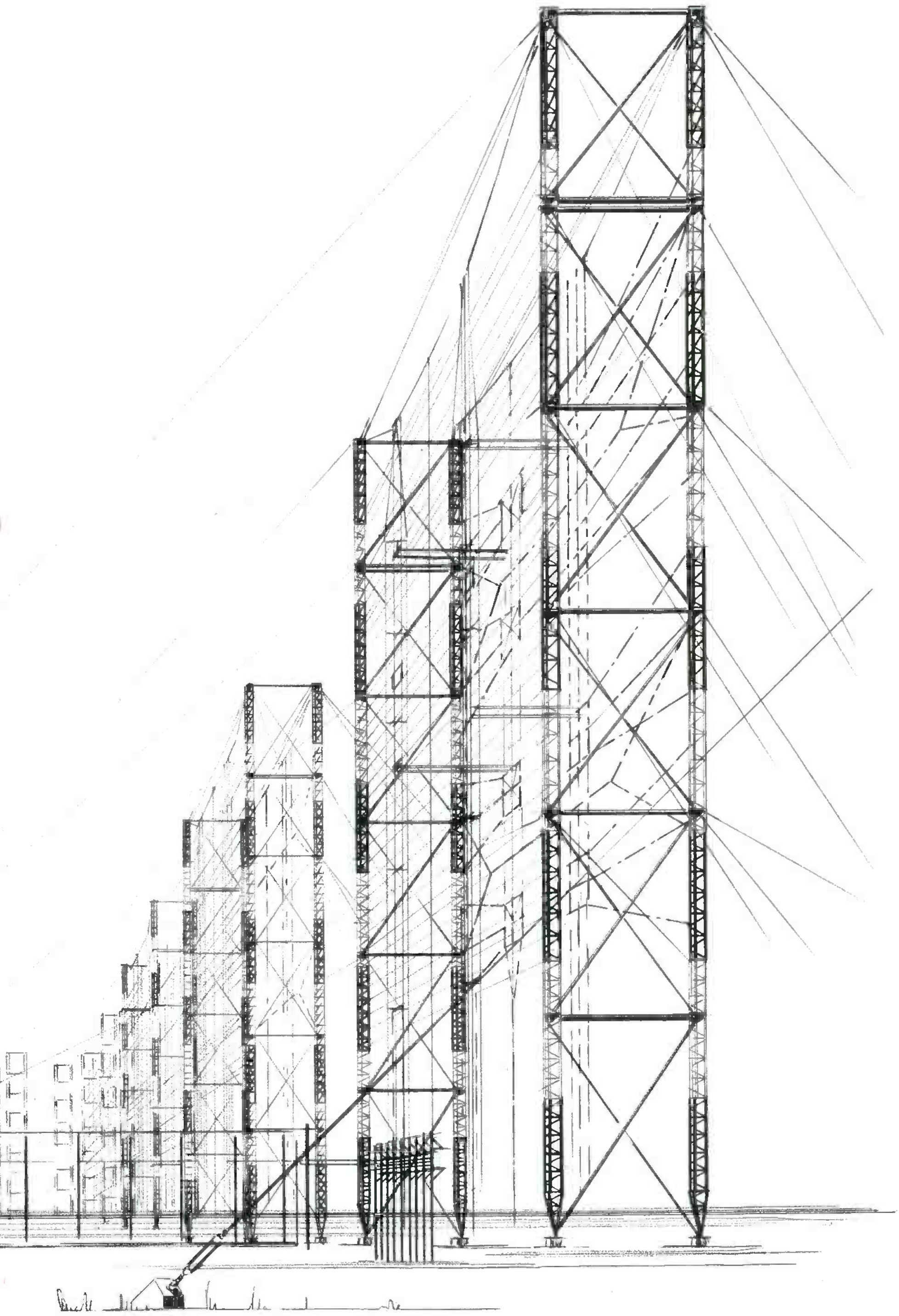
MACHLETT CATHODE PRESS



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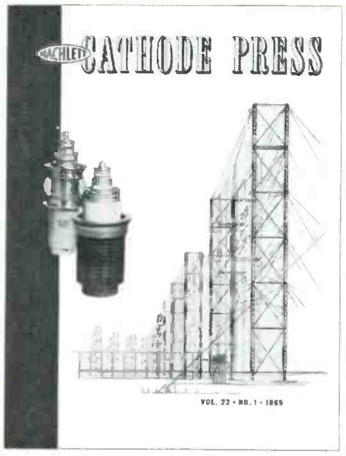

COVER . . . illustrates a portion of the Voice of America complex at Greenville, North Carolina, which consists of 18 broadcast and 4 communications transmitters, and 64 antenna systems. See article starting on Page 2.

MACHLETT CATHODE PRESS

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The Voice of America

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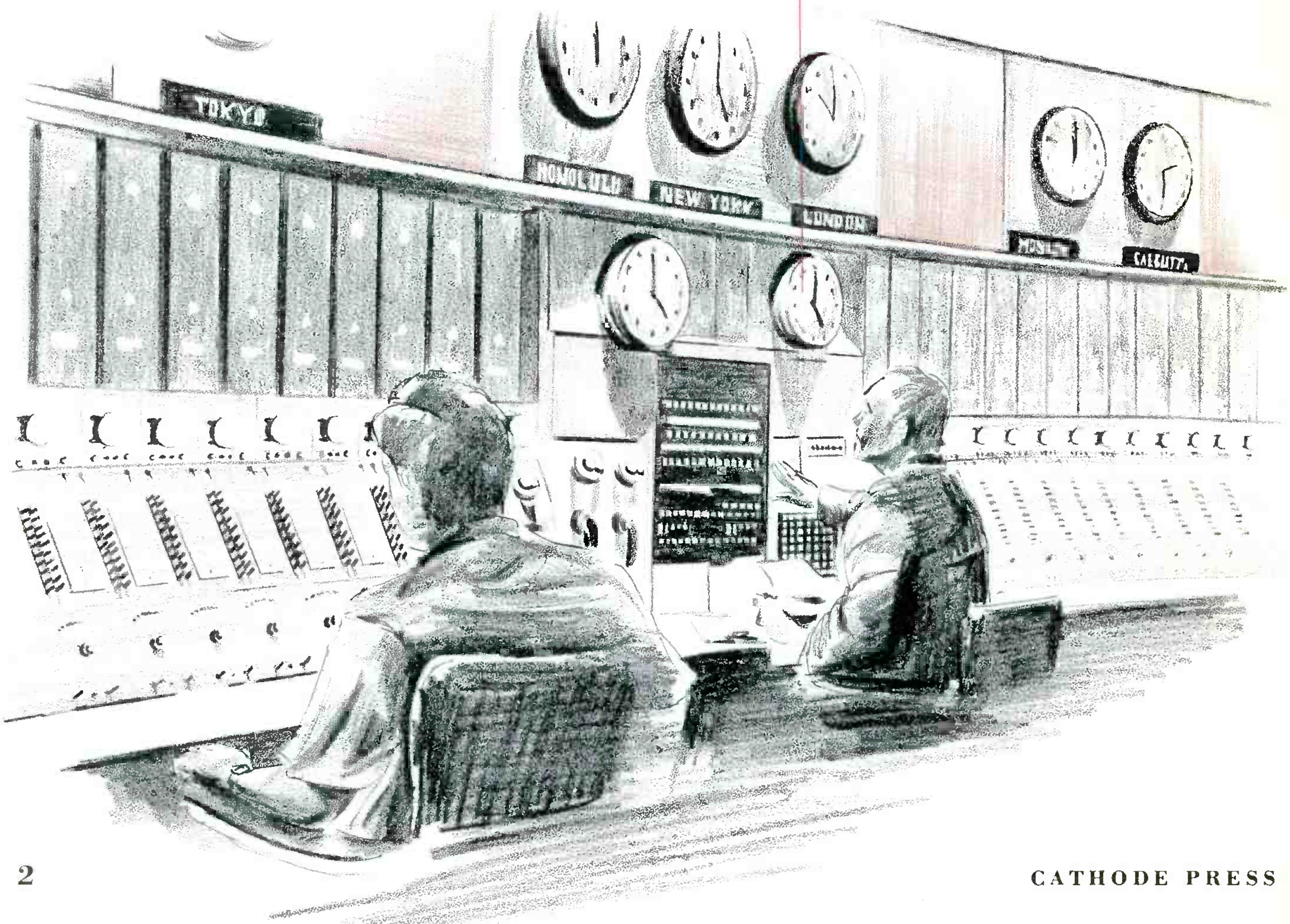


Editor's Note:

In publishing this article on the growth, and present stature of the Voice of America, CATHODE PRESS continues a tradition of long standing, one which began in 1952, Vol. 9, No. 3, with the publication of Foy D. Kohler's "This is the Voice of America". (Mr. Kohler then was Chief IBS; he is now the United States Ambassador to Russia.) This was followed, Vol. 9, No. 4, by "The Voice of America" — a description of the development of Voice's transmitting facilities — by George Herrick and Raymond Kaplan. Vol. 10, No. 1 carried an article on the 4 Mw peak power AM transmitter, employed by the VOA in Europe, and finally, in Vol. 19, No. 1, 1962, there appeared an article on the new, and immense, Voice installation in Greenville, N.C., entitled, "Vapor Cooling: Its First Major American Installation in the New 250 kW Voice of America Transmitter"; a subsequent issue of CATHODE PRESS will carry a complete description of this facility. Limited copies of the above mentioned issues are still available. It is with a pleasure borne of a long friendship that we present here the work of Messrs. Burgeni, Jacobs and Martin of the United States Information Agency.

— A Generation of Growth

Thirty-six years is hardly a lifetime, and yet it more than encompasses the full life history of what we know today as one of the most extensive technical systems in the world for communicating ideas through the use of electromagnetic radiation — the Voice of America.

Back in 1928 our economic world was in the full flush of a boom following the depressions caused by World War I. Radio, the airplane and the motor car, together with assembly line production techniques were the progressive hallmarks of our advancing industrial civilization.

The art of electronic communication had become commonplace, but relatively little was really known about the behavior of long distance transmissions via the high frequency bands of the radio spectrum. Even less was known of the power to influence men's minds by ideas transmitted through the means of radio.

However in the United States, several experimental licenses were granted for facilities to operate on high frequencies. A few pioneering broadcasters in this country as well as others elsewhere extended their interest to the shortwaves.

The large American electrical manufacturing companies engaged in shortwave broadcasting primarily to develop and publicize their products and thus create a market for devices of their own manufacture. This scheduled use of the shortwaves gave promise of expanded foreign trade for the manufacturer. Similarly the growing networks — NBC and CBS — having found success in the domestic field had visions of a world market for the sale of advertising time used to promote and sell the new and useful products of our age, and they too erected and operated shortwave transmitters.

By 1936, partly because of the public interest in the Olympic Games staged that summer in Berlin and the growing awareness of the rise of fascism and related political unrest in the world, shortwave broadcasting began its first early expansion. Ownership of an all-band receiving set became a status symbol of the times.

The next three years, 1936 to 1939, were crucial in the history of international broadcasting. The birth of the German Third Reich and the creation of the Hitler-Mussolini Axis brought forth an intense interest in improved communications for world wide direct coverage of news events as they occurred. Memorable were the rantings of the Bavarian housepainter who screamed and shouted his demands and threats across the miles. Through the medium of radio broadcasts, he and his minions were able to create fear, arouse internal conflicts among the populations of neighboring countries, and to weaken resistance to his aggressive intent.

Following the outbreak of hostilities in Europe in 1939 and the increase in international unrest in succeeding years and culminating in the attack on Pearl Harbor in December of 1941, the significant importance of a means for getting people to know what was happening and to attempt to influence their attitudes was fully recognized.

We in America had observed the success which Herr Goebbels and his Italian counterpart had achieved through the use of approximately fifty transmitters broadcasting intensively from Germany and Italy to the rest of Europe and particularly to France and the low countries. This highly organized official voice of German policy played a significant role in undermining the will to resist of the Czechs, the Poles and ultimately the Belgians, Dutch, French, Danes, and Norwegians. This propaganda machine, so effective in the initial stages of World War II, gave the word "propaganda" its present evil connotation.

It was here that what we now know as the Voice of America began.

In 1942 the entire shortwave broadcasting facilities of the United States consisted of twelve shortwave broadcast transmitters in scheduled operation. NBC had two 50 kw transmitters at Boundbrook, New Jersey. CBS had two 50 kw and one 10 kw at Brentwood, Long Island. Crosley had a 50 kw at Cincinnati, Ohio. Westinghouse had another at Boston. GE had two 50 kws at Schenectady and one more on the west coast at Belmont, California and WRUL operated a 50 and a 20 kw transmitter under the sponsorship of an educational foundation from Scituate, Massachusetts.

In addition the common carriers A T & T, Press Wireless, RCA, and MacKay had a limited number of low powered transmitters normally used in conjunction with their point to point traffic which were capable of being used for voice communication.

In the period prior to December 1941 (Pearl Harbor) and immediately following, the individual private broadcasters listed above were all actively engaged in broadcasting in a variety of languages to selected target areas. Program content was news, sports, cultural features, entertainment, religious programs and educational subjects. When the United States became engaged in the hostilities, the stations all immediately limited their program content to subjects permitted under the directives of the Office of Censorship. Broadly stated this limitation forbade broadcast of material inimical to the best interests of the United States or anything which might give aid or comfort to the enemy. Indeed, it was during this brief time, that the several skilled and dedicated individuals who found themselves engaged in what later became known as psychological warfare sought to help "win the war" by the persuasiveness of the ideas which they were able to present to both friendly and enemy foreign listeners.

The only thing wrong with this approach was that outside of the United States, the world knew only of official radio. The voice that spoke from the loud speaker in nearly all countries but ours was always the voice of government. The uncertainty, the confusion and the questions that arose in listeners' minds as to what the United States' abilities and intentions really were may be imagined when they heard one version of the news or an editorial reaction expressed by someone speaking for one network and something presented perhaps somewhat differently by another commentator from another network.

It was here that the National interest first took hold and the private broadcasters began to pool some of their most effective efforts into network operation. CBS, NBC, GE and Crosley began to share technical facilities and talent, each carrying the others' best offerings to the benefit of all concerned. The Office of War Information, created to help provide orderly insight to the American people about the extent and progress of our National war effort, soon branched into the foreign information activity and furnished, first, script material for the use of the shortwave network and, later, actual programs for broadcast over the several or combined facilities.

By November 1942 and in time for the first important American combat operations of World War II — the invasion of North Africa — the Overseas Division of the Office of War Information was established, and through it the Government contracted for and obtained the use of the international broadcasting capability of all of the private licensees.

Here began the second phase of the Voice of America, its growth and expansion to meet the needs of a world in peril.

Not only was centralized "official" programming a practical necessity for our war effort, but the means to ensure that the programming could be heard was equally a priority matter.

Additional facilities were needed: more powerful transmitters to provide stronger signals in more places on the earth; increased effective radiated power through the design and construction of more efficient antenna systems; relay stations located closer to ultimate target areas to provide that extra margin of signal and intelligibility that would get the message to the listener. These were what were needed and built and put into operation.

