome by rotation of body part. This routine method has well recognized limitations. They are:

No. 1 — Difficulty of the patient to sustain the rotation.

No. 2 — Errors in precise required angulation of patient by the technician.

No. 3 — Difficulty in duplication of the opposite side at time of initial examination or sometime later, where one or both views would have to be identical to the original.

No. 4 — Angulation of x-ray focus with respect to plane of double emulsion film.

The elimination of the grid with its shortcomings by means of the direct enlargement technique enables one to perceive that it is quite possible to:

No. 1 — Produce certain radiographs by eliminating rotation of patient.

No. 2 — Make the projection easy to duplicate initially or later.

No. 3 — Keep the plane of the film perpendicular to the central ray at all times, thus eliminating projected distortion.

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[5] Lofstrom, James E., Warren, Clark R.: from scientific exhibit, American Society of X-ray Technicians, Miami, Florida (May) 1954.

[6] Seemann, H. E., Splettstosser, H. R.: The Effect of Kilovoltage and Grid Ratio on Subject Contrast in Radiography, Radiology, 64:572-579 (April) 1955.

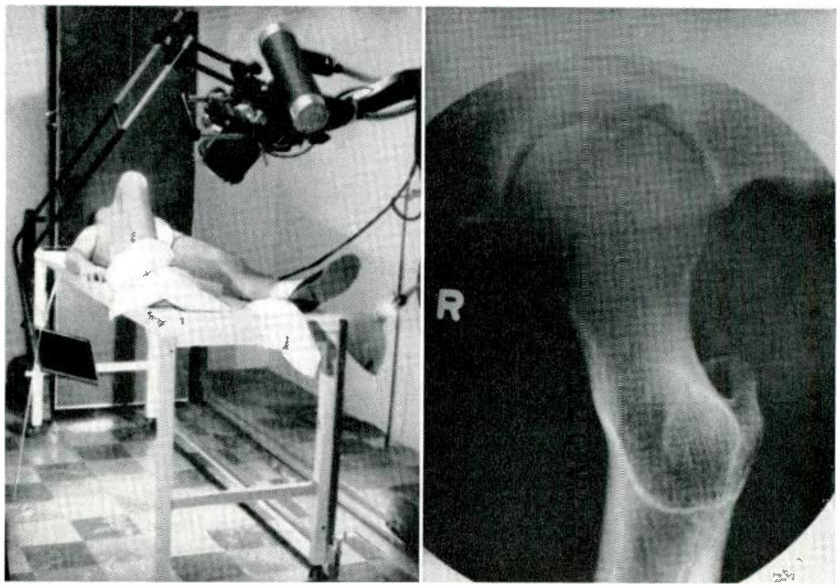

Figure 4

The above predictions can be best substantiated if we take a few specific examples:

The Stenvers: (Figures 2, 2a, 2b, 2c) A difficult view for most technicians, because it involves a double angulation. It also requires a bilateral examination that must be of near identical projection. Then too, the normal position is difficult for the patient to maintain without motion. With this enlargement technique, the patient could be placed either prone or supine, preferably supine, the base line of the skull adjusted and both required angulations (45° to side and 10° caudad) performed entirely by the x-ray tube. The plane of the film, of course, is perpendicular to the central ray. To project the opposite side with this type of tube stand, it is necessary to turn the table 180°, while the patient remains in the original position. The caudad angulation is readjusted in the opposite direction. The tube and film is then aligned and centered to this side, using the companion landmarks of the former side. Exposure factors: 80 Kvp 65 MAS.

Sacroiliac: (Figures 3, 3a, 3b) This view is difficult to duplicate for well known reasons. Using the magnification method, the patient can be radiographed in the supine position without any body rotation. A further refinement is the fact that the central ray can be angled so that it passes through the joint and body of the sacrum, perpendicular to the longitudinal axis: (a cephalad tube tilt of 20° to 30°) the projected distortion is equal in all planes. Exposure factors: 75 Kvp 120 MAS.

Lateral projection of hip: (Figures 4, 4a) A true lateral view of the neck of the femur with no obvious faults is rarely seen. This method was developed for use in post open reduction examinations to demonstrate healing of fracture site. Few of these patients will allow flexion of more than 30° to 40°. The amount of flexion that can be tolerated is determined by trial and the leg stabilized by sandbags on the foot, and extending well up on the leg; the femur abducted slightly to project the greater trochanter slightly off the neck. The central ray is then adjusted to be parallel to the shaft of the partially flexed femur, with an angulation of 30° to the side, so as to intercept the center of the femoral neck at 90° to its longitudinal axis. The film then is parallel to the neck of the femur and perpendicular to the central ray. This view projects the neck without foreshortening, which frequently occurs in many conventional views. The patient is comfortable enough to maintain this supine position without motion throughout this rather long exposure. Exposure factors: 95Kvp 170 MAS.

Oblique spine: These projections, for the same reasons, can be extended to include oblique views of the spine, where it is difficult or impossible to rotate the patient. Oblique views of the lumbar are shown in Figures 5, 5a, 5b. Exposure factors: 85 Kvp 90 MAS.

We have found this same method of special value in questionable injuries involving the cervical region, since the views can be made with a minimum of patient movement. (Figures 6, 6a, 6b)

In addition to the routine oblique cervical for examination of the foramina and pedicles, the atlanto-occipital articulation can be demonstrated bilaterally without the patient's head being rotated. These articulations can be seen well in the Stenvers projection. Incidentally, the entire cervical spine in one antero-posterior projection can be demonstrated very simply with magnification technique by immobilizing the head, and moving the mandible during the exposure. (Figures 1, 1a) The distance of the mandible from the film blurs this bone so thoroughly, that it is an exception to see it obscure the vertebrae it superimposes. This view was reported long ago, but the author has never

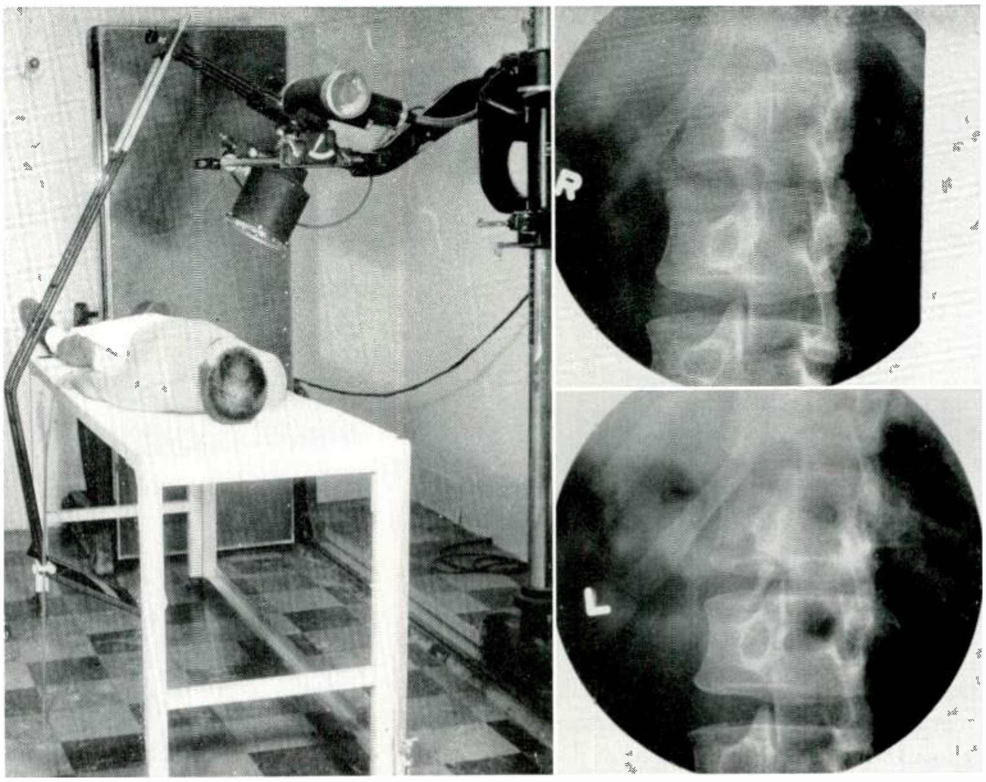

Figure 5

been too successful in doing it with conventional distances and focal spots. Exposure factors: 45 Kvp 100 MAS.

The only objection to most of these views is that they are magnified, and for oft repeated reasons, it is necessary to use the smallest cone or diaphragm that will just cover the area. In view of the fine detail possible with the fractional focus tube, magnification is not a serious drawback, so long as the area of interest is not too large. If made with medium speed screens, the resolution is the same, if not magnified over x 1.7 as a conventional projection with the same screens. In fact, Allen and Allen[7] reported that the difference in resolving power of detail screens compared to par or medium speed is insignificant and they admit their findings coincide with an earlier report by Morgan[8]. They showed the results of resolving power of various focal spots and film screen combinations in different degrees of magnification. A significant feature of their tests was that the resolving power remained constant from 0 magnification through x 1.7, while using the fractional focus with either medium speed or detail screens.

