From the Birth to the Demise of Super-Power Station XERA

By Durell M. Roth

In 1938, broadcast engineer James O. Weldon designed and installed a 500,000-watt, medium-wave, transmitter with a two-element directional antenna at radio station XERA in Villa Acuna, Mexico. Two years after the installation, Weldon wrote a detailed description of the 500-kilowatt amplifier and associated equipment, but until his death in 1993 the paper remained unpublished. Because the station was unique in terms of design, power level, and the international political atmosphere in which it operated, I felt it was important to edit and expand Weldon's work to include such historical information as photographs and program schedules that were not contained in the original document. This, therefore, is the story of XERA, owned and operated by John R. Brinkley M.D. At that time, XERA was the most powerful medium-wave station in North America.

KFKB Broadcasting Association, Inc.

Milford, Kansas

Power, 5,000 watts. Wave Length, 285.5 meters. Frequency, 1050 kilocycles.

Hours of Broadcast: Each week day from 5:00 a.m. to 7:00 p.m.

Sundays from 8:00 a.m. to 9:00 a.m. and 12:00 noon to 7:00 p.m.

DAILY SCHEDULE

5:00 to 5:30 a.m.	Hauserman and Cook.
5:30 to 6:00 a.m.	Health Lecture by announcer.
6:00 to 7:00 a.m.	Bob Larkan and his Music Makers.
7:00 to 7:30 a.m.	Hints to Good Health by announcer.
7:30 to 8:00 a.m.	Bob Larkan and his Music Makers.
8:00 to 8:30 a.m.	Prof. Bert.
8:30 to 9:00 a.m.	Old time entertainers.
9:00 to 9:30 a.m.	Markets, weather, cash grain. Hauserman and Cook.
9:30 to 10:00 a.m.	Medical Question Box.
10:00 to 11:00 a.m.	Special Features.
11:00 to 12:30 noon	Steve Love and his orchestra.
12:30 to 1:00 p.m.	Health Talk by Dr. Brinkley.
1:00 to 2:00 p.m.	Special Features.
2:00 to 2:30 p.m.	Dutch Hauserman and Cook.
2:30 to 3:00 p.m.	Medical Question Box.
3:00 to 4:00 p.m.	Bob Larkan and his Music Makers.
4:00 to 4:30 p.m.	Uncle Sam and Dutch Hauserman.
4:30 to 5:45 p.m.	Arthur Pizinger and his orchestra.
5:45 to 6:00 p.m.	Tell Me A Story Lady.
6:00 to 6:15 p.m.	Prof. Bert, French language instruction.
6:15 to 6:30 p.m.	Orchestra.
6:30 to 7:00 p.m.	Dr. Brinkley.

Schedule changes weekly but hours of broadcast are fixed.

Figure 1. KFKB daily program schedule from the Souvenir Album of KFKB published January 1930.

The story of XERA begins in 1917, in the small town of Milford, Kansas. Dr. Brinkley and his wife, Minnie, moved there after responding to Milford's request for a physician. They made their home and doctor's office in the rear of an abandoned drug store and stocked the shelves with patent medicines. Brinkley didn't stay a small-town physician long, though. He developed two controversial surgical procedures that gained him international fame: one which corrected impotency and another that cured prostate inflammation. His practice grew rapidly, and Brinkley soon built a new hospital. Although controversial, the procedures were popular; and in early 1923, Brinkley was summoned to California to perform surgery on the managing editor of the *Los Angeles Times*. While there he visited the paper's radio station, KHJ, one of the first stations in the area. Announcers reported the progress of the editor's recovery daily over the station, and Brinkley thought that radio would be a good way to inform and entertain his own patients while they recuperated. When he returned to Milford, he applied for a license to operate such a station in Kansas. On September 20, 1923, permission was granted to operate the first commercial station in Kansas, KFKB. Brinkley hired Weldon as chief engineer and nicknamed the station "The Sunshine Station in the Heart of the Nation." The KFKB studios and transmitter were in a one-story brick building dwarfed by the two three-hundred foot towers that supported the station's multiwire flat-top antenna. The original transmitter was a modulated oscillator operating on a frequency of 1,050 kilocycles. Weldon converted the station to a class-B linear system and increased its power to 5,000 watts.

Brinkley's medical and broadcasting business became successful beyond all expectations. In 1929, KFKB won a gold cup as the most popular radio station in the world. The daily schedule shows the diverse programming that contributed to its overall appeal (See Figure 1 on page 24).

With an expanding patient load and 10,000 letters directed to him at the station each day, Dr. Brinkley was not able to answer all of his mail. To alleviate the problem he started a new program, "The Medical Question Box," broadcast twice daily, in which he answered listeners' letters, offered them medical advice, and suggested one or more of his numbered medications as a possible cure for their ailments.