First, additional facilities were built at existing domestic locations; four more 50 kw transmitters at Boundbrook bringing the total to six; another at Brentwood, Long Island; a new 100 kw (the first really high power unit) at Schenectady; another 50 kw at Cincinnati; a 100 kw at Belmont, California. During this same period a new plant with one 50 kw and one 100 kw transmitter was built near San Francisco; another with two 50's was built at Wayne, New Jersey; six more very high powered units (rated output 110 kw each) were installed near Cincinnati. In 1945-1946 six more transmitters, consisting of a total of two 200's, and four 50's were installed at two locations on the west coast, one half the units at Dixon, California and the others at Delano, California. Three more 50 kw transmitters were installed at Scituate, Massachusetts and the original 20 kw unit was upped in power to 80 kw. By 1952 four additional 100 kw units were added to the west coast plants.

Now the Voice of America was more clearly heard with

42 transmitters broadcasting from the United States in 46 languages with an output of about 50 program hours daily or approximately 125 separate programs — each 15 minutes to an hour in length. This output was more than 365,000 words, or the equivalent, if printed and bound, of five novel length books written and broadcast daily.

Hand in hand with the growth of facilities at home came a corresponding and related expansion of facilities capability abroad.

The changing political scene, with the overthrow of the Axis aggressors and the emerging power and expansion of Soviet Communist influence in the World, created new obligations and pressures on the Information Agency. The need for a truly global network capable of meeting our national needs in this rapidly changing World was recognized by the Agency and plans were approved as presented to the Congress.

Development of the Global System

In developing a global radio network, three major technical problems had to be resolved. The first of these was to overcome the deterioration of the signal that occurs in broadcasting from the United States through the northern auroral zone to East Europe and Asia. Figure 1 shows how the shielding effect of the auroral zone prevents direct broadcasting from the United States to many areas of the world on the consistent basis needed to attract and hold an audience.

The second problem was that of overcoming the vast distances between the United States and other major areas of the world with a signal strong enough to be heard competitively in those areas.

The third major problem was to overcome Communist jamming which, beginning in 1948, sought to prevent clear reception of USIA broadcasts in the languages of the USSR, the Soviet satellites, and more recently China and Cuba.

Operational experience gained during the war years clearly indicated that effective world-wide broadcasting required a carefully developed integrated network or system of facilities, especially designed to deliver a strong technically competitive broadcast to a listener in any selected area of the world on either the short-, medium- or long-wave broadcasting band — whichever is popular in the specific area and can be picked up by most of the available receivers.

Long-range forward planning is essential in the development of such a system. It cannot be developed piecemeal, but must take into account all the interrelated elements of

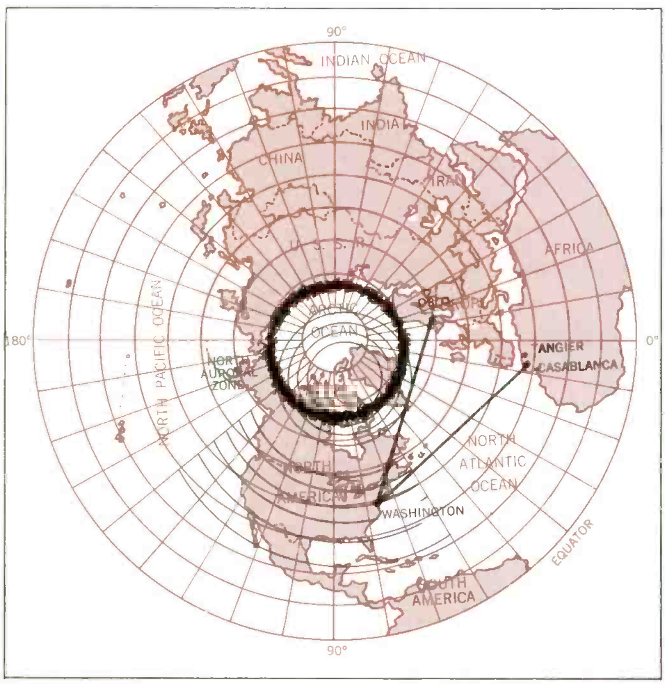


Figure 1 — Shows auroral zone through which VOA transmissions from the U.S. is heavily distorted or absorbed. Note shortwave transmission from New York to Tangier, Morocco Relay Station does not pass through auroral zones.

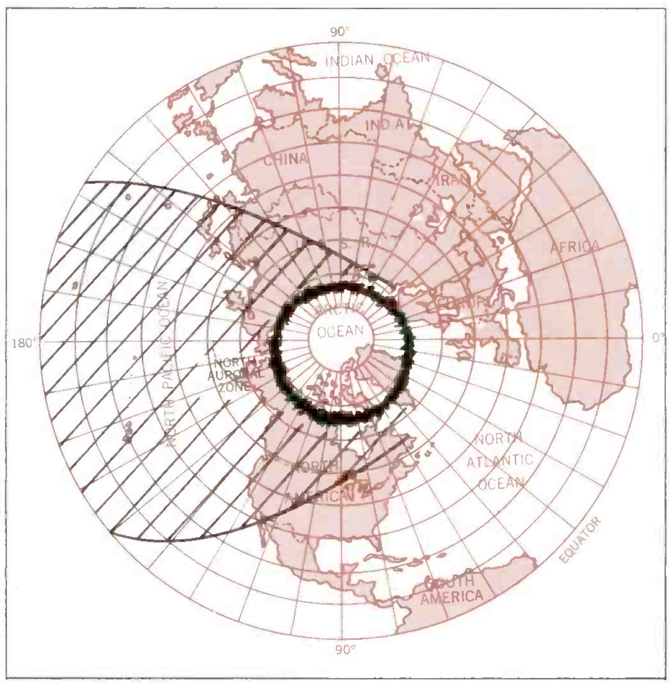


Figure 2 — Shows effects of auroral zone on transmission from Tangier, Morocco. Note that areas shielded from the U.S. in Figure 1 can be reached without difficulty from the VOA Relay Station at Tangier.

Figure 3 — Part of transmitter room of the VOA Philippines Relay Station showing Machlett ML-5682's in Continental 1 Mw medium-wave transmitter which broadcasts to Asia on 1140 kc.

the system. In the case of international broadcasting, the system begins at the microphone and ends in the receiver of the listener. In the technical development of the VOA, the "systems concept" — that of considering the performance of the system as a whole — has been of paramount importance.

Relay Stations

The development of the VOA facilities system centers upon the use of overseas relay stations, at locations where it is possible to take maximum advantage of favorable radio propagation conditions, to overcome the problems facing direct shortwave broadcasting from the United States.

While the transmission paths passing through the auroral zones are heavily distorted and absorbed, paths that do not pass near the auroral zones are not affected by this phenomenon. In Figure 1, for example, the circuit from New York to Tangier, Morocco, does not pass near the auroral zones, and it is therefore possible to maintain a reliable program service from the United States to Tangier by shortwave.

The effects of the auroral zone on circuits from Tangier are indicated in Figure 2. It can be seen, by comparison with Figure 1, that the very areas that are shielded from the United States can be reached without difficulty from Tangier. Therefore, programs transmitted to Tangier can be simultaneously relayed from Tangier directly into European or Near and Middle Eastern target areas— areas that cannot be reached effectively directly from the United States. By the use of strategically located relay stations, the auroral zone can be by-passed and technically effective transmissions can be delivered to target areas that are normally shielded from direct transmission from the United States.

Auroral zone by-passes to other areas of the world can be achieved by locating relay stations in, for example, Hawaii and the Philippines. Both the fundamental problems of distance and auroral zone absorption can be solved by this relay station concept. Relay stations in such locations can receive shortwave transmissions directly from the United States with the least possible effects from auroral zone absorption. After receiving the transmissions, the relay station can boost them in strength and simultaneously relay them directly into selected target areas on the broadcast bands that are popular in the areas and lie within the range of most of the available receivers.

Based upon this concept, VOA relay stations have been established at various locations throughout the world. Each station is a complete self-contained installation with its own diesel-power plant, small studio complement, receiving station for program reception, high-power short, medium and longwave transmitting facilities, and point-to-point radio teletype communications facilities.

The relay stations are integrated into a single system so that they can be fed programs directly from the United

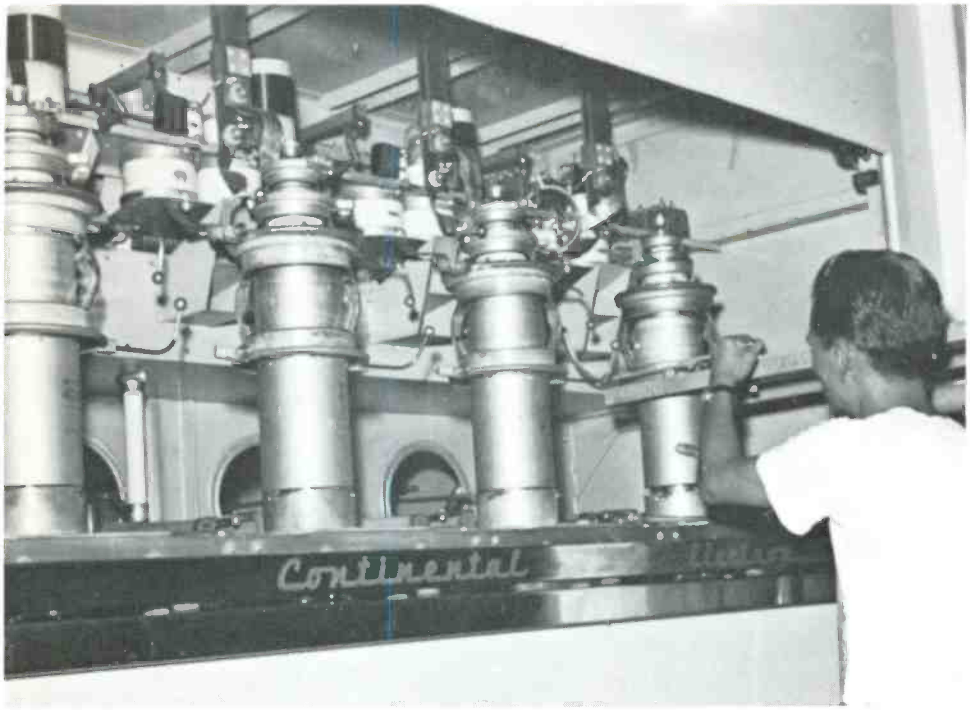


Figure 4 — Technician at Philippines Relay Station checks Machlett ML-5682 tubes in power amplifier of one megawatt transmitter.

States, or from another relay station.

The overseas relay system of the VOA consists of the following:

1. *Tangier, Morocco:* This station is used primarily as VOA's main gateway to Europe, North Africa and the Near and Middle East. At Tangier, the major facilities consist of ten shortwave transmitters ranging in power from 35 to 100 kilowatts. Twenty-five rhombic antennas are available for beaming programs to the various target areas. Figures 3 and 4 are interior and exterior views of the Tangier Relay Station.
2. *Munich, Germany:* This location is close enough to the Central European target areas so that the medium wave band can be used, as well as shortwave. The station consists of four shortwave transmitters ranging in power from 75 to 100 kilowatts, and several lower power transmitters. A 300 kilowatt medium-wave transmitter operates on a frequency of 1196 kc. Seventeen shortwave antennas are available for coverage of Europe, the Eurasian areas of the Soviet Union, Near and Middle East, and parts of Africa. The medium-wave antenna is a 4 element array providing four separate patterns each beamed towards a desired European target area. This antenna system is designed for sky-wave radiation out to about 500 miles from Munich. During the post war years and when Soviet jamming was at its height, the Agency built and established a very high powered (megawatt) long wave transmitter at Munich which operated from 1953-1964 on 173 kc. The antenna consisted of a single top loaded tower over 900 ft. high designed for omnidirectional radiation to provide coverage of Central Europe. In February of 1964, use of this transmitter was suspended when the Russians ended their jamming activity. The plant is currently in reserve in case its mighty signal suddenly becomes needed again.
3. *Thessaloniki, Greece:* This relay station was engineered to take advantage of its proximity to the Balkan target areas. The station consists of four 35 kilowatt shortwave transmitters, and a 50 kilowatt medium-wave transmitter operating on a frequency of 791 kc. Twelve shortwave antennas are available for coverage of the Balkans, the western Soviet Union, East Europe, the Near and Middle East. The medium-wave antenna consists of a 2 element directional array providing a reversible cardioid pattern with one beam centered to provide sky-wave coverage of the Balkans and the other to provide coverage of Greece.
4. *Rhodes, Greece:* VOA's station at Rhodes is used primarily for covering adjacent areas of the eastern Mediterranean. A 150 kilowatt medium-wave transmitter beams broadcasts to this area, primarily in the Arabic language, for approximately nine hours a day on a frequency of 1259 kc. Two 50 kilowatt shortwave

transmitters reinforce the medium-wave coverage. The medium-wave antenna consists of a three-tower array, producing a coverage pattern in the eastern Mediterranean similar in shape to a cardioid. Six shortwave antennas are available for beaming shortwave transmissions into the intended coverage area. From late 1951 and until May, 1964, VOA transmitting facilities at Rhodes were housed aboard a docked vessel, the U.S. Coast Guard's Courier. Since May, 1964, new land-based facilities have replaced those previously housed aboard the Courier.

5. *Philippines:* VOA maintains transmitting facilities near Manila and San Fernando on the Island of Luzon. These facilities consist of nine shortwave transmitters ranging in power from 35 to 100 kilowatts, a 50 kilowatt medium-wave transmitter operating on 920 kc, and a 1,000 kilowatt medium-wave transmitter operating on 1140 kc. There of the shortwave transmitters are transportable, and have been installed recently to provide increased VOA coverage of Southeast Asia. Twenty-five rhombic antennas are available for beaming shortwave broadcasts over an arc extending from Korea to India. The 50 kilowatt medium-wave transmitter uses a six-tower array for sky-wave coverage of the Philippines and adjacent areas of Southeast Asia, while the megawatt transmitter uses a four-tower array which produces three separate beams directed towards Southeast Asia and parts of China. This antenna system increases the effective power of sky-wave radiation to 3,500 kilowatts in certain directions.
6. *Okinawa:* VOA's Okinawa installation completes the Far Eastern coverage by beaming short- and medium-wave broadcasts to northern and central Asiatic areas. This station consists of three shortwave transmitters ranging in power from 35 to 100 kilowatts, and a 1,000 kilowatt medium-wave transmitter operating on 1178 kc. Six rhombic antennas direct shortwave transmissions to Siberia, the Far East, China and Central Asia. The medium-wave antenna consists of a six element array producing two beams directed towards China, Manchuria, Korea and Soviet Far East. In addition, two low-powered shortwave transmitters are used to augment the coverage.
7. *Colombo, Ceylon:* This installation, operated for VOA by Radio Ceylon in accordance with an agreement between the Governments of the U. S. and Ceylon, is intended primarily for coverage of India and Pakistan. The station consists of three 35 kilowatt shortwave transmitters. A large number of curtain arrays are available for beaming broadcasts to India, Pakistan, and adjacent areas.
8. *Wooferton, England:* Six 250 kilowatt and two 50 kw shortwave transmitters, operated for VOA by the British Broadcasting Corporation, on a contractual basis, beam Voice broadcasts to Europe, Africa and the Near and Middle East. Thirty-five high-gain curtain antennas are available for directing these transmissions to their target areas.
9. *Honolulu, Hawaii:* This station, located in the nation's newest state, serves as an auroral by-pass to the Far East and Southeast Asia. It consists of two 100 kilowatt shortwave transmitters and seven rhombic transmitting antennas.
10. *Monrovia, Liberia:* VOA's installation near Monrovia consists of six 250 kilowatt and two 50 kilowatt shortwave transmitters intended for coverage of the entire African continent. Twenty-nine high-gain transmitting antennas are available to beam VOA broadcasts over a wide arc from the Mediterranean to the South Indian Ocean. This installation came into full operation during 1964.