The unsharpness associated with the use of double emulsion film is well known. Some workers have attempted to overcome this factor by stripping the emulsion from one side of a radiograph[9]. These efforts were reported as futile,

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[7] Allen, C., Allen, E.P.: Enlargement Radiography with a 0.3 mm Focus, British Journal Radiology, 26:474-480, 1953.

[8] Morgan, R. H.: An Analysis of the Physical factors Controlling the Diagnostic Quality of Roentgen Images, American Journal Roentgenology 62:870-880 (Dec.) 1949.

[9] Sherwood, H. F.: Methods for Eliminating the Image on One Side of Double-Coated X-ray Film, Photographic Science and Technique, 4:151-152 (Nov.) 1953.

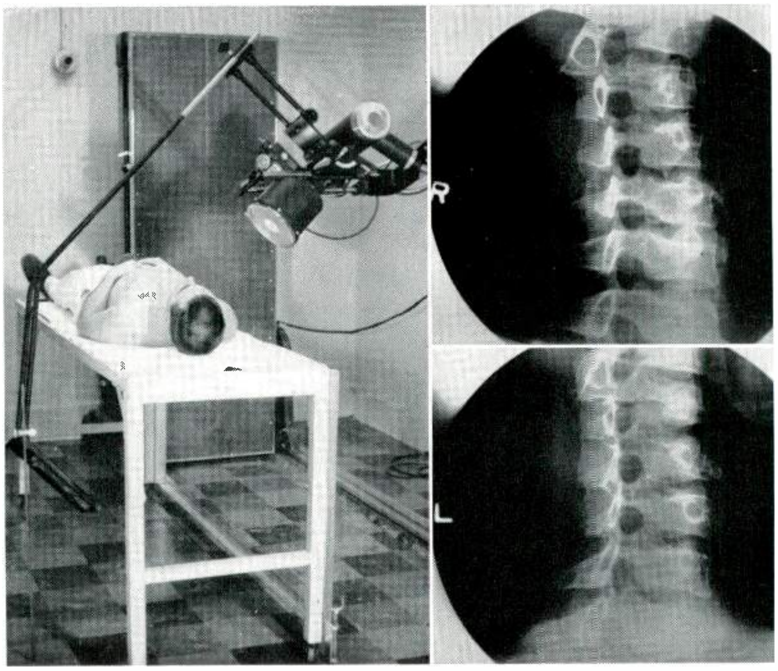

Figure 6

with no gain because of loss of sufficient contrast to visualize detail[10]. This inherent unsharpness is further aggravated by angulation of x-ray focus with respect to the plane of double emulsion film. The practice of tube angulation (only) can easily be appreciated, if one thinks of two separate images on one film but not precisely superimposed. The increased amount of detail in these views, which eliminates the above mentioned unsharpness is, of course, difficult to demonstrate with slides of photographic prints from radiographs. It is readily apparent when viewed direct, and is even more obvious when it is put to the test of optical magnification by a small hand lens.

We have found few reasons for going beyond a 60″ target film distance or having the film at a greater distance than 25″ from the object. With this in mind and taking the Allen and Allen report of no loss in definition up to x 1.7, it seems logical to use this factor for optimum results — for if we can enlarge an image and have it retain the same delineation of structural outline, then it becomes easier to visualize objects particularly as they approach in size the dimensions of the effective focal spot. Since there is a critical distance between the object and the film as shown by Frantzell[11] and beyond this distance, the image of an object becomes amorphous. All projections were made with a target film distance of 60″ and 35″ target object distance. All radiographs were developed 5 minutes at 68° Fahrenheit.

Summary

A method has been described and discussed for making optimum magnified projections with the fractional focus (0.3 mm) tube. It is thought to be superior to conventional views in selected instances for the following reasons:

1. Few compromises have to be made in regard to central ray traversing the correct anatomical plane, thus eliminating unequal distortion in the selected plane.
2. Produce certain radiographs by eliminating rotation of patient.
3. Easier to duplicate initially or later.
4. The plane of the film is perpendicular to the central ray at all times, thus eliminating projected distortion and the unsharpness associated with tube angulation (only) on double emulsion film.

Acknowledgment

The author wishes to express his gratitude to Dr. Robert D. Shepard, Radiologist, for suggestions and encouragement during the evolution of these projections. He is indebted to the entire staff of the X-ray Department for their splendid assistance. Finally, he wishes to recognize the cooperative attitude of the Good Samaritan Hospital officials.

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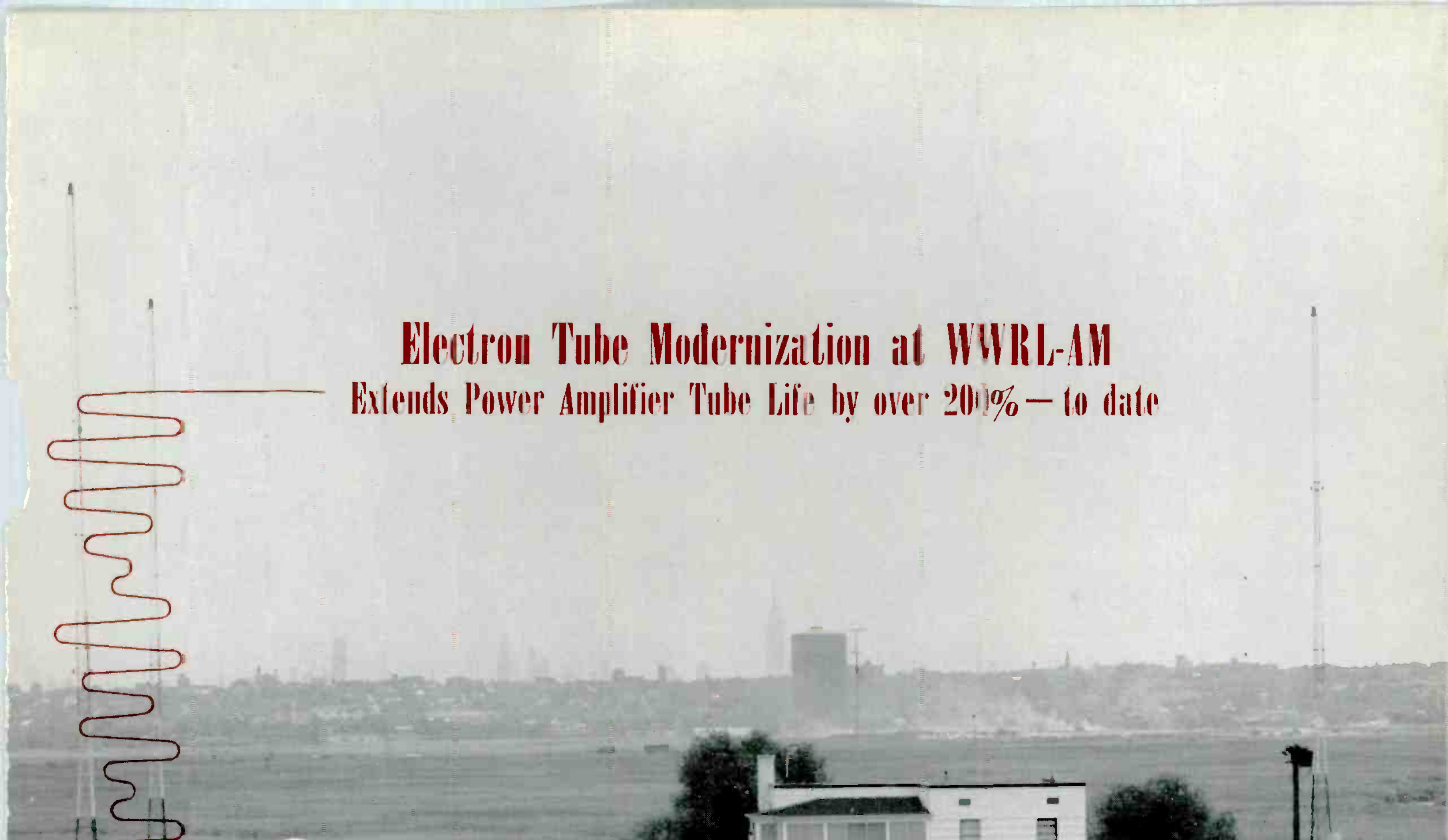
[10] Gilardoni, A., Schwarz, G. S.: Magnification of Radiographic Images in Clinical Roentgenology and its Present Day Limit, Radiology, 59:866-878 (Dec.) 1952.

[11] Ibid, 7; Frantzell, A., Acta Radiol., 1951, 35:265.



Electron Tube Modernization at WWRL-AM

Extends Power Amplifier Tube Life by over 200% — to date

by ***BENTON R. BARTLETT****, Chief Engineer, WWRL*
as told to ***George W. Whitney****, Field Engineer, Machlett Laboratories, Inc.*

EDITOR'S NOTE:
The conversion to the ML-6421 has already saved Radio Station WWRL the price of a power amplifier tube and has, beyond this, provided a superior signal. As one of a growing group of stations in Machlett Laboratories' continuing program of transmitter modernization, WWRL is pleased to report completely satisfactory results with the new tube. Similar conversion stories will appear in subsequent issues of Cathode Press.

Radio Station WWRL-AM has converted its final stage tube to ML-6421 and has achieved, to date, tube life equal to more than twice that of the longest previously achieved in that position. In addition to this, hum level and driver power have been reduced and cubicle heat is considerably lower.