Modernization Needs Stimulate New Facilities

The overseas system of the VOA, consisting of fifty-nine high-power transmitters, effectively by-passes the auroral zone and bridges the vast distances between the U.S. and the target areas, enabling VOA to reach listeners with competitively strong signals in the broadcast bands most popular in the areas.

Still the network was not complete. Changing economic and domestic political factors had their effects. As a result of necessary economies in 1953, the Agency cut back some of its stateside facilities, eliminating the most obsolete and least efficient (high cost per KWH on the Air) elements. During this period the domestic system was reduced by 12 transmitters and operations were carried on by the remaining thirty.

Meanwhile the Soviet jamming effort, begun by them in 1948, continued and intensified. At the same time, the Russians and their satellites together with the United Arab Republic and the Chinese greatly increased their shortwave operations with the latter two passing both the BBC and the VOA to take over 2nd or 3rd place (Russia was and is first) in total number of program hours broadcast daily.

Many newly emerging countries and developing nations began, or increased their shortwave broadcasting, too. For these countries, shortwave radio provides an effective, simple and relatively inexpensive means of mass communication. Even the Soviet Union depends to a great extent on shortwave radio for keeping its people in the hinterlands informed.

The increased availability of transistorized radio receivers at steadily lowering costs also played an important part in the upsurge in the popularity of shortwave broadcasting. With receivers independent of power lines and capable of being operated for months on a few cheap batteries, radio could and did penetrate into rural and under-developed areas, opening up vast new audiences, both for the Voice

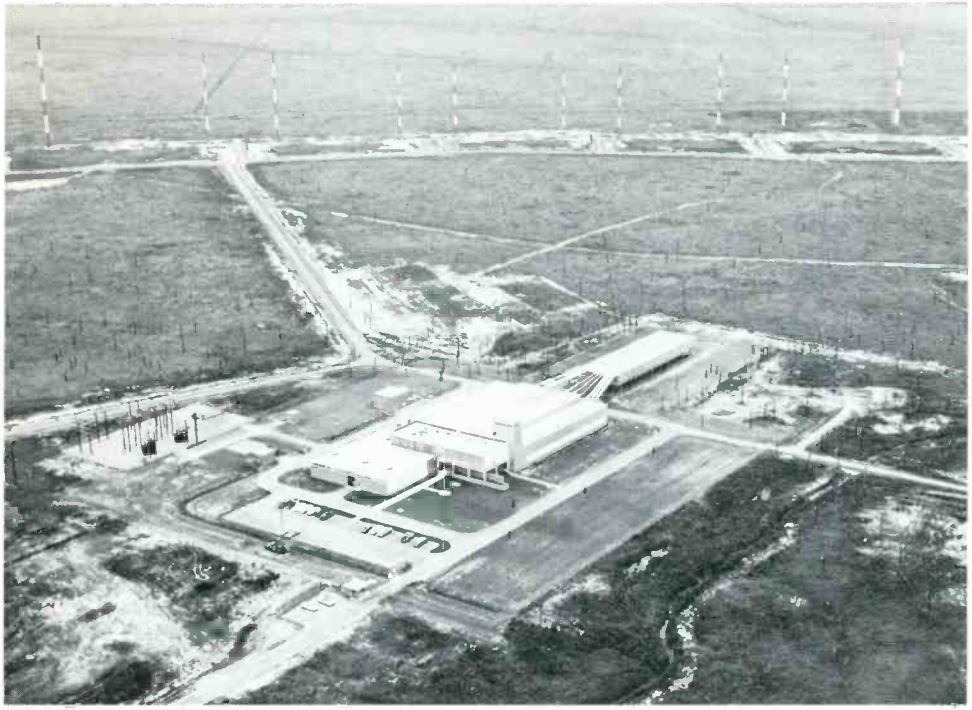


Figure 5 — Aerial view of Greenville, N.C. complex which consists of 18 broadcast and 4 communications transmitters, and 64 antenna systems.

of America and its competitors.

VOA reviewed and reprojected its long-range facilities planning program to meet the growing world competition in shortwave broadcasting. Basically, this plan called for eliminating coverage deficiencies which existed, and for boosting signal strengths in the more important target areas where competition was greatest.

The Greenville Complex

To compete in the now crowded spectrum, higher power and improved antenna systems were required. Plans were developed and construction begun on what has since become known as the Greenville Relay Station near Greenville, North Carolina. This huge complex consisting of 18 broadcast and 4 communications transmitters at two separate locations, a program receiving and distribution center at a third location and 64 elaborate antenna systems is believed to be the largest most powerful radio facility in the world today. Its 22 transmitters consisting of six-500 kw, six-250 kw, six-50 kw and four-5 to 15 kw SSB and communications units radiate a total energy output in excess of 4,800,000 watts. It serves as the primary East Coast feeder for all the European Mediterranean and African relay stations. In addition, it provides direct coverage for African area listeners as well as those in Latin America.

Inauguration of scheduled operations from Greenville in early 1963 made possible a further reduction in the use of the obsolete stateside units at Schenectady, Brentwood and Wayne which had served so faithfully through the war years and beyond.

It serves as the primary East Coast feeder for all the European Mediterranean and African relay stations. In addition, it provides direct coverage for African area listeners as well as those in Latin America.

At the time of writing, plans are going forward for 2 additional major relay stations — one to bolster our signals from the Eastern Mediterranean area and another in the Far East. These projects, now only in the initial phase of development will soon move into the construction phase with air dates set for 1967 or 1968.

Further modernization is under way at the older stateside plants as well. Three of the Bethany, Ohio transmitters will be replaced by modern 250 kw. units. These will strengthen the station in its mission to support the Greenville coverage. The two west coast plants will each be augmented by three-250 kw transmitters and two-50 kw units with completion scheduled for late 1965.

One additional facility placed in operation within 11 days after the site was picked is the medium wave element of the VOA Transportable Station. It, like its shortwave counterparts, is self contained and van mounted. At the time of the Cuban crisis in October, 1962, the transmitter was on the test floor at its manufacturing plant in Texas. A VOA engineering task force was dispatched, some members going to Texas to oversee completion of the transmitter — others to the Florida Keys to locate and negotiate arrangements for a suitable site. By early November the station was on the air with a directional antenna system that enabled it to be clearly audible throughout Cuba.

This then is the Voice of America transmitter system — a vast and complex but highly integrated network of over a hundred modern powerful transmitters, located at 17 stations throughout the world. This system has been designed and operated to the highest standards of the radio transmitting art.

We have described how development of the VOA network overcame the first two problems affecting our ability to deliver useful signals to target area listeners. Relay stations provided the essential by-pass of the auroral zone and high powered close in relay points made our signals strong and competitive. There remained the problem of jamming.

Jamming

Communist jamming of VOA Russian-language broadcasts was first observed in February, 1948. It is believed that the Communists used more than 2,000 radio transmitters to jam Russian, European-satellite and Chinese-language transmissions of the VOA and other broadcasters.

Jamming consists mainly of irritating noises which sound like buzz saws, sirens, white noise, etc., placed on the same frequency as the VOA transmissions for the purpose of making reception of the program difficult, if not impossible. Although intentional interference of radio transmissions violates international radio agreements, these transgressions continue.

The VOA early realized that the most effective way to combat or nullify the effectiveness of jamming was to adopt a dynamic, versatile approach requiring a wide range of latitude in engineering, operating and programming techniques. Such an approach was necessary because there is no single "magic" solution to this problem — a technique that is successful today may be blotted out by increased jamming efforts tomorrow.

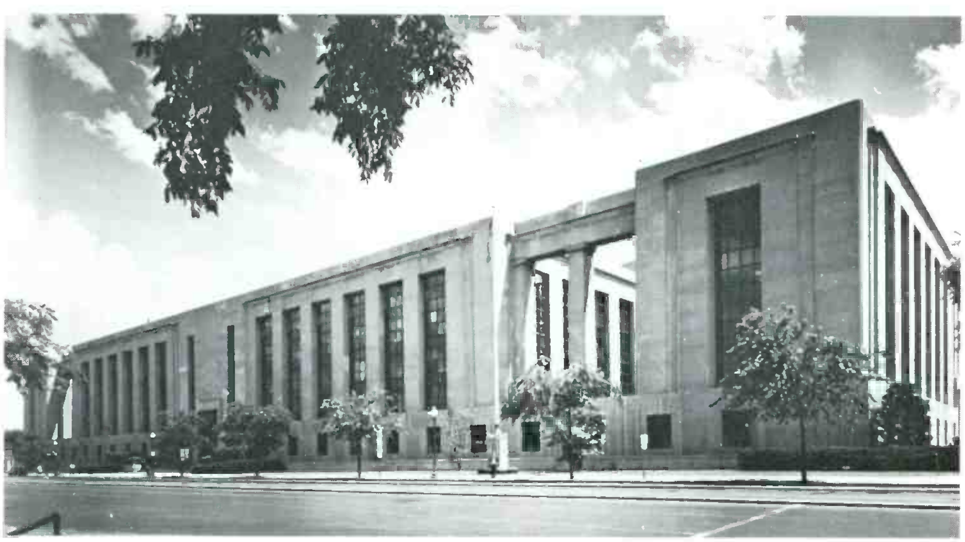
Concurrent with the development of the system itself, certain techniques have been devised in the form of electronic devices such as heterodyne filters, speech clippers, exalted carrier-type receivers, etc., the use of high-power transmitters and high-gain antennas, the advantageous use of favorable propagation conditions when these exist, the transmission of the same program simultaneously from various relay stations located at different geographical locations, broadcasting on an around-the-clock basis, increasing the number of broadcasts in the English language, which is not jammed, as well as continuous study of the problem. These have permitted various degrees of, and in some cases complete, penetration of the jamming barrage.

Recently for reasons best known to themselves, the Russians and some of the satellites (Rumania, Hungary, Czechoslovakia and Poland) discontinued jamming. Whether this was a move to reduce tension of the cold war or whether they found it no longer practical to pour out vast energy in a vain attempt to keep their people from hearing free uncensored ideas is a matter for conjecture. Of significant importance is the fact that we have now entered a new phase in the life of the Voice of America. A period in which VOA broadcasts can be heard louder and clearer than ever before.

Washington Headquarters

For the most part, VOA programs originate from its Washington, D. C. headquarters plant. The Washington facilities, located at 330 Independence Avenue, S. W., include nineteen studios, equipment to make forty different disc or tape recordings simultaneously, ten tape-editing booths, a

Figure 6 — Headquarters and studios for Voice of America are located in the Department of Health, Education and Welfare Building, 330 Independence Ave., Washington, D.C.



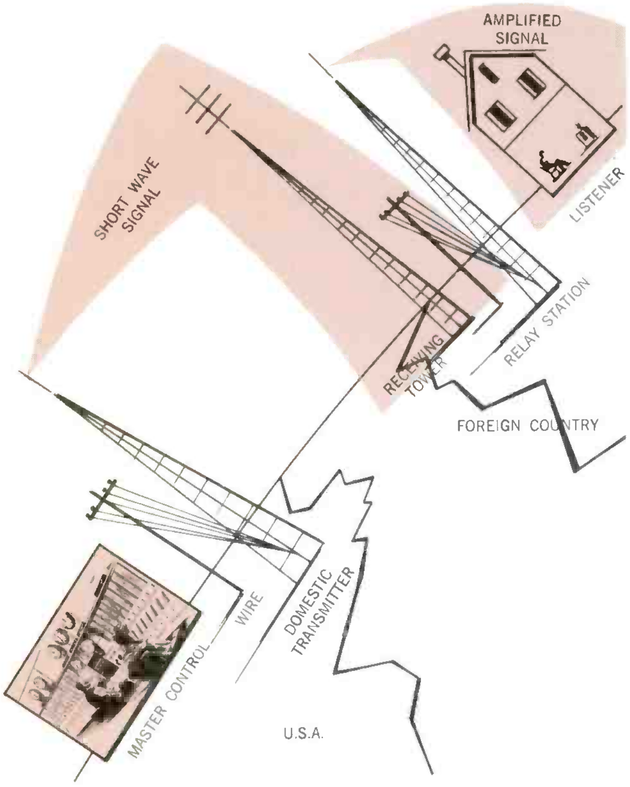


Figure 7 — Shows pictorially how VOA broadcasts originating in the Washington studios are transmitted to foreign listeners.

recording control center, the Master Control, engineering offices, editorial offices, music and transcription libraries, and various other service units which are required to keep VOA in operation twenty-four hours a day.

VOA's Master Control is one of the largest and most flexible in the world. It feeds programs originating in VOA studios, through special telephone circuits, to the shortwave transmitters in the United States. The Control Console (see Page 2) is capable of selecting program material from one hundred sources and of handling twenty-six programs simultaneously.

This rounds out the systems concept of the VOA worldwide international broadcasting network. VOA broadcasts originating in studios located in Washington, D. C., are fed through appropriate control equipment and landline circuits to any of the feeder transmitters located at the seven plants in the Continental United States. These programs are then broadcast over the high-power shortwave "feeder" transmitters, employing high-gain directional-antenna systems, to any one of the high-power transmitters located at the overseas relay points throughout the world. The circuits to the relay stations by-pass the auroral zone of exceptionally heavy rf absorption. The relay stations, located at optimum distances from the selected target areas boost the level of the signals received from the "feeder" transmitters and simultaneously relay the broadcasts directly into the target areas on either short, or medium-wave broadcasting bands, whichever are popular for broadcasting in the target areas. Often during periods of favorable propagation conditions, secondary target-area coverage is also obtained directly from the transmitters located in the continental U.S.A.

Figure 7 shows pictorially how VOA broadcasts originating in the Washington studios are transmitted to overseas listeners. Figure 8 shows the areas of the world that VOA broadcasts now reach.

Science and Research

Research has played an important part in the development of the VOA broadcast system. The VOA has established, during the development of this system, a research program at various colleges and universities, other Government departments and agencies, and commercial research organizations having experience along the lines most important to the technical development of the VOA. In general, this research program has explored the broad field of electronics, communications, and radio propagation. VOA's research program played a very significant role in the early development of ionospheric scatter communications, advancement of the state of knowledge concerning auroral and other anomalous types of radio propagation, and development of high-power transmitters, high-speed self-calibrating modulation monitors, peak audio clippers and other devices which have benefitted both the VOA and the communication field in general.

VOA is keenly aware of the necessity for keeping abreast of technical improvements in broadcasting and communications. To focus attention on scientific research and development, VOA often calls upon specialists from the academic world, industry, and Government to serve both as an informal forum for review of technical plans and as a source of technical ideas and information. Through this arrangement, VOA has available to it for consultative purposes, some of America's engineering and scientific leaders in the field of communication.

VOA is actively participating in Governmental long-range planning for space communications. It has urged that international radio and television broadcasting be considered as a high-priority goal for this country's space communications program.

VOA also participates actively in the Inter-departmental Radio Advisory Committee (IRAC) and other Government and international groups concerned with telecommunications planning.

Engineering Personnel

The Office of the Engineering Manager, VOA's engineering headquarters in Washington, is made up of approximately two hundred engineering, communication specialists, technicians and supporting clerical personnel. Of this number, more than one-fourth hold degrees in the various fields of engineering or associated sciences, or are registered professional engineers. Overseas, VOA employs approximately 750 communication specialists and technicians, 100 of whom are American.

Effectiveness

The question may certainly be asked whether all these technical facilities are effective — can the VOA actually be heard well throughout the world. To determine how well the VOA can be heard, monitoring stations have been set up in key areas throughout the world to act as "ears" for the VOA. At each of seven monitoring stations, manned by trained technicians, all VOA language broadcasts to the particular areas are monitored under reception conditions that are typical for the average listener in the area. Reception information amassed at these monitoring stations during 1963, amounted to well over a million individual monitoring observations. Over 90% of the VOA programs monitored were reported as being received satisfactorily.

The Agency's Research and Reference Service conducted a series of transistor radio contests during 1963 to determine the size, composition, and geographical distribution of VOA's audience for specific language broadcasts.

To participate in the contest in which portable transistor radios were awarded to winners, listeners were asked to send to the Voice of America the following information: name and address, age, sex, occupation and the date and program on which they heard the contest announcement. (Announcements were made daily for a one-week period.)

As a result of a recent transistor radio contest conducted for VOA English language broadcasts, a total of more than 85,000 cards and letters were received from listeners in one hundred and sixty-seven countries and territories from every corner of the world.

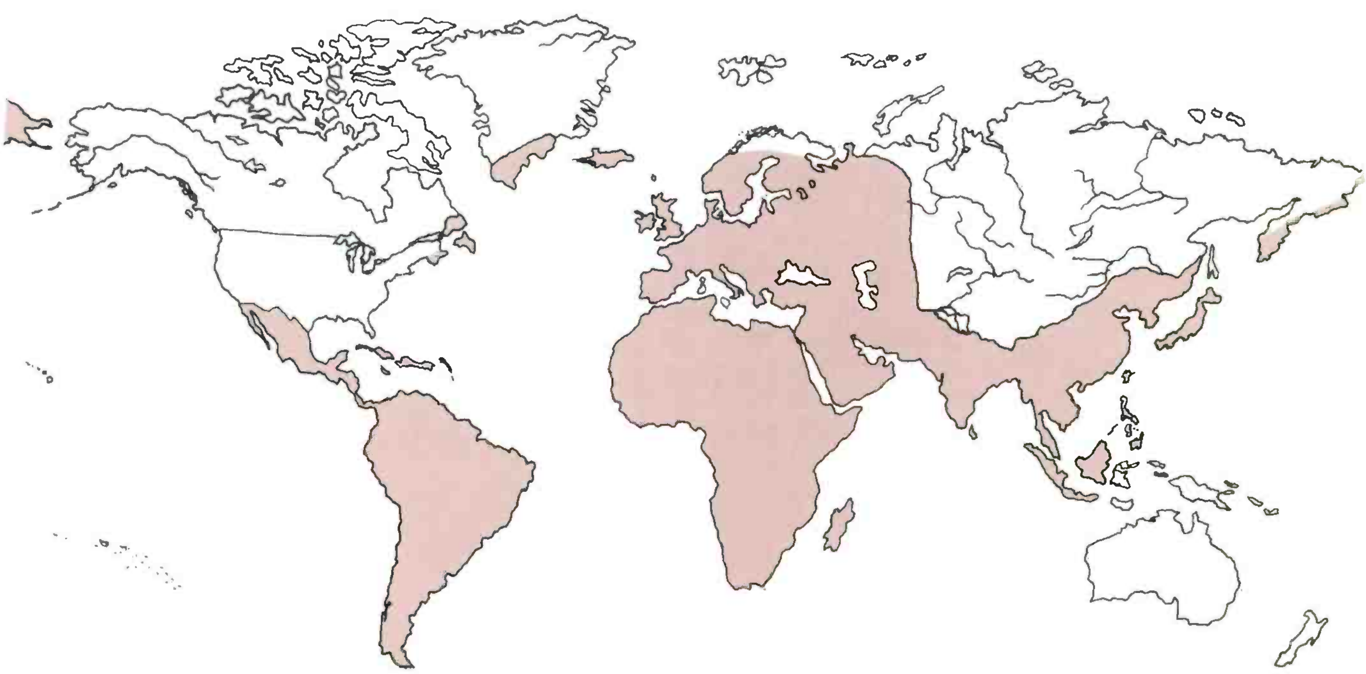
Based on such contests, and material from several other research sources, it is now estimated that between seventeen and twenty-six million people tune in a VOA broadcast during a typical day!

Technical monitoring conducted on-the-spot, scientific surveys and contests and letters from listeners all provide convincing evidence that the VOA's world-wide international broadcasting system has been successful in overcoming the natural and man-made obstacles and is getting through well with its message from America.

The Voice of America, broadcasting through its technical facilities, seeks only to be the radio mirror, without distortion, of America and the American people.

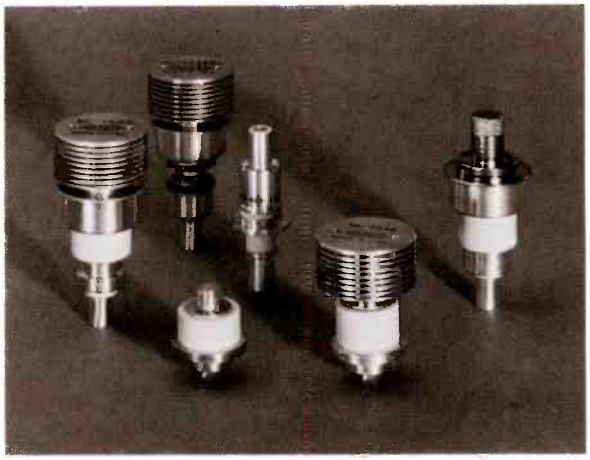
The Voice of America's Washington studios are located at 330 Independence Avenue, S. W. Free public tours are conducted from 9 a.m. to 5 p.m., Monday through Friday, holidays excepted and visitors are cordially invited.

Figure 8 — The Voice of America broadcasts around-the-clock programs to a daily audience of between 17 and 26 million listeners in all corners of the world. VOA's transmission coverage includes areas shown in tinted sections of the map below.



The Reliability of the Machlett Planar Triode

Because of the emphasis being placed on reliability in recent years, it will be the policy of CATHODE PRESS to revise the failure rate figures[1] periodically as additional experience is gained from the life tests being conducted per the requirements of the respective military specifications. During the period, from 12/1/63 to 12/29/64, no failures occurred. This added information not only improves reliability figures but provides, as well, assurance that Machlett's high quality level continued to be maintained.



Tube Type	MIL Spec	Test Description	No. Tested	Total Tube Hours	No. Failed	Failure Rate in % per 1000 Hours Confidence Factor 60%	90%
ML-7289/3CX100A5 Oscillator, Frequency Multiplier Amplifier to 2500 MCS	MIL-E-1/1120B	Group C: Freq = 2000 MC Time — 200 hrs.	133	48,768	1 (2)	4.2	8.0
ML-7289/3CX100A5 Oscillator, Frequency Multiplier Amplifier to 2500 MCS	MIL-E-1/1120B	Group C: Freq = 500 MC Time — 500 hrs.	182	127,515	0	.72	1.8
ML-7815 Grid or Plate Pulsed Oscillator, Frequency Multiplier or Power Amplifier to 3000 MC	MIL-E-1/1429A Navy	Group B: $E_f = 6.0$ Vac. Filament Standby Time — 500 hrs.	260	191,108 PLVS 300,000 Hrs Controlled Field Life	0	.48	1.2
ML-7698 Grid or Plate Pulsed Oscillator, Frequency Multiplier or Power Amplifier to 3000 MC	MIL-E-1/1470	Group B: $E_f = 6.3$ Vac. Filament	207	142,244	0	.65	1.6
ML-6442 Plate-Pulsed Oscillator or Amplifier Frequency to 5000 MC or CW Oscillator, RF Power Amplifier or Frequency Multiplier at Frequencies to 2500 MC	MIL-E-1/1055A	Group C: Freq = d 3450 MC Time — 500 hrs.	170	94,434	1	2.15	4.1

(1) see CATHODE PRESS, Vol. 21, No. 1, 1964.
(2) Catastrophic-Leaker at 1791 hours.

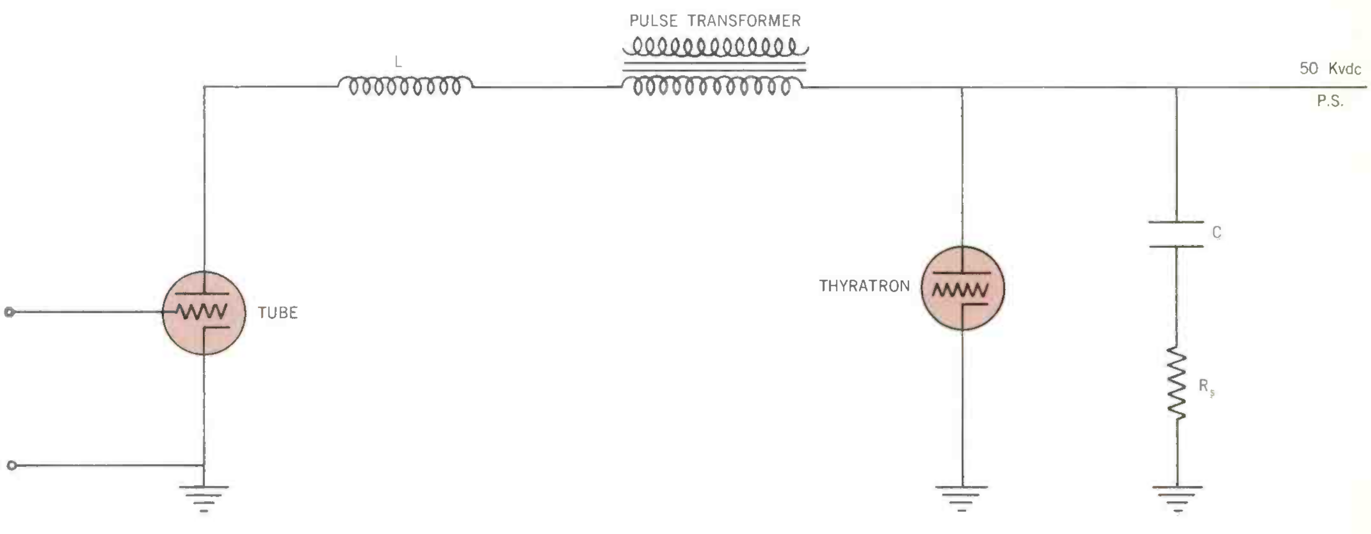
Flash Arcing In Power Tubes Due To Circuit Excited Transients

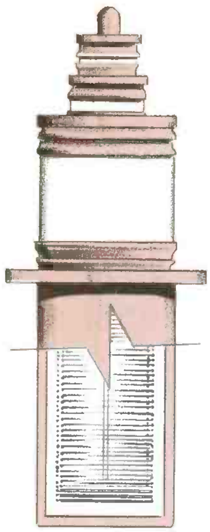
By BARRY SINGER, Development Engineer

It has been known for a long time that transients developed in a circuit containing power tubes may over-volt the tube and cause instability. The instability manifests itself as an internal flash arc. Although the exact nature of the physics of the arc is unknown, there is a great deal of evidence which supports the existence of microprojections from the surfaces of the electrodes which can field emit and may cause high voltage breakdown.

Once a high voltage arc occurs, the probability of a second arc's occurring is greatly enhanced because of the sputtered material from the first arc which can give rise to new microprojections or "whiskers". The power tube designer makes the tube with suitable spacings to hold off the voltage for normal tube operation. However, it is well known that the circuitry of some applications, especially those in which the power supply impedance has a low value, may have a tendency to arc. This is probably because spurious oscillations, transients, and parasites are not damped out and may cause an over-volting on the anode, which will result in an instability. The spacing of importance is the spacing between the anode and the last grid (screen grid in a tetrode, control grid in a triode, suppressor grid in a pentode, etc.). This spacing must be made large enough so that the tube can withstand its rated voltage but must not be too great. If the grid-plate spacing is made too large, the electron space charge makes the tube drop excessive during normal operation, and hence the tube becomes inefficient. Also, an over-spaced tube will have a weak field in the open

Figure 1 — Pulse Generator Circuit.





part of the grid and hence will draw more grid current and generally degenerate the tube characteristics.

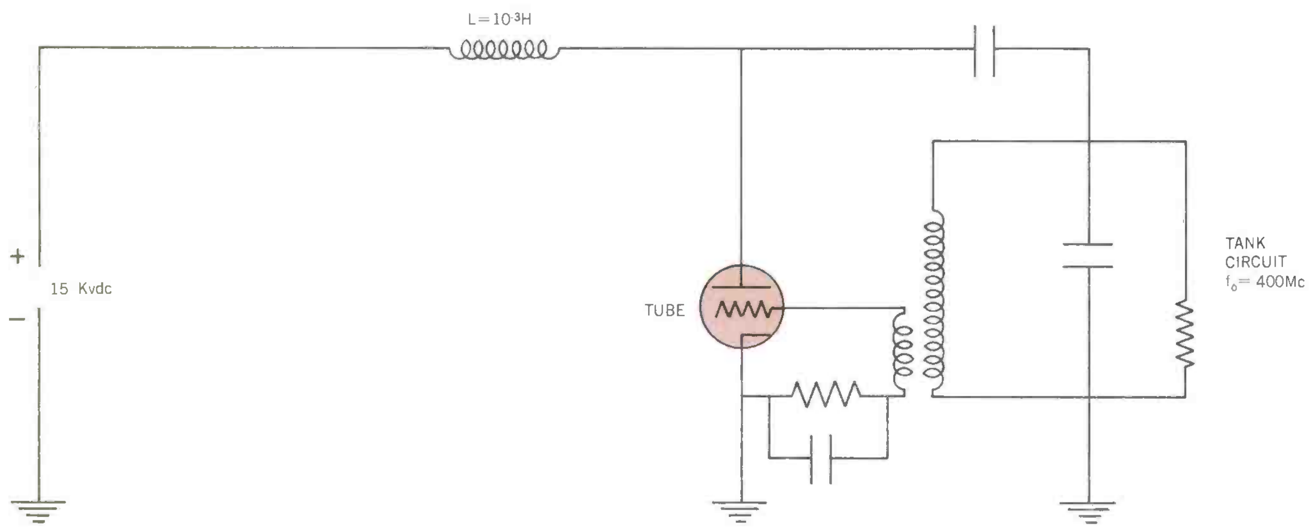
Furthermore, it should be pointed out that vacuum tube breakdown is a statistical event. A vacuum tube may operate stably with only a few kickouts in a thousand hours. However, because of the previously mentioned growths of the microprojections (whiskers) on the electrodes, the tube may suddenly become unstable and arc more frequently. There is considerable debate as to whether the arc is touched off by continued growth or by transients in the circuitry. It is known, however, that the greater the stored energy in the circuit the greater the chance of an arc; and it is more probable that succeeding arcs will occur. However, until a detailed physical understanding of the mechanism of high voltage breakdown is confirmed, it will be very difficult to find a prevention for arcing, except by increased interelectrode spacings. Crowbar circuits substantially improve high voltage stability by diverting energy from the tube in case of an arc. The use of crowbars has long been recommended by tube manufacturers for application of moderately high power and beyond.

Circuit Analysis — Pulse Circuit, Oscillator Circuit

It will be the purpose of this paper to discuss in semi-quantitative detail two vacuum tube circuits. These are shown in Figures 1 (Pulse Circuit) and 2 (Class C Oscillator Circuit) below.