Figure 1 — Home of WWRL-AM, Seacaucus, New Jersey.

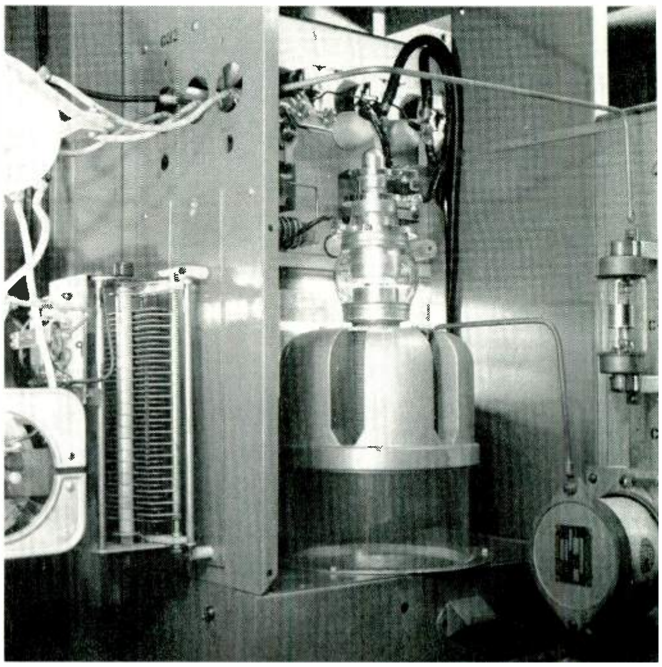


Figure 2 — Rear interior of transmitter. ML-6421 fits conveniently in power amplifier cubicle. Bus leads from C-47 and C-37 require reshaping. New filament lead posts, upper right, were installed; existing posts may be used.

During the thirty-one years of its broadcasting experience. WWRL has increased its facilities many times. A multi-audience, multi-transmitter station today, WWRL-FM fulfills the needs of high fidelity devotees in the New York City area and WWRL-AM, with approximately the same coverage, reaches the foreign language and negro markets.

Operating on 1600 kilocycles, WWRL-AM employs two transmitters, now both of 5kw power, to provide 24 hour continuous service. A 5kw Western Electric 405B2 and a 1kw transmitter had been in use for several years, but some time ago the smaller equipment was replaced by a new Gates Model BC5E. As tube life in the final stage of this transmitter was not entirely satisfactory, means were sought to alleviate this condition.

Initially a line regulating device was installed to feed constant voltage to the primaries of all filament transformers. Matters did not improve sufficiently and conversion to a new tube type was considered. The Machlett ML-6421 was chosen. This tube has proven its value to WWRL-AM in many ways. Its advantages are tabulated below:

Previous Final Amplifier Tube 3x2500F3	**New Final Amplifier Tube ML-6421**
Longest Life:	Life (As of 12-20-57)
2300 Filament Hours	6500 Filament Hours
Noise, below 100% Modulation at 1000 cycles:	
61db	65db
Driver Input Power, Watts:	
525	450

Conversion to the ML-6421 tube was easily accomplished. Space was available for the new components and no sheet metal work* or difficult wiring was involved. The existing blower provides more than enough air for the new tube which, at the power levels required, needs an extremely small amount of cooling air. In fact, when dissipating the required 2500 watts the ML-6421 needs only 50 cu. ft. of air per minute.

Needed for the conversion are the following parts:

A. Available from Machlett
  1. ML-6421 Triode
  2. Air Distributor. Machlett Part No. F-17996
  3. Tube Support, Machlett Part No. F-17794
  4. Terminal Connectors, Machlett Parts No. F-17487. F-17488, F-17489
  5. Spring Clips (to attach distributor to support) 3 R'qd. Machlett Part No. P-2113
  6. Filament Transformer, Nothelfer Part No. 8606

B. Optionally Available from Machlett
  1. Socket Mounting Plate. Use existing screws. (This

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*See Item No. 1 under B in the list following.

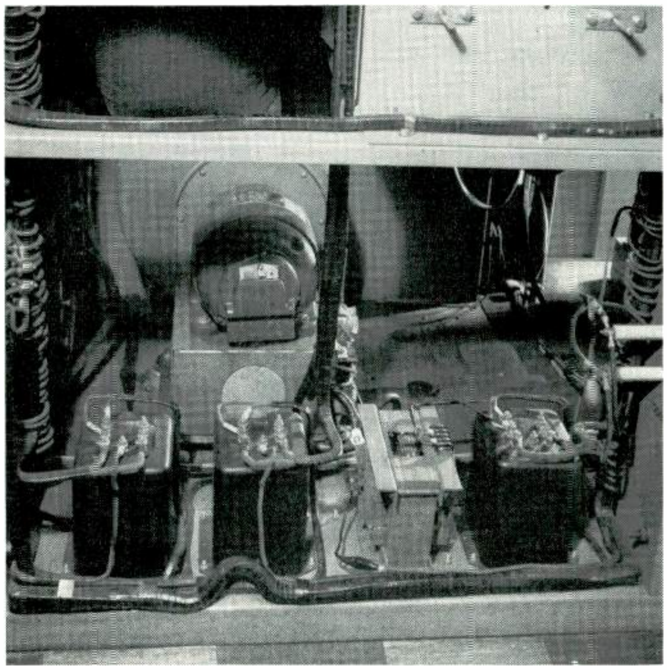


Figure 3 — Front interior of transmitter. New filament transformer fits in space available between T-5 and T-3.

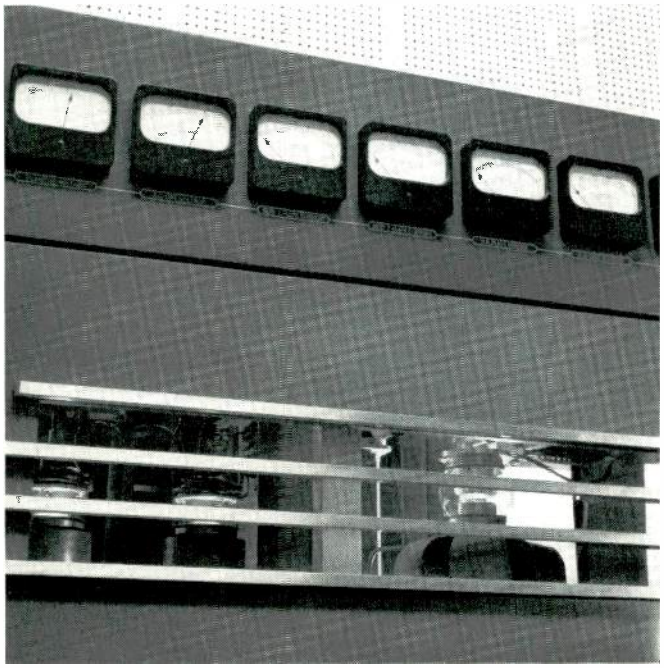


Figure 4—Completed conversion. ML-6421, right, is driven by two 810's. Load on drivers is reduced. Life of the new final has already exceeded average life of previous final tubes by nearly three times.

mounting plate was made by WWRL for the original conversion)

2. 6 sheet metal screws, for attaching air support to Socket Mounting Plate, supplied by Machlett

C. Optional if the line voltage regulation is poor

1. Constant Voltage Line Regulator (3kw)

D. Other

1. Insulating Tape
2. Modified busses, as described, constructed from #1 Gage Wire. Two strands required, each about 10 feet long.

The entire conversion may be made in two hours, more or less, provided that all hardware, tape and components are at hand. Steps for conversion are as follows, after opening front and rear of the transmitter:

1. REMOVE: a) Existing P.A. Tube; b) Lead from C-47, Figure 2, to neutralizing tap on Coil L-9; c) Anode connection to C-37, Figure 2; d) Socket Mounting Plate, complete; e) Grid resistor R-1 (it may be shorted from the circuit) only 3000 ohms bias is required for the new tube.
2. INSTALL: a) Filament Transformer (see Note 1); b) #1 gage wire from Transformer to filament mounting lugs (see Note 2); c) Socket Mounting Plate; d) Air Distributor; e) Re-shaped anode bus from C-37; f) Re-shaped neutralizing bus from C-47; g) ML-6421, with terminal connectors attached.
3. ELECTRICAL CHANGES: a) Select input voltage to filament transformer to obtain 6.65 to 7.0 volts under load; b) Use highest plate voltage available; c) Slight neutralization may be required after conversion is completed.

NOTE 1: *If filament transformer T-3 has a common primary for the modulator tubes and power amplifier tube, remove leads to the P.A. tube and then install the new filament transformer.*

NOTE 2: *New mounting posts may be installed as shown, upper right in Figure 2, or the existing posts may be used.*

The higher power ML-6421 tube when operated at 5400 or 5450 plate volts and 1.45 amperes provides excellent transmitter response. Line voltage swings will bring changes in current-voltage relationships. So that safety margins will be adequate for components associated with the output circuit, plate current should not exceed 1.6 amperes.

The filament voltage at which WWRL-AM operates the ML-6421 is slightly below the design bogey of the tube, yet ample power is provided for the installation. Good filament voltage regulation makes this arrangement practical, and, since the filament strands are running slightly cooler than normal, tube life should be exceedingly good.