The circuit in Figure 1 is the pulse generator type, and

Figure 2 — Class C Oscillator Circuit.



here the tube is used to generate pulses of current, which in turn may be used to drive a klystron or some similar load. The capacitor element is usually on the order of 1-10 μf for high-power circuits. The inductance is usually stray and depends on the circuit size and the leakage inductance of the pulse transformer. Its value may run between 10-100 μh for high-power circuits. The resistor R_s is put in the circuit to limit surge currents under fault conditions, which protects both the load and the tube by dissipating some of the stored energy in the condenser and preventing ringing. A typical value for resistance R_s is 2 ohms. This value is severely limited and must be small in high-power circuitry. The reason for this is quite obvious. Suppose the circuit has a .1% duty cycle, with 1000 peak amps, in which case the 2-ohm resistor dissipates 2000 watts average power under normal operation. If this resistor had been 10 or 20 ohms, it would provide very good protection for a tube and load that arced; but under normal operation it would dissipate 10 and 20 KW respectively. This would tend to make the circuit inefficient, but also, in order to get the required power output, one would have to increase the plate supply by 10 or 20 kV, which may be too much voltage for the tube to withstand during holdoff, and hence it could tend to be unstable. Also, additional cost is incurred to provide cooling for the 10 and 20 KW of power being dissipated by the resistor.

The second circuit (Figure 2) is typical of industrial heating applications in which the tube runs as a Class C oscillator. If the plate-grid feedback is not present, the circuit is that of a Class C amplifier. Also, if the plate is modulated with audio frequency, it becomes typical of circuits used in high-power AM transmitting. The typical values which are included next to the circuit elements are for the case of industrial heating application at 400 kc/sec.

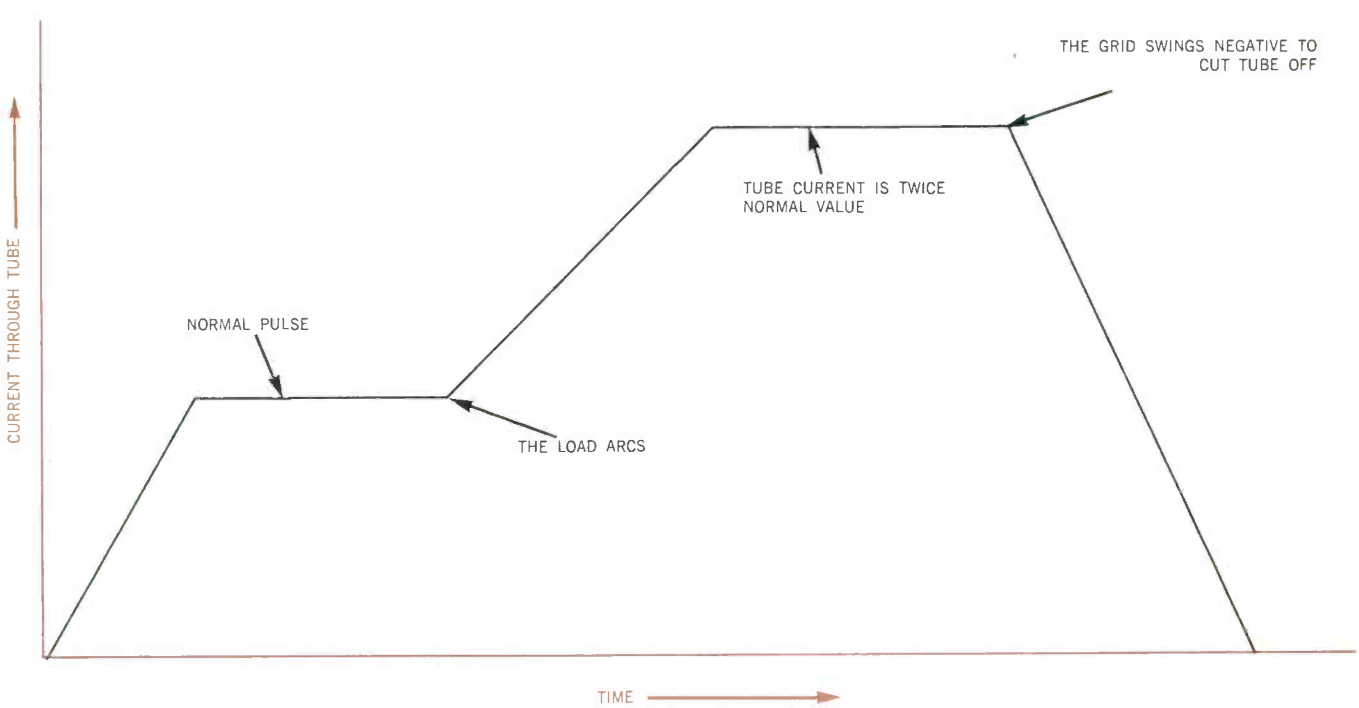
Analysis of Pulse Generator Circuit

Before a quantitative analysis is undertaken, a qualitative analysis, which will describe the situation from the time the load arcs, will be given. When a circuit is operating normally, the tube governs the energy supplied by the condenser to the load. As stated previously, the load may be a travelling wave tube, magnetron, or a klystron, or simply a resistor. During the on time of the pulse, the anode voltage of the tube drops to its minimal value, which is typically 5 kV, while the capacitor remains charged, typically to 50 kV. This means 45 kV is put across the load. If the load arcs, the plate of the tube is "yanked" from 5 kV to 50 kV assuming the resistance for a load arc is negligible.

Figure 3 below shows pictorially what happens.

After the load arcs, the increased plate voltage increases the current to perhaps double what it was under normal operation. Some time later the grid swings negative and cuts the current in the circuit off. It is during this time, when the tube is being cut off, that the changing current through the inductor induces very large surge voltages on the tube, as will be shown subsequently. The surge voltage causes the tube to arc, and thereafter the current is limited only by

Figure 3 — Diagram of an effect of load arc.



the resistance in the external circuit, R_s, and the resistance of the arcing tube, R_t, in series. The usual case is that where

$$\left(\frac{R}{2L}\right)^2 \gg \frac{1}{LC}$$

R is the resistance of the tube and external circuit. As a consequence, except for the first instant, the currents may be obtained from those in an RC circuit. This is shown in Figure 4, which plots I, the current, versus time in units of RC.

Assume that the values for the circuit in Figure 1 are: R_t = tube resistance = 25 ohms
C = capacitance = 10 μf
L = inductance = 38 μh
R_s = external circuit resistance = 2 ohms

Suppose the pulse is as in Figure 5 below; that is, a 10 μs pulse width with a rise and fall time of 1 μs. Now let us compute the current flow in the circuit after the load has arced but before the pulse starts to fall. This circuit will be equal to

$$I = \frac{V_o}{R} e^{-\frac{\tau}{RC}} = \frac{50 \text{ kV}}{27 \text{ ohms}} e^{-\frac{10}{270}}$$

$$I = 1780 \text{ amperes}$$

Now let the grid swing negative. The fall time is one-tenth of one microsecond. During the fall time

$$I = I_o\left(\frac{\tau}{t^*} - \frac{t}{t^*}\right)$$

where I_o is the current before the fall time, τ is the total length of the pulse, including the rise time and the fall time, and t^* is the fall time. The voltage induced in the inductor is equal to

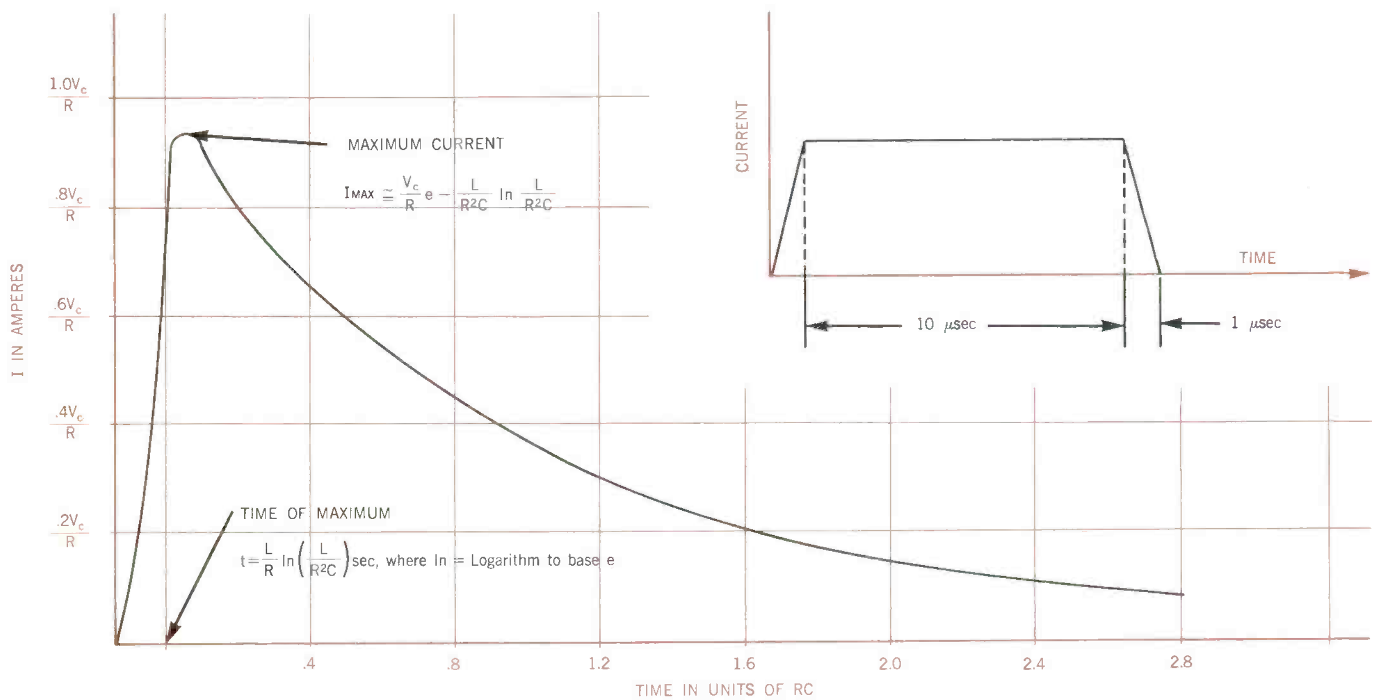
$$L\,\frac{di}{dt}$$

We have V_{ind} = voltage across the inductor = $\frac{LI_o}{t^*}$.
Hence, the voltage across the tube is made up of two components, (1) the capacitor voltage, and (2), a voltage spike lasting for t^* seconds equal to $\frac{LI_o}{t^*}$.
To get an estimation for this voltage, we have V_c = voltage across the condenser = 50 kV, $\frac{LI_o}{t^*}$ = voltage in the inductor = 67,000 volts. Hence, the voltage across the tube = V_t = 117,000 volts. Now the tube which is conservatively rated for 50 kV will surely break down in the form of an arc with 117kV impressed across it.

Once the tube arcs, the resistance of the tube becomes very low. Typical values have been reported as low as 1 to 2 ohms and as high as 20 to 25 ohms. Perhaps a normal value is 15 ohms. Figure 6 shows the fractional ratio of energy dissipated in the tube to energy in the capacitor as a function

Figure 4 — Time vs Current in units of RC.

Figure 5 — 10 Microsecond Pulse.



of time. If no crowbar is provided, the ultimate energy dissipated in the tube will be the energy in the capacitor times $\frac{R_a}{R^*}$ where R^* is the total resistance of the external circuit, plus the resistance of the arcing tube, and R_a is the resistance of the arc in the tube under breakdown.

Crowbar

For the circuit in Figure 1 and the values previously quoted, except that a tube resistance of 15 ohms may be used, the energy dumped in the tube will be 11,000 joules. This is enough to cause serious damage to the grid of the tube and cause the tube to become momentarily gassy. In severe cases, a hole may be burned in the anode or grid of the tube.

In order to prevent such serious damage, the need for a crowbar is obvious. Shortly after the tube arcs a crowbar should be switched on. The crowbar should be ignited before 10% of the energy is dumped into the circuit resistor R_s.

It may be well to mention a few important precautions that have to be taken in crowbar circuitry. The most obvious precaution is that the resistance of the crowbar circuit must be very much smaller than the resistance of the arcing tube; for if this is not so, most of the energy in the capacitor will continue to dump through the tube, or in any case there will be enough energy feeding into the tube circuit to maintain the arc.

The second important precaution is that the circuit breakers on the power supply feeding the main condenser must open sufficiently fast, so that once the condenser is discharged it is not sufficiently recharged to perpetuate another arc. Hence, the circuit breakers should act so that the condenser is only charged to one-half of its value under normal operation. If a thyratron is used as a crowbar, an extra precaution must be taken. This is to insure that the stray inductance in the crowbar circuit is small enough to insure the circuit is critically damped. This is necessary since if the crowbar is not critically damped, the voltage across the crowbar will swing negative and cut the thyratron off. The remaining energy in the capacitor will continue to discharge through the tube until the crowbar ignites again. In order to insure that the voltage on the crowbar does not swing negative, the crowbar circuit must be critically damped, $L \leqq R_s^2 \frac{C}{4}$. For the values given previously, this means $L \leq 10\ \mu h$. The circuit in Figure 1 was assumed to have 12 μh, which was small enough to insure that most of the energy is dissipated in the resistance, R_s, before the circuit swung negative.

As a further precaution it must be understood that the presence of a crowbar in a circuit does not prevent the load from arcing. In the preceding analysis, the arcing could be traced directly to a transient over-volting of the anode caused by the rapid fall time of the pulse. It is analytically shown that short fall times induce high transient voltages. In order to prevent this, the fall time of the pulse must be increased so that the transient voltage

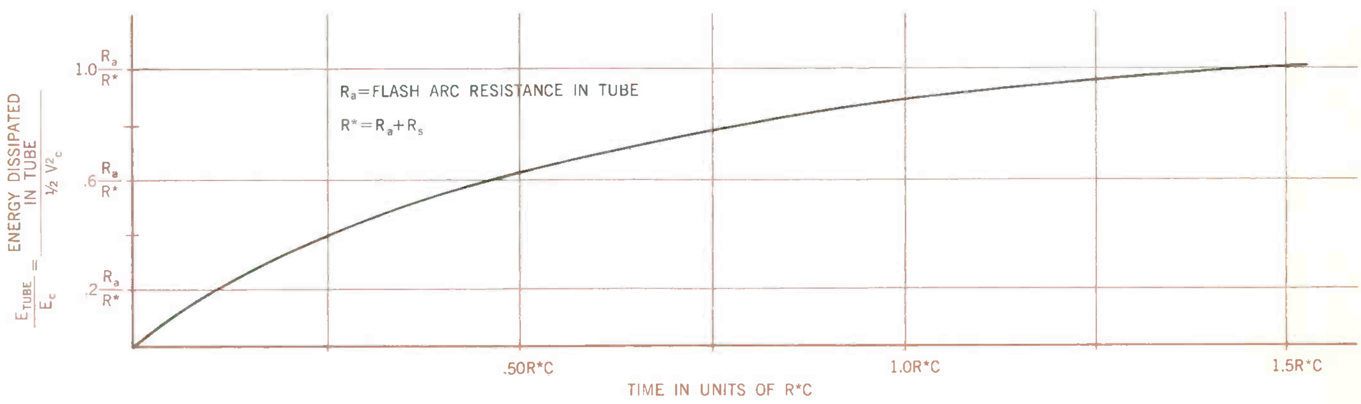
$$\frac{L\ I_o}{t^*}$$

is made negligible in comparison to the condenser voltage. Needless to say, very little can be done with the plate circuit to increase the fall time of the pulse, because the grid circuit essentially controls the pulse shape. Hence, suitable modification of the grid circuit can reduce the 67 kV induced voltage spike in the example shown, and the circuit can be made to operate stably.

Analysis of Industrial Heating Circuit

Although the analysis has been restricted to circuit 2, which is that of a Class C oscillator, the results hold to a fair degree for Class C amplifier circuits and plate modulated audio amplifier service. In this case, it is not immediately evident how the tube will react if the load arcs. In the previous case when the load arced, a voltage surge was set up due directly to the load arcing. Here too one can

Figure 6 — Ratio of Energy Dissipated In Tube to Energy Initially Stored in Capacitor.



surmise that when the load arcs, transients can be set up which cause the tube to become unstable. Suppose, for instance, that the tank circuit arcs to ground when the tank capacitor is fully charged negatively. Since the by-pass condenser must maintain 15 kVdc between the tank circuit and the power supply, if the tank circuit arcs to ground the by-pass condenser will be "yanked up" to a voltage equal to the voltage drop that was across the tank circuit. This can cause an over-volting of about 15 kV, which is approximately the rf voltage in the tank circuit. In the case of industrial heating circuits, it is not quite as easy to trace transients induced by the arc as it was in the previous case. However, we may surmise that parasitic transients serve to over-volt the anode as in the previous case of the pulsed generator circuit when the load arcs to ground. Evidence of such over-volting is often manifested by arc marks at the grid and anode seals.

Let us suppose that due to one of the means mentioned previously, the tube breaks down. Then, the DC power supply will conduct current through the tube. The current through the tube is given in Figure 7a, and the subsequent power dissipated in the tube is given in Figure 7b.

Circuit breakers are usually provided in the transformer which supplies the DC voltage. These circuit breakers are usually geared to open between 10^{-3} and 10^{-1} seconds. Let us assume that the circuit breaker opens in the following times: 10^{-4} seconds, 10^{-3} seconds, 10^{-2} seconds. Also, assume the resistance of the tube during breakdown to be 15 ohms (the value previously assumed). The inductance of the coil in Figure 2 is 10^{-3} h. The power dissipated in the tube for the three values of time given above will be:

10^{-4} seconds = 600 KW = 60 joules
10^{-3} seconds = 1000 KW = 1000 joules
10^{-2} seconds = 10,000 KW = 100,000 joules

It is evident from these values that a large amount of energy is dissipated in the tube, and an auxiliary circuit breaker or crowbar is needed to shunt the current away from the tube. The crowbar, of course, must operate much faster than the circuit breaker on the dc power supply.

Conclusion

It is evident from the analyses of the two circuits shown in Figures 1 and 2, and because once a tube arcs its sensitivity to arc again is increased, that the need for protective devices in high power circuits is vital. If such devices are not provided, instabilities in the tube may cause extremely serious damage to both the tube and load. It is hoped that the preceding analyses will give to the user of high-power tubes some idea of the speed with which protective devices have to operate. A protective device which takes too long is as good as no protective device at all.

Figure 7 (a) — Tube Current During Breakdown.

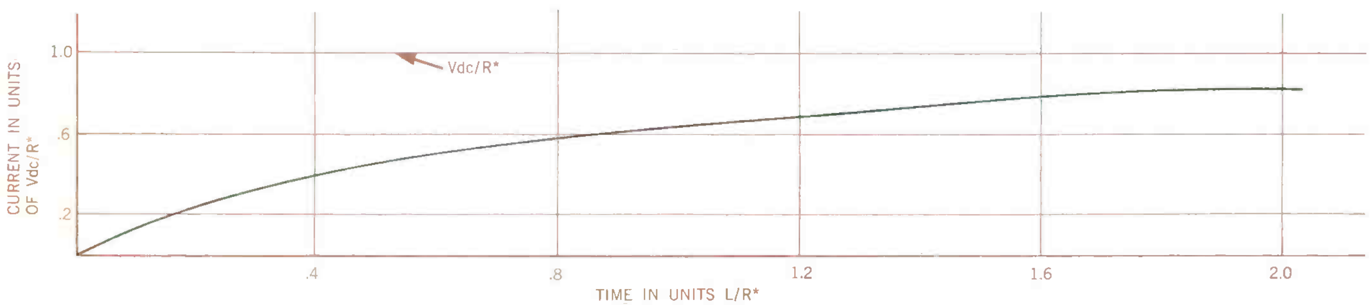
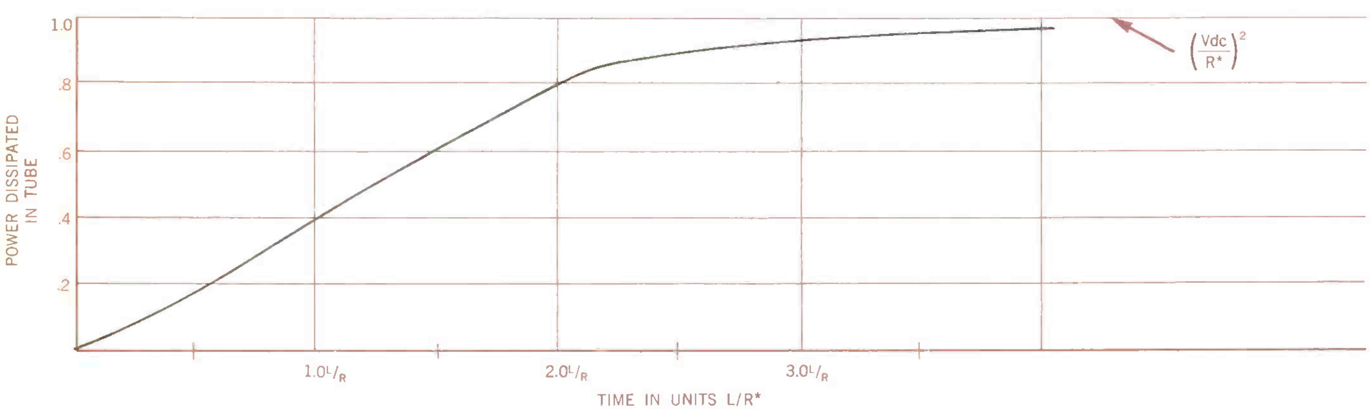
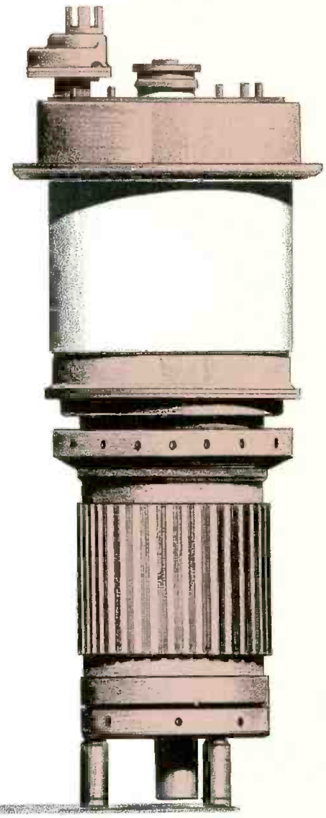


Figure 7 (b) — Power Dissipated in Tube During Breakdown.



The ML-LPT17 High Voltage,



By *HELMUT LANGER*
Senior Development Engineer
and
ERICH PETER
Development Engineer

The ML-LPT17 is a further extension in the Machlett development of high voltage, high power pulse modulator tubes for use as switching elements in today's and tomorrow's long-range, high-power radar equipment. This tube is rated for operation at dc holdoff voltages up to 200KV. Its thoriated tungsten filament has been conservatively designed to provide in excess of 225 amperes of pulse cathode current. The ML-LPT17 is capable of switching pulse power in the order of 25 megawatts at a plate voltage efficiency of approximately 90%, and with less than 60 amperes of pulse drive current. The anode is capable of dissipating in excess of 30KW when cooled with a moderate flow of oil; grid dissipation capabilities exceed typical drive circuit requirements. The tube is designed for operation in insulating oil or an equivalent dielectric gas.

Design Considerations

The principal approach in the design of the ML-LPT17 was to use proven basic Machlett power triode construction and processing techniques, yet modified and considerably extended in some areas, in view of the relatively high operating voltage requirement. The technical considerations of tubes that are to be operated in the 200KV range are not merely ones of internal spacings between electrodes, or length of the breakdown path over the external surface of the grid anode insulating envelope. Important design considerations include: due consideration and provision for optimizing field gradients in relationship to geometrical shape of electrodes, chemical and vacuum treatment of tube components, surface conditioning of components, internal shielding to avoid concentration of electrical charge, special high temperature and high vacuum processing of the tube itself, and evolving effective high voltage ageing techniques which are considered a part of the manufacturing process. A special large volume, high temperature double vacuum system was designed and constructed by Machlett to extend high temperature high vacuum processing required for tubes and tube components such as the ML-LPT17 and the recently developed ML-8549, Super Power, Magnetically Beamed Triode.

A coaxial-cylindrical design was chosen for the ML-LPT17, whereby the main ceramic insulator and the anode (collector) forms the outer cylinder, while the grid-cathode system forms the inner cylinder. This is in keeping with proven tube construction practice as it permits the maintenance of relatively close tolerances in component fabrication, tube assembly, and a general reduction in abrupt discontinuities of electrode surfaces. In a cylindrical electrode system, the field strength at the inner electrode is

High Power, Pulse Modulator Tube

$$E = \frac{V}{2.3 \times r \text{ Log } R/r}$$

wherein V = applied voltage, R = outer radius, r = inner radius. The minimum field gradient V/r occurs when R/r = 2.72. At low dc potentials, several hundred KV/cm can be insulated between cylindrical electrodes without breakdown, while at the higher voltages, the maximum field strength has to be reduced considerably to avoid breakdown. Furthermore, in practical tube construction, the grid electrode surface is not a smooth cylinder, but is composed of small diameter wires wound into a helix, and exhibiting some structural discontinuities gving rise to field enhancement factors of the order of 3 to 5. Vacuum spacings between grid and anode cannot be made unduly large for the sole purpose of achieving better high voltage stability, as this would seriously impair the efficiency of the tube. This is seen by the maximum current density j_o in mA/cm^2 collected at the active anode area as given by

$$j_o = \frac{2.33 \times 10^{-6} \, (e_b{}^{1/2} + e_g{}^{1/2})^3}{d^2}$$

where d is the grid to anode spacing in cm. In other words, plate efficiency is a consequence of grid to anode spacing. Metallic cathodes, such as thoriated tungsten, will withstand field gradients in the grid-cathode region in the order of two times that permitted with tubes with oxide cathodes.[1, 2]

The cathode of the ML-LPT17 consists of a self-supporting thoriated tungsten filament structure, with nominal filament characteristics of 11.0 volts and 350 amperes. Peak pulse cathode currents of approximately 250 amperes can be obtained at nominal filament voltage, and in excess of 300 amperes when the filament voltage is raised by 5% to 10%; the latter, however, results in shortened filament life. This in itself, in some applications, may not be of undue concern since several thousands of hours of cathode life may be realized even when operating at slightly higher filament voltages. Pulse duration with thoriated tungsten cathodes of this type are actually only limited by rise in grid temperature.[1] Generally, pulse durations of several milliseconds can be handled.

The grid structure is a wire helix similar to those used in many large transmitting tubes, however, this structure does represent a compromise between low field gradients and low grid screening fraction. Due to the grid-anode spacing required for 200KV, the tube becomes a high-mu triode. Surface treatment of the grid is based on the primary emission inhibiting properties of platinum on molybdenum, which results in low thermionic emission from the grid at its maximum dissipation rating of 1000 watts and enhances long pulse width operation. The cathode and grid structure of the ML-LPT17, as mounted on the terminal assembly, is shown in Figure 1.

The anode structure is made from a high density copper forging, brazed to appropriate rings for tube mounting and handling. Longitudinal fins are provided on the outer surface to establish maximum heat transfer to the circulating oil. Special internal surface treatment and extended pre-outgassing of the anode structure is a fundamental requirement to achieve optimum high voltage stability.

closely fitted oil jacket around the finned section of the anode allows removal of approximately 30KW from the anode with a forced flow of mineral oil in the order of 40 gpm. The upper terminal section is designed to allow low inductance connections to the cathode filament and grid terminals of the tube. A one liter/second Vac Ion sputter pump is a permanent attachment to the tube, allowing continuous maintenance of low gas pressure in the tube. The Vac Ion pump can also be considered as a monitoring device of the tube's operating performance, particularly when a new tube is installed as a replacement in an existing circuit or during the "shake out" phase of a new circuit complex. The anode structure is provided with two sets of rings with

Figure 1 — Cathode-Grid and Mounting Assembly of ML-LPT17.

Figure 2—Anode and Ceramic Insulator Assembly of ML-LPT17.

The high voltage insulating envelope is made from high purity aluminum oxide. Internal ceramic surface configurations are such that any possible formation of metallic films which may occur during tube manufacturing processes at voltages in excess of 200KV, or as a result of prolonged tube operation, will not exhibit a continuous pattern. Both the cathode and anode side of the ceramic-metal junctions are shielded, maintaining essentially field-free sections to inhibit high field emission from these junctions which could cause tube instability.[3] The anode-ceramic insulator assembly is shown in Figure 2.

The completed tube, as shown in Figure 3, has been designed to be operated vertically with the anode down. A tapped holes which are intended for use in mechanically lifting the tube and mounting the tube in its socket.

Electrical Processing of the ML-LPT17 Tube

Without attempting to cover all mechanical, chemical, temperature and vacuum processing procedures that the tube is subjected to before any high voltage is applied, some general notes on the electrical and high voltage processing of the tube may be of interest to the reader.

In order to obtain high-voltage, high-current operating stability at the required level, aging of tubes must be extended to levels which are at least 20% to 30% higher than the maximum rated values. The ML-LPT17 is "aged" in the

Machlett 270KV, 200mA Hard Tube Modulator Test Equipment.[4] (The voltage level of this equipment has recently been increased from 200KV to 270KV). The typical test circuit is shown in Figure 4. In the initial aging procedure, the tube is subjected to increasing voltages from zero to approximately 260KV. During this phase the grid is kept at a negative potential of 1500 Volts, which is well into the cutoff region. Leakage current to the anode (field emission), gas pressure in the tube, X-ray radiation and electrode sparking are constantly monitored. During this period, the plate series resistance is reduced from an initial value of 40,000 ohms to 250 ohms. After the tube has reached a specified stability level at 250KV, as judged by general tube stability, reduction in field emission, X-ray yield, and tube gas pressure, the actual operational aging commences.

The tube is now grid pulsed by a hard tube modulator, using the ML-6544 shielded grid triode as a driver. Pulse duration is variable from 1 to 10 microseconds and pulse repetition rate can be varied from 20 to 500 pulses per

Figure 3 — ML-LPT17 High Power, High Voltage, Pulse Modulator Tube.