EG-180 X-Ray Tube Series —
Forced-Air-Cooled, Portable Tubes For Industrial Radiography

New tube types continue to augment the already extensive line of Machlett industrial x-ray tubes. Latest additions are found in the EG-180 series of forced-air-cooled tubes for portable radiographic equipments. EG-180 tubes incorporate an integral blower and cooling fins and are so designed that warm-up periods of extremely short duration may be employed.

For some time now Machlett has pursued a program for developing portable industrial x-ray tube designs. Nearly 10 basic types of tubes, all of recent design, together with their many individual variations are included in this program. The recently introduced PR series, for instance, includes rugged tubes for gas or oil insulated portable tube heads, operating from 120PKV at 5MA to 260PKV at 10MA.

For those many applications in which an end-grounded tube is desirable the Machlett line offers the EG-25, AEG-50, OEG-50, OEG-60, EG-252, and now the EG-180-R series. The water or forced-air-cooled anode types can be operated at very high power levels, but must be designed to have the anode work at ground potential. This, however, places a premium on tube design. Whereas anode overloading is virtually eliminated, the problems related to high voltage gradients (field currents, bombardment of the glass wall, etc.) increase. Conventionally, x-ray tube voltage is "split" between terminals; in an end-grounded tube the full voltage is applied to a single terminal. The complete adequacy of the Machlett design to handle this rigorous operating characteristic has been proven in hundreds of applications. Included among these are many in the nuclear field, in which the highest standards obtain.

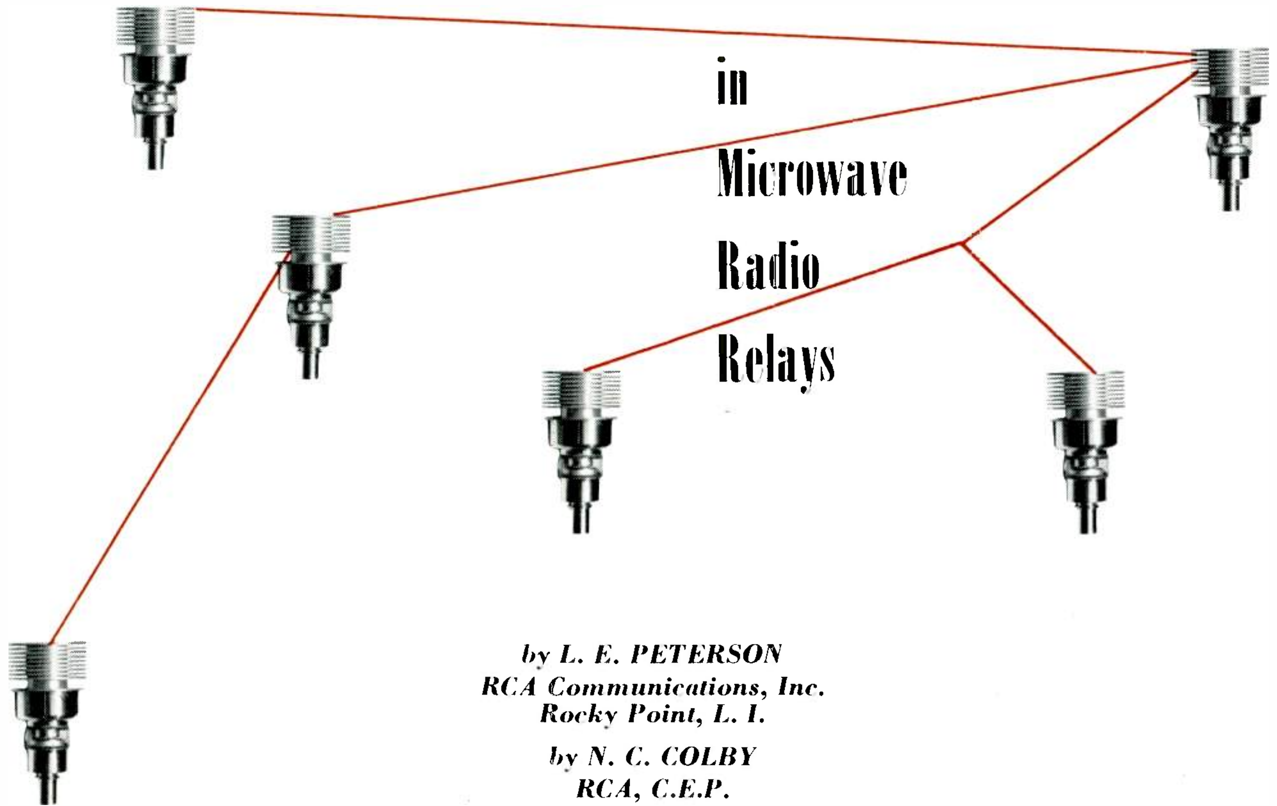
A continuous, stable, high roentgen output is obtained with the Machlett end-grounded x-ray tubes. To these many "EG" advantages — compactness, high output, ruggedness — the EG-180-R series adds forced-air-cooling. For field installations where portability is at a premium these tubes possess a unique advantage in design. Heretofore, power of the order available from the EG-180's has been available only from water-cooled tubes. With these latter tubes, hose lines and/or heat exchangers limit mobility. Air cooled tubes, on the other hand, rid themselves of hoses and exchangers at the sacrifice of power, 30% or more. So effective is the cooling system used in EG-180-R tubes that, even under extreme hot weather conditions (to 135°F) there is no reduction in ratings.

Electrically, the EG-180-R tubes are extremely rugged. Under normal operating conditions, morning set-up or warm-up time may be limited to two minutes or less; thereafter, individual exposures require less than ½ minute warm-up. The EG-180's are designed with a high factor of safety, using electrode geometry of a type proven in Machlett x-ray tubes operating at 250PKV and higher. Two basic versions are available, the EG-180-R-B, a beryllium window tube providing at 40° cone of radiation, and the EG-180-R-X. a nickel window tube providing at 360° band of radiation.

Preliminary Specifications

	EG-180-R-C	EG-180-R-X
Maximum Energy Ratings	180PKV, 10MA continuous.	180PKV, 4MA continuous.
Focal Spot	3.5 mm. square, projected.	360° beam. For angular coverage of 35° the focal spot size is 1.0 x 4.0 mm. For angular coverage of 16° the focal spot size is 0.6 x 4.0 mm.
Insulation	Compressed Gas or Oil.	Compressed Gas or Oil.
High Voltage Source	60 cycle (self rectified) or high frequency resonant transformer.	60 cycle (self rectified) or high frequency resonant transformer.

The Life and Times of the 2C39 in Microwave Radio Relays



by L. E. PETERSON
RCA Communications, Inc.
Rocky Point, L. I.

by N. C. COLBY
RCA, C.E.P.
Camden, N. J.

When the development of RCA's current line of 2000 mc radio relaying equipment, known as type CW-20 was begun, the 2C39A was chosen after a thorough investigation of several possibilities as the most economically and technically satisfactory for use in the UHF circuits.

The 2C39 is the outgrowth of some intensive development work during the early years of World War II to find a successful ultra high frequency tube design. The design originally marketed, and much refined since, was a planar triode carrying the developmental number ZP572. The shape of the tube, which was one of a family, resulted in their being called "light house" tubes (at times they were even called "oil-can" tubes). A planar tube is one in which the electrodes (in a triode the cathode, grid, and anode) are parallel planes. In the 2C39's as now manufactured the spacing between the planes of the cathode and grid is 0.005 inches and between the grid and anode it is 0.0225 inches. The intended use for the 2C39 when it was first developed was in countermeasures equipment of medium power and wide tuning range. Its application was studied quite extensively in many of the radar and countermeasures laboratories operating during World War II. Its application during the war and in many designs since has been in expendable equipment not intended for long life. The necessity of improving the characteristics responsible for long life was not felt strongly until its use became more widespread in radio relay equipment where long life and unattended operation are of paramount importance.

The tube, as available now from a number of manufacturers in the U.S., appears under type number 2C39A if glass insulators separate the electrodes, and 2C39B when ceramic insulators are used. A ruggedized longer life version manufactured under specially controlled conditions for military and commercial applications where reliability is of prime importance is available as a 2C39WA. Only type 2C39A life data is included here as the later types were only recently installed.

There are yet other versions available only in sample quantities bearing X numbers of the particular manufacturer.

The "tube characteristics" of the 2C39A. 2C39B and 2C39WA are very nearly the same. The nominal values of the more important characteristics are given in Table I. Generally speaking the tubes from the various manufacturers are interchangeable in a given equipment design.