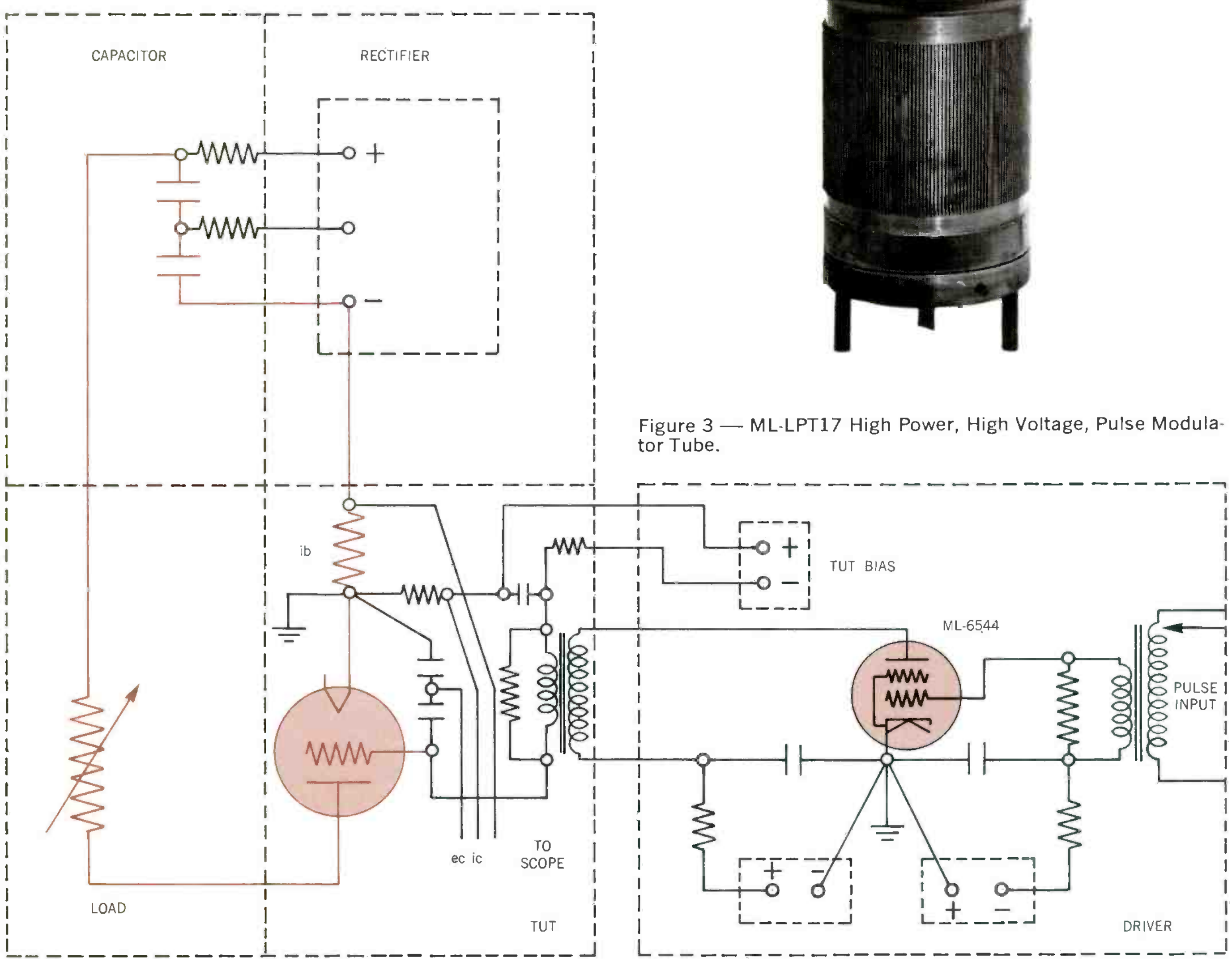


Figure 4 — Simplified Test Circuit Diagram of 270KV 200 mA Hard Tube Modulator Test Equipment.

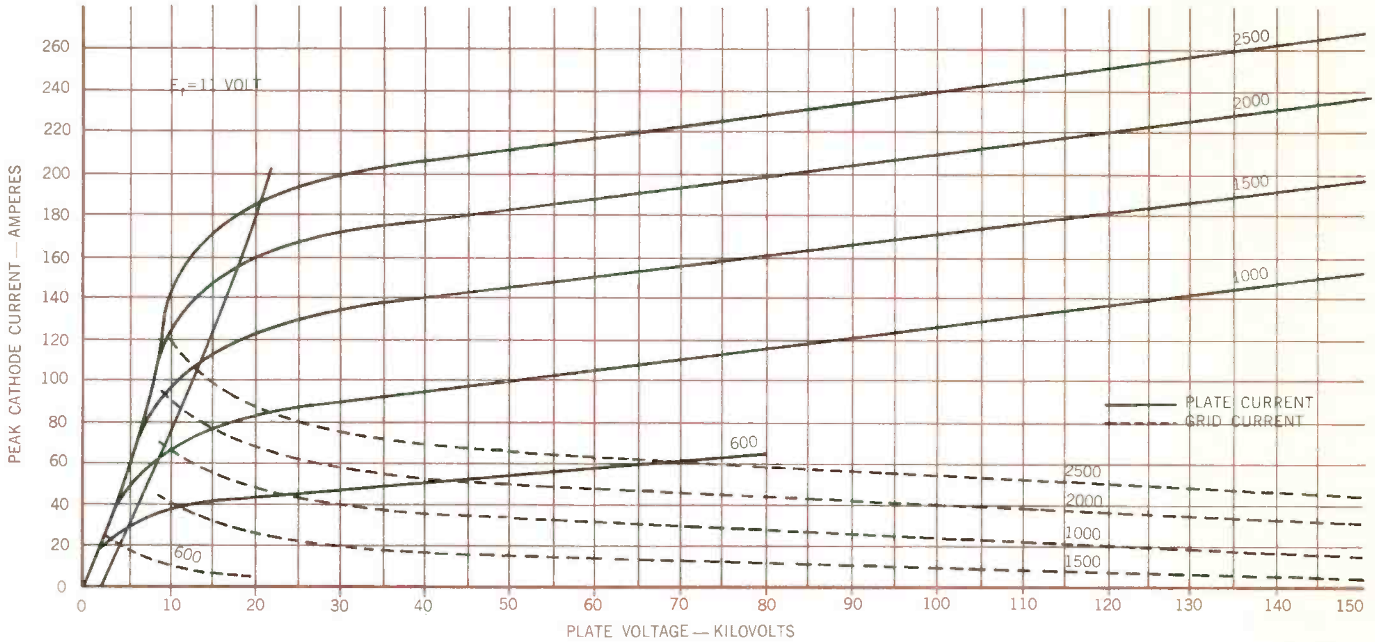


Figure 5 — ML-LPT17 Constant Grid Voltage Characteristicsfor High Cathode Current and High Plate Voltage.

second. The ML-LPT17 is grid pulsed at 5 microseconds at a pulse repetition rate of 100 pps to 200 pps, at plate voltages up to 240KV, and with a pulse cathode current value in excess of 225 amperes as limited by the 250 ohm load resistor. Again the series load resistor is changed from an initial 40M ohms to 1000 ohms, and then as low as 250 ohms, until the tube is operated for several hours without indication of instability at voltages in excess of 200KV.

During this "aging" procedure, the tube undergoes all possible operation modes: i.e., high voltage, high cathode current, high grid current and subsequent grid dissipation, low grid current, high tube drop and resulting high tube plate dissipation. A final test procedure specifies operating the tube at 200KV and 200 amperes of pulse cathode current for a period of 8 hours.

Electrical Design Data

In order to aid the circuit designer in using the ML-LPT17 in different modulator applications, a series of test data and tube characteristics are presented. It should be understood, however, that some of the data presented here are subject to minor changes from tube to tube. Some slight changes from the initial test data with extended tube life may be anticipated, as is the case with all power tubes. A classical example of a parameter that changes in all power tubes, or can change, is the secondary emission from a grid as its surface changes with time. The degree of grid surface change is primarily a function of the operating temperature of the grid.

Static Electrical Drive Characteristics

Figure 5 shows the constant grid voltage characteristics of the ML-LPT17 to a plate voltage level of 150KV and 2500 volts of positive grid voltage. In Figure 6, the same characteristics are shown in more detail for the low plate voltage, low grid drive voltage region of the tube. Both plots show a solid line along the diode line of the tube; it is strongly recommended that operating points be chosen to the right of this line in order to prevent Barkhausen-Kurtz Oscillation.[2] Figure 5 also shows that at higher plate voltages the grid current may actually become negative, i.e., opposite to the normal electron current arriving at the grid. This is caused by secondary emission from the grid and normally does not cause any problems in tube operation, but may initiate pulse stretching when the load arcs during a pulse and therefore warrants attention. (See Reference 2 for further discussion on this subject.)

Grid Bias Versus Plate Voltage

Figure 7 shows actual and recommended grid bias voltage versus plate voltage for cutoff during the inter-pulse period of the ML-LPT17.

Plate Leakage Current vs High-Plate Voltage

Figure 8 shows actual test data as recorded on several ML-LPT17 tubes showing plate leakage current (or field emission from the negative electrodes) versus plate voltages up to 200KV. This current must be provided by the plate power supply and it is recommended that provisions be made to accommodate leakage currents of about 10 to 15 times higher than indicated in Figure 8. The reason for the latter precaution is that in case of circuit malfunctions (crowbar failure, etc.), appreciable amounts of energy may be discharged into the tube, giving cause to tube instability

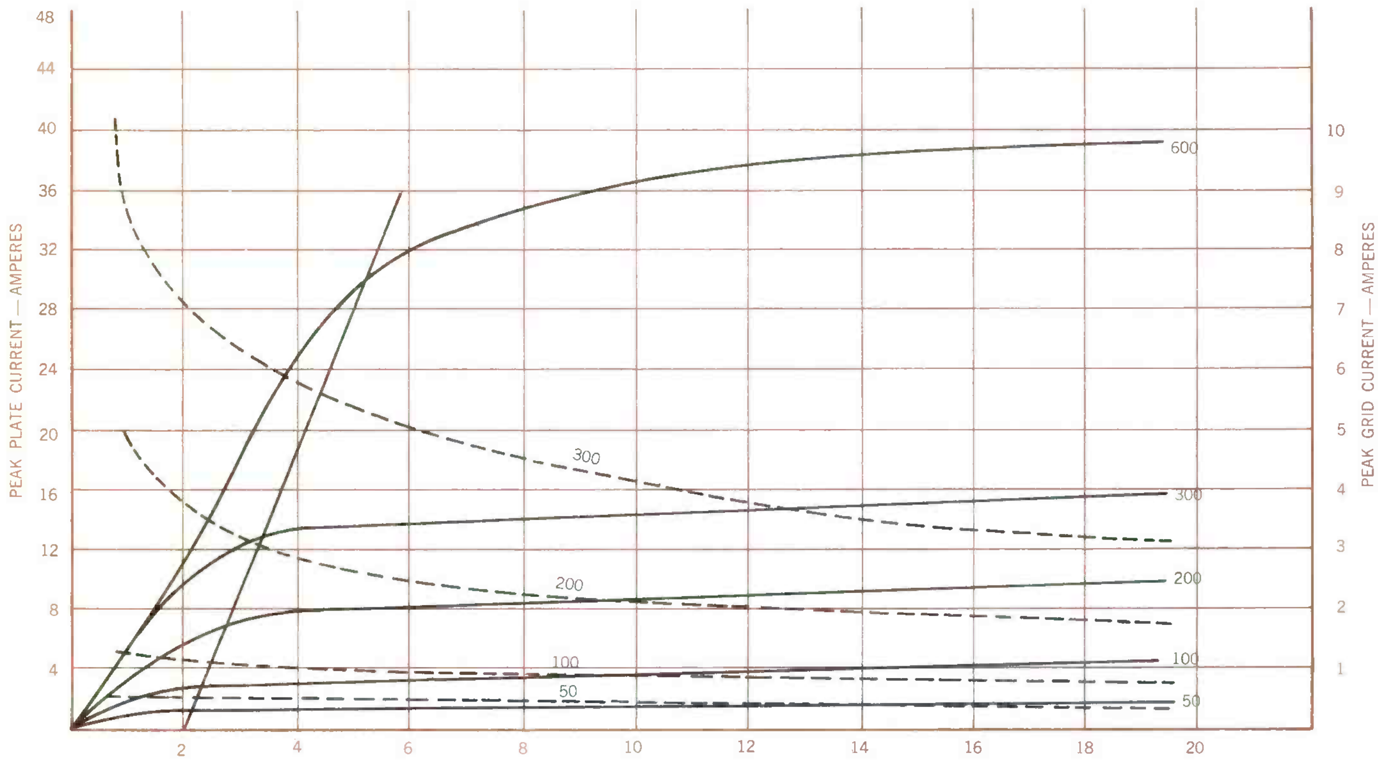


Figure 6 — ML-LPT17 Constant Grid Voltage Characteristics for Lower Cathode Current and Lower Plate Voltages.

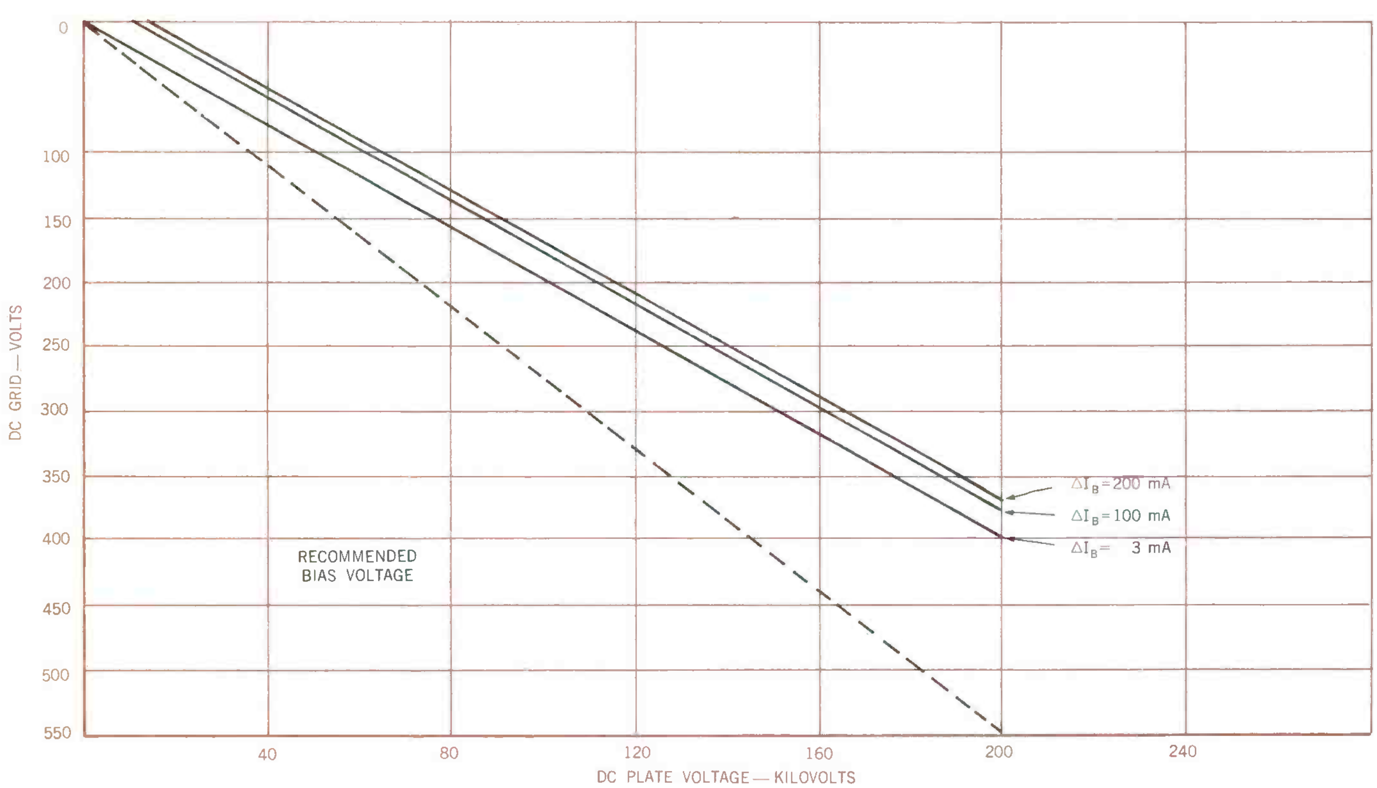


Figure 7 — Grid Bias versus Plate Voltage for Cutoff in Interpulse Interval.

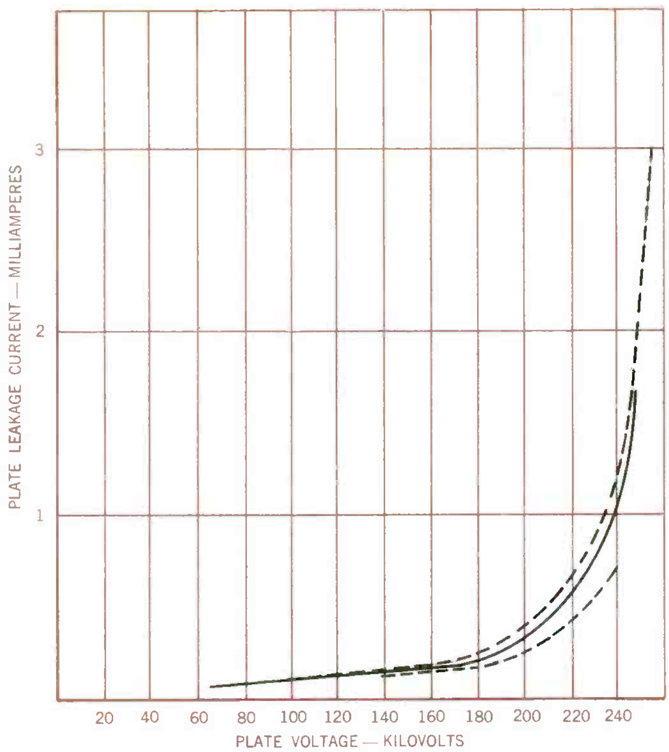


Figure 8 — Plate Leakage Current vs Plate Voltage Under Cutoff Conditions—Typical Values.

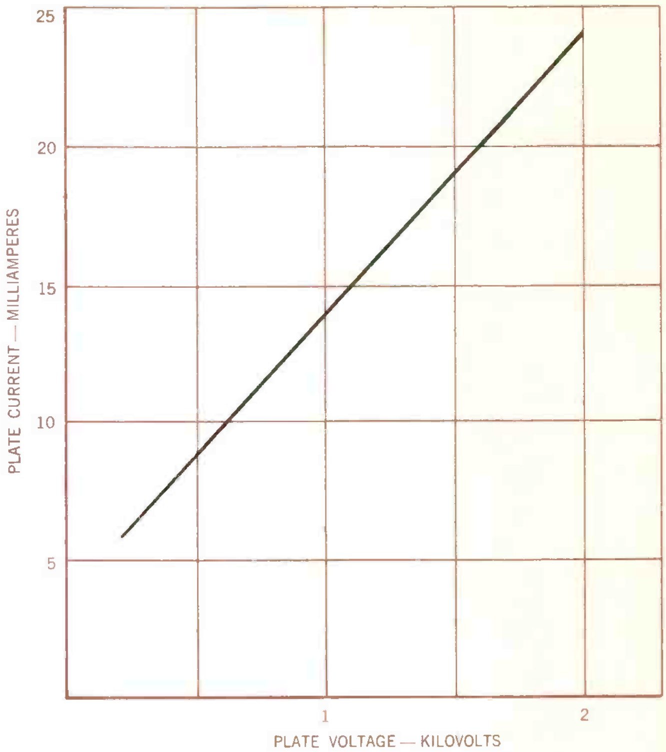


Figure 9 — Plate Current vs Plate Voltage at Zero Bias—Typical Values.

and higher leakage currents. With appropriate reaging of the tube at approximately 10% above required voltage levels, this condition may be rectified again. The plate leakage current may return to its original value. However, during the reaging, more power supply capability is necessary.

Plate Current vs Low Plate Voltage Potentials

Figure 9 shows data at zero bias and plate voltage from 250 volts to 2000 volts.

Resonant Frequencies of the Electrode Systems

Resonant frequency values for the ML-LPT17 in the grid-plate system are ≅ 45 Mc, and in the grid-cathode system ≅ 35 Mc. In taking this data, three 1″ wide copper strips were clamped to the respective terminals and the resonant frequency determined by using a grid-dip meter.

Interelectrode Capacitances

Values, as measured directly at the appropriate terminals are:

Grid-Plate	=	23 pF
Grid-Cathode	=	175 pF
Cathode-Anode	=	20 pF

X-Radiation Levels

Operation of the ML-LPT17 at voltage levels above 100KV will produce considerable X-ray radiation and appropriate precaution must be taken. It is recommended that shielding be provided based on a level of approximately 200 mR/hours, measured 30″ away from the tube, and that radiation levels outside the tube-tank enclosure be measured to assure complete safety to operating personnel.

Tube Applications

The ML-LPT17 tube is finding applications in high power radar systems to switch and transfer energy from the storage device to the rf tube. Typical circuit arrangements are of the floating deck and series-type modulators.

In any type of application, the use of crowbars or energy diverters is highly recommended and such be considered a requirement. Use of a crowbar, which will act in less than 10 microseconds to divert energy from a flash-arcing tube to a shunting circuit, has been of tremendous value in maintaining the high voltage stability of high power tubes. It has to be borne in mind that in high power pulse modulators, flash arcing in switch tubes can be caused by over-volting induced by circuit or load malfunctions. A good, fast-acting crowbar device will protect the tube and provide continuous, stable, high-voltage operation of the tube and the transmitter.

REFERENCES

[1]Doolittle, H. D., "Vacuum Power Tubes For Pulse Modulation—Part I," *Cathode Press, Vol. 21, No. 1, 1964.*

[2]Doolittle, H. D., "Vacuum Power Tubes For Pulse Modulation—Part II," *Cathode Press, Vol. 21, No. 2, 1964.*

[3]Kofoid, M. L., "Effect of Metal-Dielectric Junction Phenomena on High Voltage Breakdown Over Insulators In Vacuum," *AIEE Power Apparatus and Systems*, 999-1004, December 1960.

[4]Weden, C. V., "Hard Tube Modulator Test Facility 200KV, 200 mA Capability," *Cathode Press, Vol. 19, No. 1, 1962.*

About the Authors

EDWARD F. BURGENI

Edward F. Burgeni, associated with the "broadcasting" side of broadcasting in 1938, served as news editor and English language broadcaster for international stations prior to joining the Office of War Information in 1943. With the Dept. of State in 1945 and USIA in 1953, he has been Chief of both Domestic and Overseas Transmitter Divisions for the VOA. Prior to his present post as Manager of the VOA's important Munich operation, he was Domestic Area Operations Officer.

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Edgar T. Martin who, in addition to other degrees, holds a BSEE and MSEE from Virginia Polytechnic Institute, served with the U.S. Army Signal Corps, rising to Lt. Colonel. He joined the VOA in 1952 as Chief of the Frequency Division. In 1954 Mr. Martin was appointed Engineering Manager, the position he now holds, being responsible for research, planning, design, construction, operation and management of the VOA's immense and extensive broadcasting and communication facilities.

GEORGE JACOBS

George Jacobs, who received his BEE Degree from Pratt Institute and his MSEE from the Univ. of Maryland, served as a Communications and Radar Officer during World War II. Joining the Engineering Staff of the VOA in 1949 he was a Radio Propagation Engineer and later was promoted to Chief of the Frequency Division, the post he now holds. He is responsible for directing telecommunication affairs, engineering and research in the field of radio propagation and frequency spectrum management.

HELMUT LANGER

Helmut Langer, who received his EE degree from the Ingeneurschule Barth, Berlin, in 1949 and who attended the Technical University there, worked as an engineer for the Telefunken Company prior to coming to Machlett in 1954. Now a Senior Development Engineer, Mr. Langer has developed high voltage, high power radar and transmitting tubes, both oxide cathode and thoriated-tungsten cathode types. Other important work includes: vapor cooling systems, magnetic beam tubes, and tubes for severe mechanical environments. He holds electron tube patents both here and in Germany.

ERICH PETER

Erich Peter, who received his ME degree from the University of Bridgeport and who is currently engaged in studies for his MS at the University of Connecticut, has been a member of The Machlett engineering staff since 1959. Mr. Peter has been active in the design and development of high voltage, high power radar and transmitting tubes; tubes for operation in severe mechanical environments; on novel cooling systems and on the new magnetic beam triode line.

BARRY SINGER

Barry Singer, who obtained his BS in applied mathematics from the University of Colorado and his MS in the same subject from New York University, has been with Machlett since 1960 as a Design Engineer. Among the many projects Mr. Singer has undertaken are theoretical design studies for magnetic beam power tubes; he has performed similar studies on UHF cavities for use by the Company in the design and testing of its planar triodes.

New Machlett Developments

ML-8171/4CX10000D

ML-8629

The ML-8171/4CX10000D is a high frequency tetrode designed for stable, long-life oscillator, amplifier, or modulator service. Internal structure permits high rf operating efficiency with low rf losses at frequencies to 110 Mc.

MAXIMUM RATINGS AND TYPICAL OPERATING CONDITIONS

RF Power Amplifier & Oscillator (key down conditions)

Maximum Ratings, Absolute Values

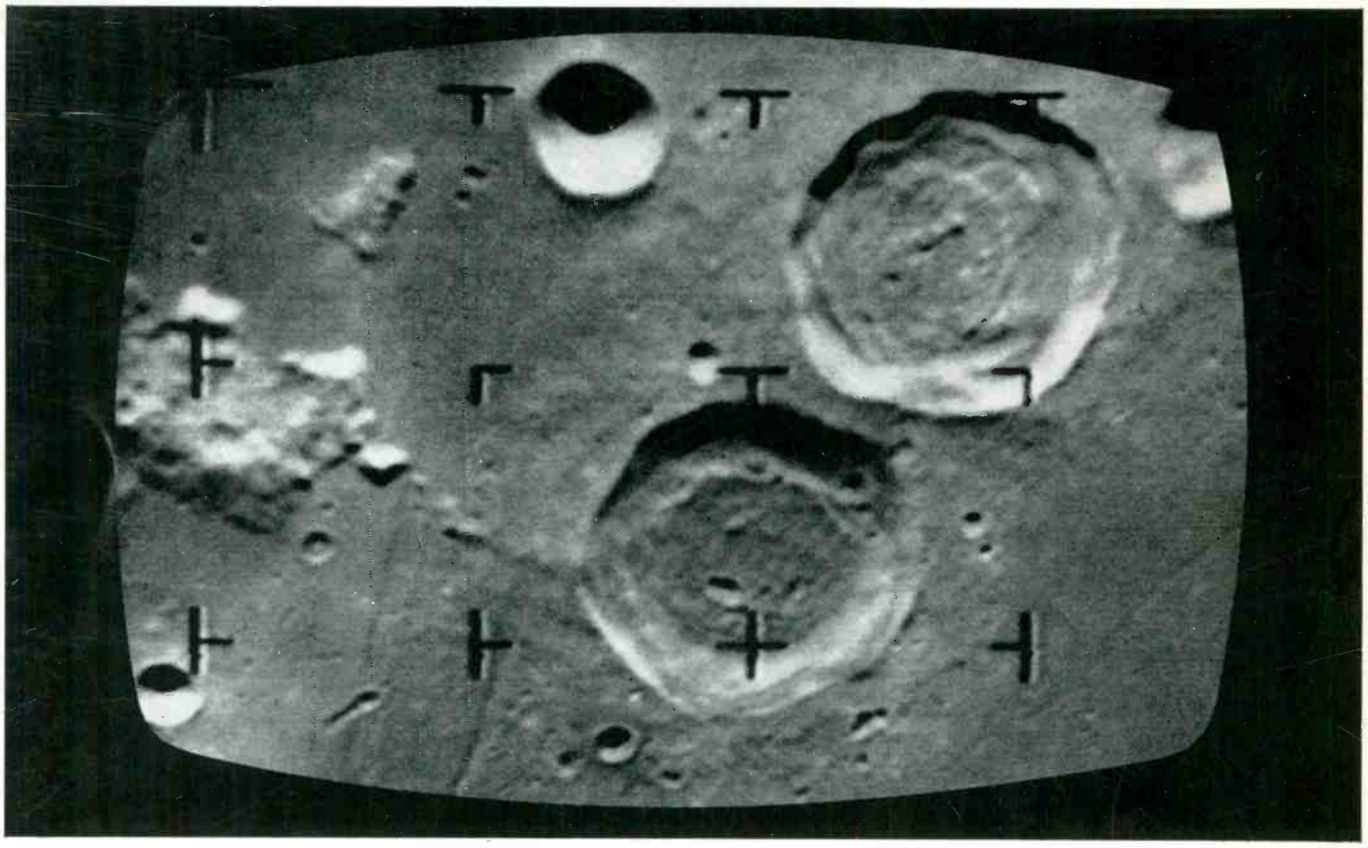
DC Plate Voltage	7.5	kV
DC Screen-Grid Voltage	1500	V
DC Plate Current	3	A
Control-Grid Dissipation	75	W
Screen-Grid Dissipation	250	W
Plate Dissipation	10	kW
Typical Operation, at Frequencies to	30	Mc
DC Plate Voltage	7.5	kV
DC Control-Grid Voltage	—350	V
DC Screen-Grid Voltage	500	V
Peak RF Grid Voltage	590	v
DC Plate Current	2.8	A
DC Control-Grid Current	.25	A
DC Screen-Grid Current	.50	A
Plate Dissipation	5	kW
Driving Power, approx.	150	W
Plate Power Output, approx.	16	kW

The ML-8629 is a miniature UHF planar triode with electrical characteristics similar to those of the ML-6442. The ML-8629, which employs the phormat cathode for high voltage stability, is designed for use as a grid and/or plate pulsed oscillator to 5Gc. It can also be used as a CW oscillator, rf power amplifier or frequency multiplier.

DESIGN CHARACTERISTICS

Transconductance	21	mmhos
Tube Gain Bandwidth	2	Gc
Grid Cathode Capacitance	6.0	pf
Grid Plate Capacitance	1.7	pf
Heater Voltage	6.3	V
Max. dc Plate Voltage	2	kV
Max. Plate Current at .0025 Duty and 6 usec Pulse Width	2.8	A
Plate Dissipation (Forced-Air-Cooled)	100	W
Maximum Envelope Temperature	250	°C
Max. Length	.980	in
Max. Diameter	.704	in
Solderable	Yes	

TV Transmitting Tube For CHANNEL MOON, On Target, On Frequency



The ML-7855 frequency stable Machlett UHF planar triode transmitted all of the moon pictures—sharp and clear—for Rangers 7, 8, and 9. On frequency, and at full power within seconds, the ML-7855 powered TV transmitters have been an outstanding success. In space, in the military service, in the nation's airliners—wherever the highest reliability and performance is required, use of Machlett planar triodes demonstrates the continuing confidence in the capability of the Machlett organization. Whether you require high power/high voltage triodes or tetrodes, UHF planar triodes, X-ray tubes, vidicons, or need assistance in research or design development, write: The Machlett Laboratories, Inc., Springdale, Conn. 06879. An affiliate of Raytheon Company.

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