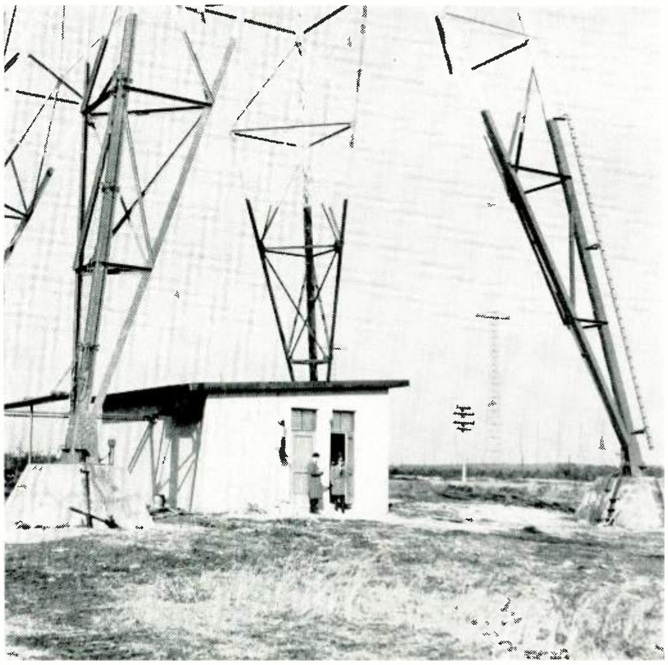


Figure 1 — Microwave terminal building at Rocky Point, Long Island.

Figure 2 — Portion of microwave relay equipment in New York City.

TABLE I

Heater Voltage	5.5 to 6.3 volts
Heater Current	1 amp.
Amplification Factor	100
Transconductance (I_b=70 ma, E_b=600 V)	22,000 micromhos
Plate Dissipation (forced air cooling)	100 watts

The 2C39A, B, and WA are used today in a wide variety of military and commercial equipment manufactured in the U.S. and several foreign countries, notably France and Germany. It is used in equipment operating over the entire frequency spectrum from 400 mc to 3000 mc. It is used in both pulsed and cw service. The characteristics that make it popular with equipment designers working in the UHF range are its small size, relatively large plate dissipation, rugged construction, and its nearly ideal geometry which allows it to be used in either coaxial, cylindrical or waveguide cavities.

The CW-20 equipment uses three 2C39A's (2C39B, or 2C39WA) in the transmitter — one as an oscillator, one as a high-level mixer, and one as an RF power amplifier. The circuits of which the tubes are an intimate part are of the waveguide cavity type. The use of the waveguide type of cavity resulted in three important circuit advantages. It resulted in circuits with a wide tuning-range, a convenient physical size, and a structure in which it was possible to provide good circulation of air around all parts of the tubes and yet enable one to change the tubes quickly without tools of any kind. The tube operating currents and voltages were chosen so that under no circumstances of recommended operations does the plate dissipation exceed one half the manufacturer's rating and under the most usual operating conditions found to be satisfactory by users, the dissipation is one third or less of the maximum rated value. The heater voltage was chosen to obtain a compromise between long life and stable operation. The combination of excellent ventilation, low anode dissipation and optimum heater voltage is important in obtaining the long life that has been recorded.

The 2C39A tube life obtained in the New York City to Riverhead system operated by RCA Communications, Inc., is especially interesting because of the accurate and thorough methods employed in keeping tube life records. This system consists of a Terminal at New York City, a Thru Repeater at Dix Hills, a Drop Repeater at Rocky Point and another Terminal at Riverhead, Long Island. The company's principal overseas shortwave transmitting station is located at Rocky Point, Long Island. The principal receiving station is at Riverhead. The microwave radio relay equipment employed is the RCA type CW-20. To obtain maximum reliability, needed for the common carrier traffic service, parallel radio beams are used. The system is operated under circumstances that are ideal for getting significant tube life data. All tubes are in service continuously. There are no tubes in rarely used standby equipment included in the samples. Voice multiplexing facilities are provided for each of the independent parallel radio circuits.

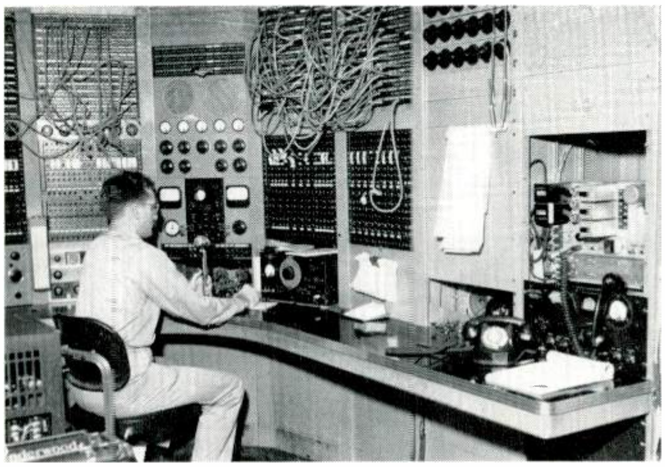


Figure 3—Main incoming switchboard at Rocky Point where incoming signals are channelled to individual transmitters.

The traffic carried is chiefly teletype signals and program channels. The same information is transmitted over the parallel circuits simultaneously with the best circuit being automatically selected at the terminal making use of the information. No tube failures have resulted in the simultaneous loss of both circuits between New York City and Riverhead in a period of 2½ years.

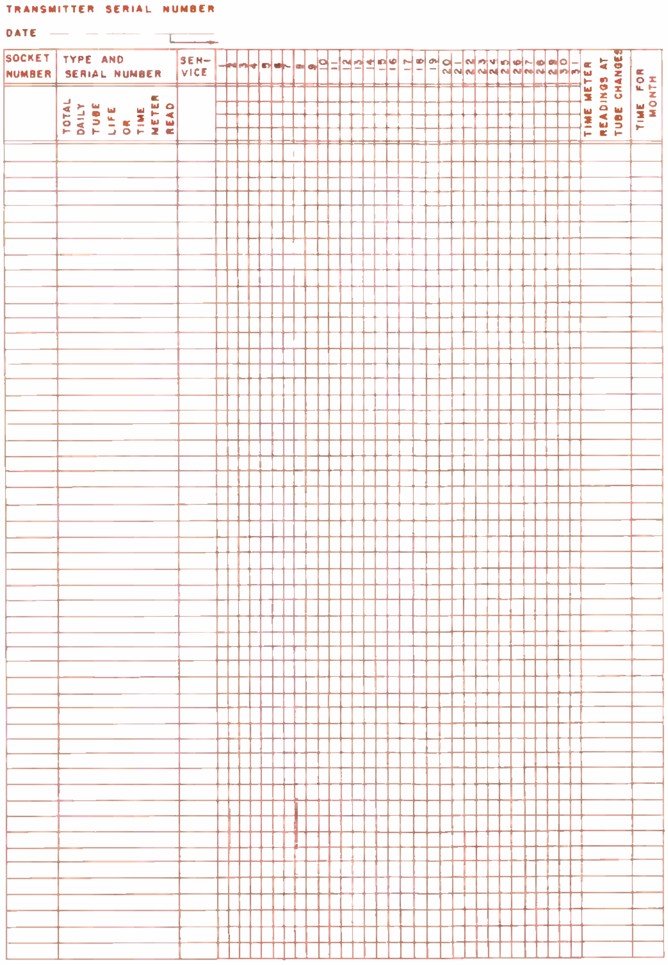
Figure 1 shows the equipment housing at Rocky Point. Figure 2 shows a portion of the equipment at the New York City Terminal. Figure 3 shows a portion of the terminal facilities at Rocky Point.

The means of keeping records used by RCA Communications will be described in some detail since they have resulted in the accumulation of much valuable tube life data.

To obtain accurate tube life history a means of identifying individual tubes is essential. Fortunately this problem is easily solved since all 2C39A, B, and WA tubes are given a serial number by the manufacturer. A convenient printed form on which to record data is a second essential. Figure 4 shows the form currently in use. A form is filled out for each transmitter each month. As indicated by the column headings the socket number, tube types, tube serial number, and type of service is recorded. The "type of service" may be oscillator, mixer, amplifier, etc. The day of the month and the running time meter reading when a tube failure occurs are recorded in the appropriate column. The serial number of the replacement tube is recorded along with the date and running time meter reading. Thus a continuous record for each socket is available. The periodic readings that are taken which indicate failure or incipient failure are not recorded on these forms.

It is unfortunate (for the purpose of determining tube life) that all failures are not catastrophic. Unless a filament burns out or a seal breaks some more or less arbitrary performance criterion must be applied to determine whether or not a tube is unfit for service. Each user will develop performance limits based on his particular system requirements and operating experience. Except in cases of outright failure the criteria used by RCA Communications maintenance men are the value of maximum obtainable cathode current or relative power output measured with the metering facilities built into the transmitter. An analysis of the tube life data obtained is given in the following paragraphs.

The system has thirty-six 2C39 tube sockets. The records from which data are taken cover a period of approximately 22,400 hours. Figure 5 shows graphically the history of each transmitter socket in the system. The crosses mark the points in time at which a tube replacement was made. Of the original thirty-six tubes ten are still in service in the same socket. To date, reclamation (for example, using a tube as an amplifier after it will no longer serve as an oscillator) has not been practiced although it is intended to do so in the near future. During the period covered by this report 52 tubes have been removed from service either during routine maintenance or at the time of failure.



TRANSMITTER SERIAL NUMBER

DATE

SOCKET NUMBER	TYPE AND SERIAL NUMBER	SERVICE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TIME METER READINGS AT TUBE CHANGES	TIME FOR MONTH
	TOTAL DAILY TUBE LIFE OR TIME METER READ																																		

Figure 4 — Form for obtaining individual tube life history.

Calculations based on the life data of the 52 tubes that have been removed and the life data of those original tubes still in service show an average life of 10,211 hours and a median life, or the life which 50% of the tubes exceeded, of 8,600 hours. These figures are pessemistic because in making the calculation it was assumed that all of the 10 original tubes still in service had failed at 22,400 hours. Accurate average and median life figures can only be calculated from data obtained from systems that are in "statistical equilibrium."

Studies of tube failure data indicate that the failure rate after the first 500 or 1000 hours is proportional to the number of tubes still in service. Figure 6 is a plot of the number of the original tubes still in service against the number of hours of service. With the number of tubes plotted on a logarithmic scale a straight line function is obtained. This substantiates the proportionality relation previously stated. An extrapolation of this line indicates that at the end of 10,000 hours 3 of the original tubes will still be in service.

The slope of this curve indicates that one-half of an initial set of tubes can be expected to remain in service for 13,000 hours (the median life). If experience continues to follow the extrapolation the computed average life will be 15,000 hours.

It can be concluded that careful conservative equipment design is an important factor in achieving long tube life, and in order to know what tube life is being actually obtained, accurate records are essential.

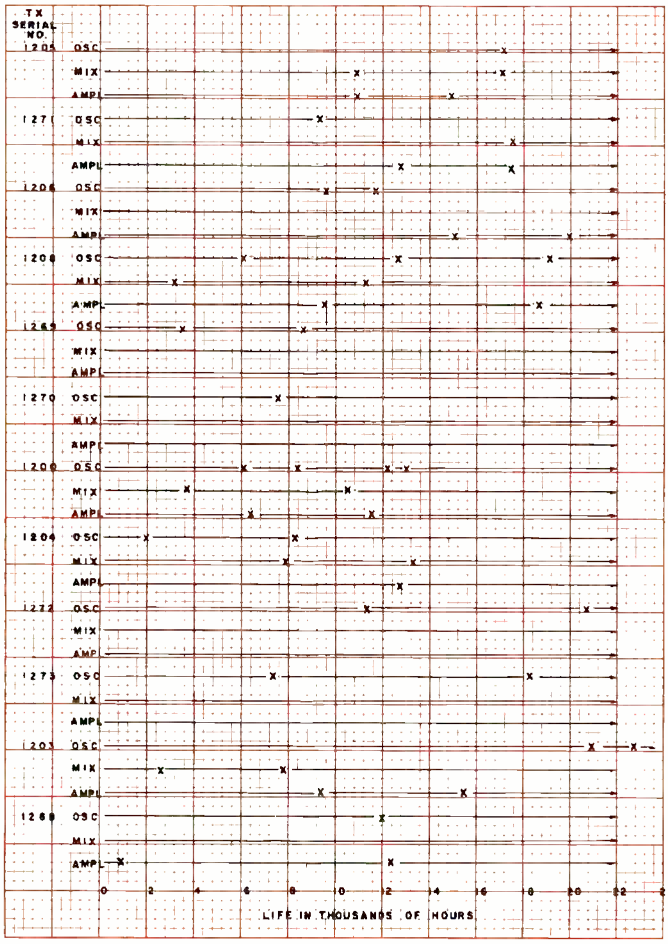


Figure 5 — Record for maintaining history of each transmitter socket.

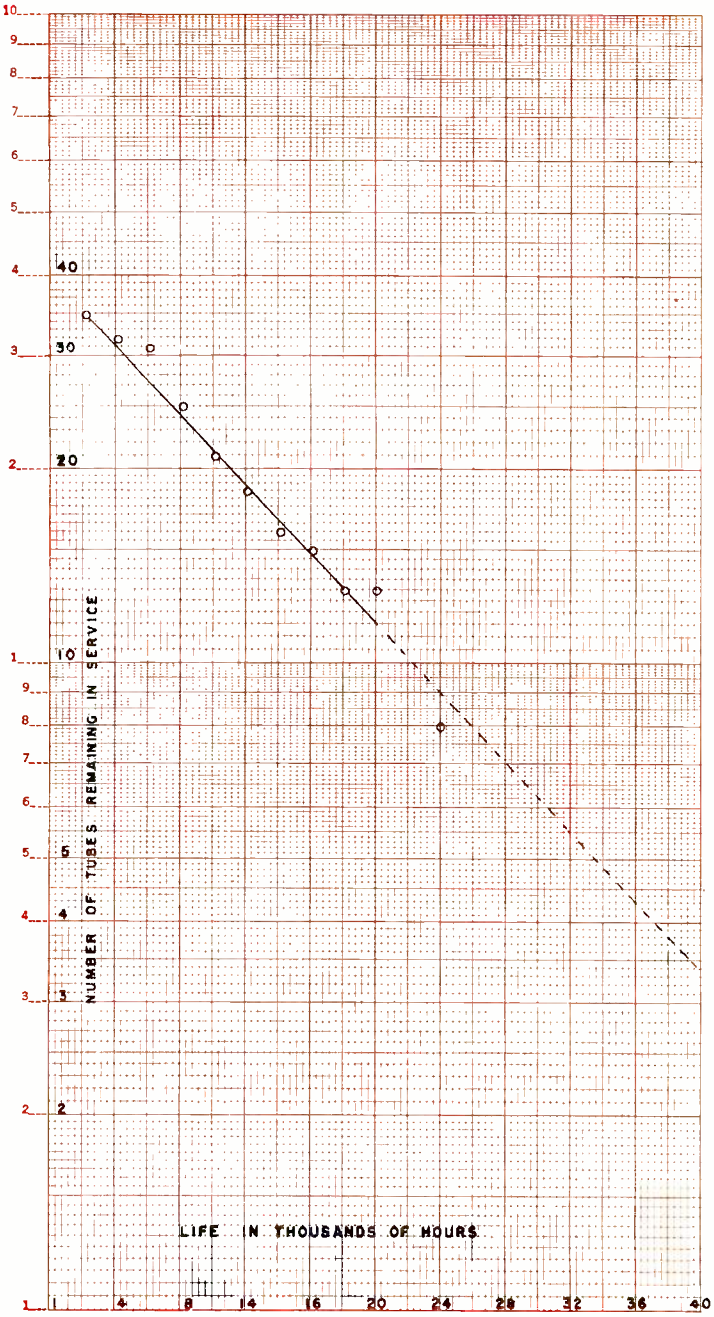
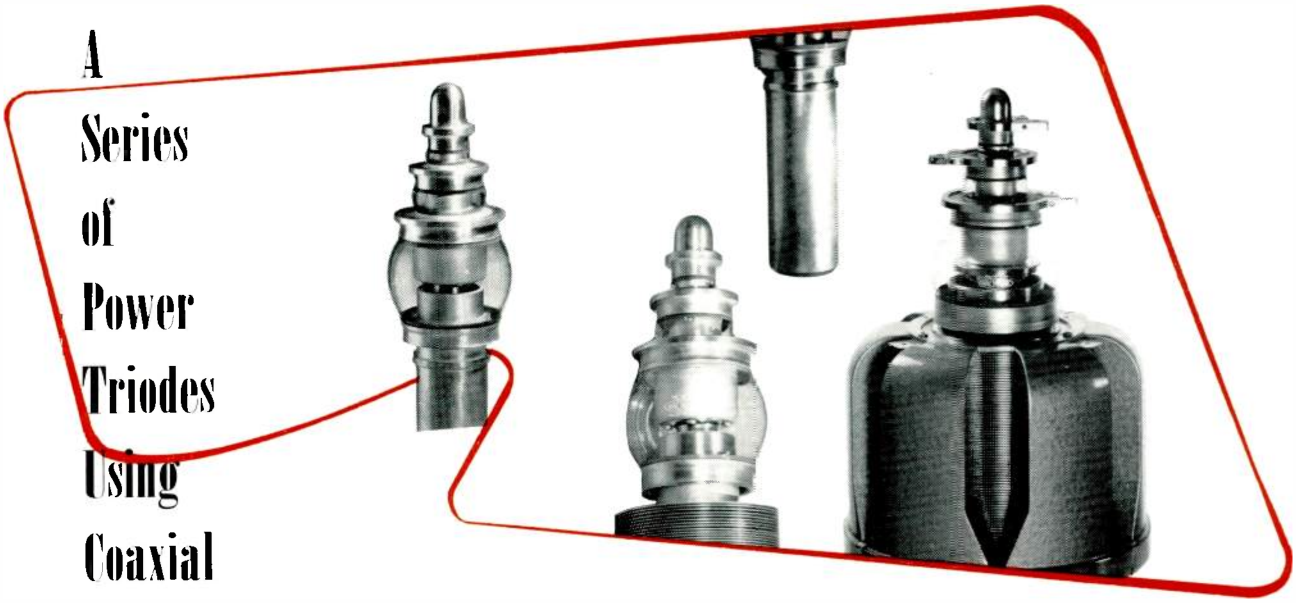


Figure 6 — Proportion of number of tubes still in service against number of hours of service.

A Series of Power Triodes Using Coaxial Terminal Construction



by C. V. WEDEN, Machlett Laboratories, Inc.

In November 1954, Machlett Laboratories announced a new line of power triodes for use in the continuous-wave power output range of 10- to 50-kilowatts. The series consists of four water cooled types and four corresponding forced-air cooled types and is designated ML-6420 through -6427. In March 1956 another pair of tubes, ML-6696 and -6697, was added to the line extending the nominal power output capability to 75 kilowatts. Wide acceptance of these tubes by a diversity of interests including industry, radio broadcasting, communications, and research, has been gratifying. In high-frequency induction- and dielectric-heating service, for example, tubes of this line are being used in equipments rated from 7.5- through 60-kilowatts useful load power. In the field of AM broadcasting, a pair of ML-6427's is being used in the final stage, and another pair in the modulator, of a forced-air cooled 50 kilowatt transmitter recently announced by a prominent manufacturer[1]. A representative group of these tubes is shown in Figure 1. It is an example of design technique usually restricted to ultra-high-frequency tubes applied to a series of general purpose power triodes.

Background

A brief history of power tubes may be illustrated by the three tubes shown in Figure 2: representing the "early" period is a typical pre-war broadcast tube, type 892; it has a thin-wall anode, feather-edge copper seals, long wire filament and grid leads, and a stem press which needs liberal cooling and is difficult to cool. In 1947 Machlett brought out an industrial version of this tube, the ML-5668, electrically replacing the 892 but featuring many mechanical and thermal improvements; the pure tungsten filament is retained, but heavy copper posts support the grid and cathode structures, and stronger kovar-to-glass seals and a heavy-wall anode are used. The ML-6422 continues this development to include coaxial terminals and electrode supports for the grid and cathode, and the filament wire is now thoriated-tungsten, requiring only about 40% as much heating power and insuring longer life. This tube will replace the two predecessors with minor equipment modification and adjustment. Electrical characteristics have been improved, and cooling requirements have been reduced to the extent that no auxiliary forced-air cooling of the bulb and seals is necessary in many applications.

Figure 3 shows one of the forced-air cooled tubes in operating position with accessories: insulating tube support, air distributor, and grid- and cathode-terminal connectors. Figure 4 shows the largest pair of tubes in this series, the water cooled ML-6696 in its water jacket, and the forced-air cooled ML-6697. The latter tube is rated for 35 kilowatts anode dissipation, which is an achievement for a tube of this size and weight. It can be handled by one man, and complete with air distributor, is less bulky than a conventional tube of comparable power level.

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[1] R. L. Dyer, N. W. Mapham, O. F. Walker, "New 50-kW AM Transmitter Designed Around Modern Components," NARTB conference paper, 1957.

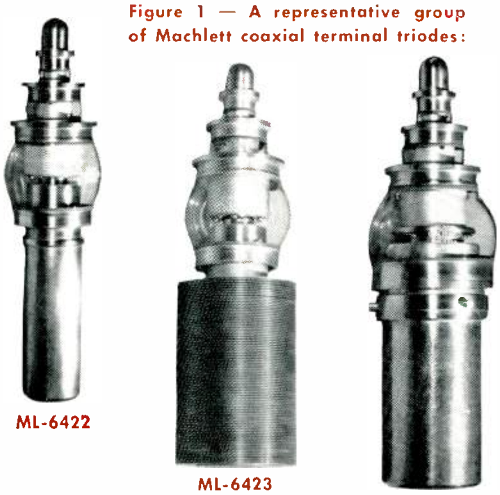

Figure 1 — A representative group of Machlett coaxial terminal triodes:

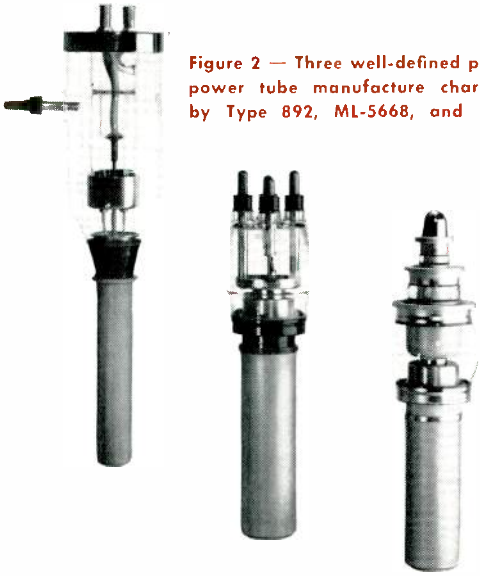

Figure 2 — Three well-defined periods of power tube manufacture characterized by Type 892, ML-5668, and ML-6422.

Figure 3 left — ML-6425 in operating position showing insulating tube support, air distributor, and cathode terminal connectors.

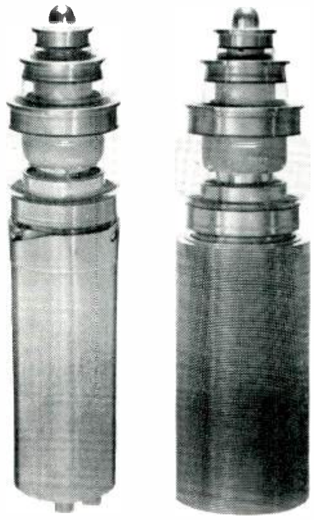

Figure 4 — ML-6696 in water jacket, and (right) ML-6697.

Features and Advantages

Electrode structures are mounted directly to sturdy copper cylinders. The chief advantage of this design is mechanical stability such that prescribed interelectrode spacings are maintained within close tolerances, as verified by the reproductibility of electrical characteristics. Table I shows the median, x, and the standard deviation, σ, of four static test results from a pilot run of 20 tubes made between February and August, 1955, and from a production lot of 50 tubes made between October, 1955 and June, 1956. For comparison, the established design-center values and tolerances are given; this data represents very good control for transition from direct engineering supervision to regular production. Figure 5 is a distribution curve of one of these test results plotted in cumulative form on probability paper. This presentation of the data is convenient to use when the distribution is reasonably normal is indicated by a straight-line plot; the median is then the ordinate at which the curve crosses the 50% line. In a normal distribution approximately 68% of the sample lies within plus and minus of 1 σ from the median, so σ may readily be found graphically. It can be seen that the median of the production lot has not shifted greatly from the figure for the pilot run, and it is well within the limits ($\bar{x}$ min. and $\bar{x}$ max.) established. All of the readings, furthermore, lie between −515 and −560 volts; no individual tubes are out of tolerance and most of them are within the absolute limits by a generous margin.

A corollary to the assurance of electrode stability is that relatively close grid-cathode spacing is feasible. This results in high perveance, which is a desirable characteristic for an electron tube operated as either a self-excited oscillator or a driven amplifier. Perveance is the constant of proportionality K (for a given electrode geometry) in the familiar space-charge current law,

$$I=K\,(eg + ep/u)\;3/2$$

K is proportional to the cathode emitting area and inversely proportional approximately to the square of the grid-cathode spacing. High perveance raises the practical upper limits on both plate efficiency and power gain. In the conversion of a forced-air cooled 5-kilowatt broadcast transmitter, for example, replacement of the 892R final amplifier tube with an ML-6423 showed an increase in plate efficiency from 70% to 80% and an increase in power gain by a factor of more than two to one[2].

Other advantages of the coaxial terminal construction are:

1. *Increased seal strength which is proportional to seal diameter.*
2. *Reduced seal heating, a consequence of the larger areas for dissipation of heat conducted from the cathode, and heat due to high-frequency charging cur-*

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[2] E. A. Browning, "Performance of Radio Station WTAG Improved by Replacement of Trial Stage Type 892E Tube with New ML-6423-F." Cathode Press, Vol. 13, No. 4; 1956.

TABLE I

Static Test Results of ML-6420
Showing Median, x, and Standard Deviation σ

	NO. TUBES	Ec		(1)Eb		(2)Eb		Mu	
		$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ
PILOT RUN FEB. AUG. '55	20	−524	7	6.93	0.70	2.87	0.10	20.3	0.4
PRODUCTION OCT. '55-JUNE '56	50	−533	11	6.93	0.11	2.89	0.09	19.9	0.4
SPECIFICATION		−525	±45	6.90	±0.60	2.90	±0.30	20.0	±2.0

Ec = GRID VOLTAGE Eb = PLATE VOLTAGE Mu = AMPLIFICATION FACTOR

rents. Because of skin effect, the latter is particularly important at the higher frequencies used in short-wave communications and dielectric heating. The current which charges the grid-plate capacitance flows over both the grid and plate seals, so a balanced design calls for the diameter of these seals to be as large as practical and substantially equal.

3. *Lower lead inductance, which minimizes the dangers from parasitic oscillation.* This form of instability is usually accompanied by high voltages developed across lead inductances. There is less tendency to excite a parasitic if lead inductances are low, and less chance that the voltages developed will reach dangerous magnitudes should a parasitic occur. In this regard, lower cathode lead inductance as well as grid lead inductance has been found to be effective.

Economic Considerations

There is no question that the coaxial design is a good one. In some cases it is found to be necessary for a given application; in other cases it is at least highly desirable. This type of construction is admittedly more costly, and for many applications the question may be raised, "Is the additional expense justified?"

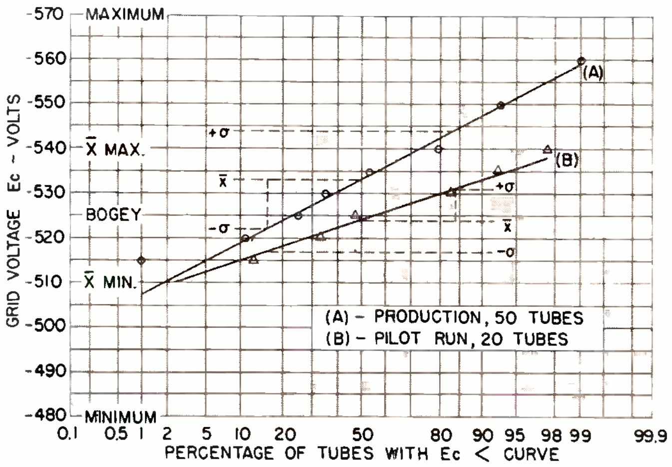


Figure 5 — Probability plot of ML-6420 grid voltage showing relation to test limits.

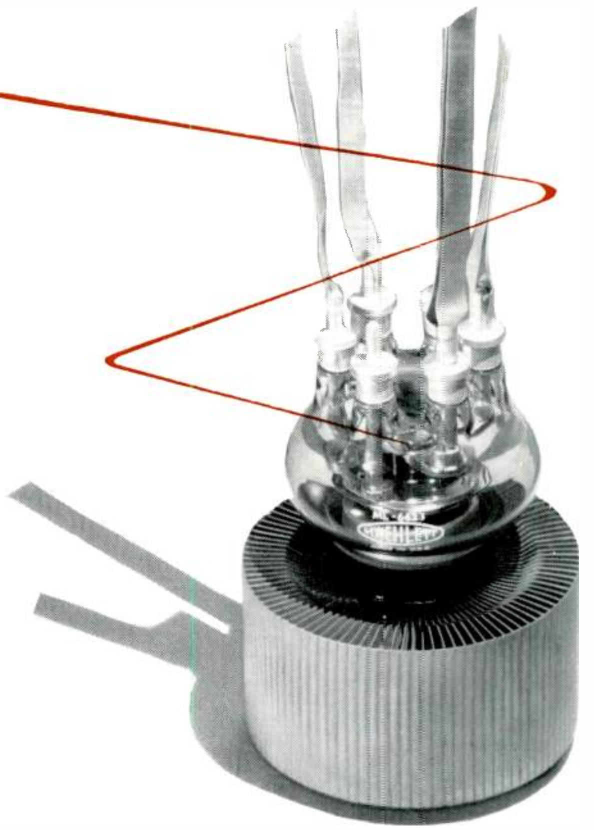
The answer is categorically in the affirmative. Through careful design resulting in the standardization of many parts among several tube types, it was feasible to undertake an extensive tooling program insuring the precise fabrication of parts and their precise assembly. This precision, with the electrode stability afforded, is effective in maintaining low shrinkage. These two factors, economy through standardization of parts and low shrinkage, have made it possible to offer a line of premium tubes at prices competitive with tubes of the more conventional post-and-dish design.

During the course of more than one year in regular production, the yield has been extremely high. From the total number of tubes begun for all types of this series combined, the overall in-plant shrinkage, exclusive of engineering tests, has been approximately 6%. This figure represents tubes lost due to accidental damage and the normal run of defects such as glass cracks, leaks, and gassiness, which are expected to some degree. Field returns also have been favorably low. Except for three or four tubes early in the development program returned for faults which since have been corrected, to date only one tube has been returned which is clearly attributable to a manufacturing defect.

Conclusion

A series of power tubes has been developed with design concepts not usually found in tubes of this general type. The coaxial terminal and support arrangement has been shown to give the tubes improved mechanical, electrical, and thermal characteristics. More precise fabrication of parts and more precise assembly add up to higher cost, but this has been balanced by the standardization of parts and low shrinkage so that tubes of this advanced design are competitive with those of more conventional construction.

ML-6623 Rugged Triode for Industrial Heating and AM Broadcasting



The ML-6623 forced-air-cooled triode is designed for use in industrial electronic heaters and AM broadcasting transmitters. One of the nearly twenty new industrial triodes offered by Machlett within the past three years, the ML-6623 incorporates a large low-pressure radiator and permanently attached terminal straps. To make the tube stable under all operating conditions and to eliminate any tendency toward inter-electrode short circuits, the ML-6623 uses a unique grid-filament alignment technique and r-f final seal-in. Further improvements include the use of a specially brazed radiator and novel final seal-off.

Because it employs the r-f final seal-in construction, the ML-6623 filament and grid can be accurately positioned inside a completed glass portion of the envelope. Lateral adjustment of the grid, made possible by a special flange design* accomplishes this and assures the correct grid-filament alignment. The tube is "sealed-in" or completed with a metal-to-metal seal made by r-f induction heat in a controlled atmosphere. This heat process takes but a few seconds, as compared to minutes for conventional flame heat. Internal elements are not oxidized and require no further processing or cleaning after the seal-in; further there is no tendency toward mis-alignment in the seal-in process.

The anode cooling fins of the ML-6623 are brazed directly to the anode prior to the final completion of the tube. Again, heat introducing operations are completed prior to the tube's final assembly. An additional and important advantage of direct fin brazing is found in the increased efficiency of the heat removal characteristics of the anode cooler or heat radiator. Final seal-off is done by the cold weld method at the base of the anode. Silver plated flexible copper straps, permanently attached to the grid filament terminals facilitate circuit connections.

The ML-6623, well suited to induction and dielectric heating equipments in the 2.5kw to 4kw range, is capable of long service under rigorous conditions. Economy of operation is provided both by its thoriated tungsten filament and low air flow requirements.

General Characteristics

Filament Voltage	6.0 volts
Filament Current	60 amps
Type of Cooling	Forced-Air
Air Flow on Anode	150 cfm at 0.9″ water
Maximum D.C. Plate Voltage	5000 volts
Maximum D.C. Grid Voltage	−1000 volts
Maximum D.C. Plate Current	1.4 amps
Maximum Plate Input	5000 watts
Maximum Plate Dissipation	2500 watts

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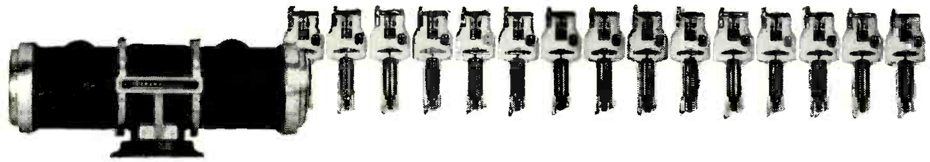
*Patent applied for.

In Diagnostic Radiography



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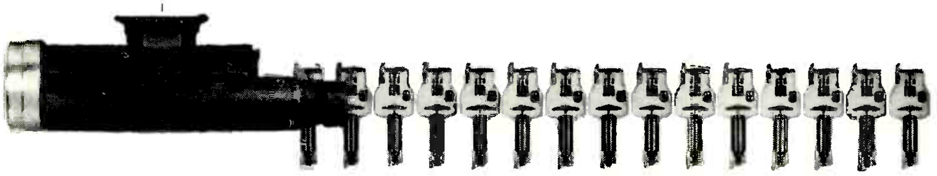

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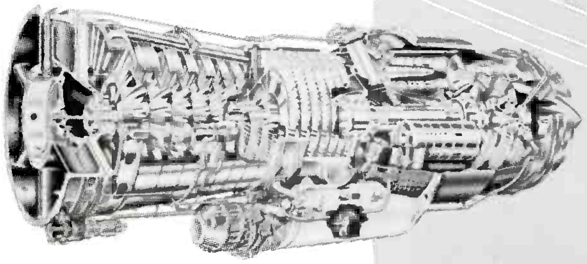
Precision Brazing at PRATT and WHITNEY AIRCRAFT

Relies on R-F Induction Heating With

ML-5668*

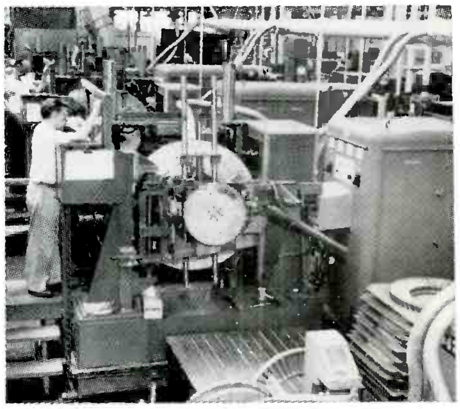
Industrial Electron Tube



J-57, one of the most famous jet engines in the world . . . its low compressor shrouds and blades, center, are brazed with equipment using Machlett ML-5668 industrial electron tubes.

Compressor shrouds for the famous J-57 jet engine are precision brazed with r-f induction heat at Pratt & Whitney Aircraft, East Hartford, Connecticut. R-F power, reliably provided by Machlett electron tubes, permits Pratt and Whitney to obtain the same heat pattern and uniform heat cycle at the root and tip of each blade. A two minute cycle brazes both blade ends simultaneously.

*Machlett induction heater triodes are original components in over 85% of the induction heating equipment models now available in the 5kW to 100kW power output range.



A battery of induction heaters is used in the assembly of Pratt and Whitney's low compressor shroud for the J-57 jet engine.

*The ML-5668 electron tube was designed by Machlett specifically for heavy duty industrial applications.

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