The American Medical Association (AMA), however, frowned on Brinkley's questionable techniques and chastised him for his on-the-air practice of medicine. When the KFKB license came up for renewal, the Federal Radio Commission (FRC) refused, with the admonition that the world's most popular radio station was not serving in the public interest. KFKB continued to operate under appeal of the FRC's ruling until Brinkley sold the station for $90,000 and applied to the Mexican authorities for a permit to build a broadcasting station somewhere along the Texas-Mexico border.

In early 1931, the Mexican authorities granted permission to build XER near Villa Acuna, Mexico, just across the Rio Grande form Del Rio, Texas. In late spring of that year construction began on the 50,000-watt "Sunshine Station Between the Nations" (Fowler 23-24).

Weldon and another engineer, Will Branch, began construction of the XER transmitter in Fort Worth, Texas, in mid-1931. When the broadcasting site was ready, the equipment was transported to Villa Acuna, Mexico, where the construction was completed. Weldon and Branch moved to Del Rio to oversee the final construction of XER, but the Brinkleys remained in Milford to supervise the Brinkley hospital and set up remote studios to broadcast, via phone line, over the border station. In the interview with Weldon, video taped in February 1993, he discussed the development of XER and remarked that he remembered the line from Milford as being nearly high-fidelity.

On October 21, 1931, XER began regular broadcasting on the mid-channel frequency of 735 kilocycles, with programs originating from both Milford and Villa Acuna. The primary target area of XER, and other high-power border stations, was both the United States and Canada. The stations, therefore, depended on the night-time medium-wave skip to reach their audience and adopted a dusk-to-dawn schedule for their normal broadcasting hours. The schedule worked not only to the financial advantage of the stations, but also aided their maintenance and modification efforts because the work could be done during the daylight hours when the stations were off the air.

The original XER transmitter used a 50-kw linear r-f power amplifier consisting of six Western Electric (W.E.) 232A tubes operating in a class-B, push-pull, parallel circuit. The antenna was a flat-top, approximately 24 feet long by 8 feet wide, suspended between two 300-foot towers. The ground plane for the antenna consisted of parallel wires laid three feet apart and soldered to collector ribbons for connecting to the remainder of the ground system.

XER was an immediate success. In an April 1932 letter to Dr. Brinkley, station manager H.L. Munal attached a statement of income and expenses for the first six months of operation which showed a profit of more than $48,000 (Munal 2). Brinkley reported, over XER, the national success of his Milford-based medical practice and made frequent private plane trips to Del Rio to oversee his expanding radio business.

The First Power Increase

In mid-1932, Weldon increased the transmitter output power to 65 kw by adding two tubes to the class-B amplifier, thus making a total of eight W.E. 232A's. He also modified the antenna system by adding a parasitic reflector that increased the station's signal to the north by approximately three decibels. To install the reflector, engineers erected a third tower forming an equilateral triangle with the other two and installed messenger cables to support the reflector.

The driven element and passive reflector were installed approximately ninety electrical-degrees apart. The system formed a cardioid pattern that provided maximum signal over a 180-degree section in the northern half of the coverage area. The reflector increased the station's ground-wave signal to about 300 miles and its sky-wave signal beyond 1,000 miles. The territory within the 300 to 1,000 mile area was served by high-angle radiation and was not affected by the reflector. Writing in a December 1932 letter to Brinkley, Weldon reported an antenna current in the new system of 42 amperes with carrier only and 55 amperes on modulation peaks. He installed a ground system identical to that of the driven element under the reflector and connected the two systems to form one large ground plane.

Making Plans for 500,000 Watts

Even as early as 1932, the engineering staff made plans to increase the station's power to 500,000 watts using a transmitter with a class-C final amplifier and high-level modulation. But when considering power in the 500-kilowatt range, the increased physical size and weight as well as the cost of parts like transformers, tubes, and generators became major factors in designing the new transmitter for XER. Weldon wrote in a December 2, 1932, letter to Brinkley that the power transformer for such a system weighed 32,000 pounds and that the filament generators alone would cost about $15,000 each. When all parts, including spares, building expansion, power supply line, and arrangements with the power company were considered, the total estimated cost was $150,000 (Weldon 3-4).

Weldon originally planned to build a new class-C final and push-pull class-B modulator using ten RCA type UV-862 tubes, four in the modulator and six in the final amplifier. With this configuration he could use the existing transmitter and modulator to drive the new equipment. Although this system was never constructed, equipment modifications were made that would accommodate some type of future power increase.

In spring 1933, Weldon made extensive modifications in the station's power supply. He replaced the original mercury-vapor rectifiers with a pair of six-phase, mercury-arc rectifiers manufactured by Brown-Boveri Co. of Switzerland. Each rectifier system was grid-controlled and had a rating of 1,800 kilowatts or 100 amperes at 18,000 volts. The six-phase system, contained in a steel cylinder, is described by S.R. Durand in his paper for the

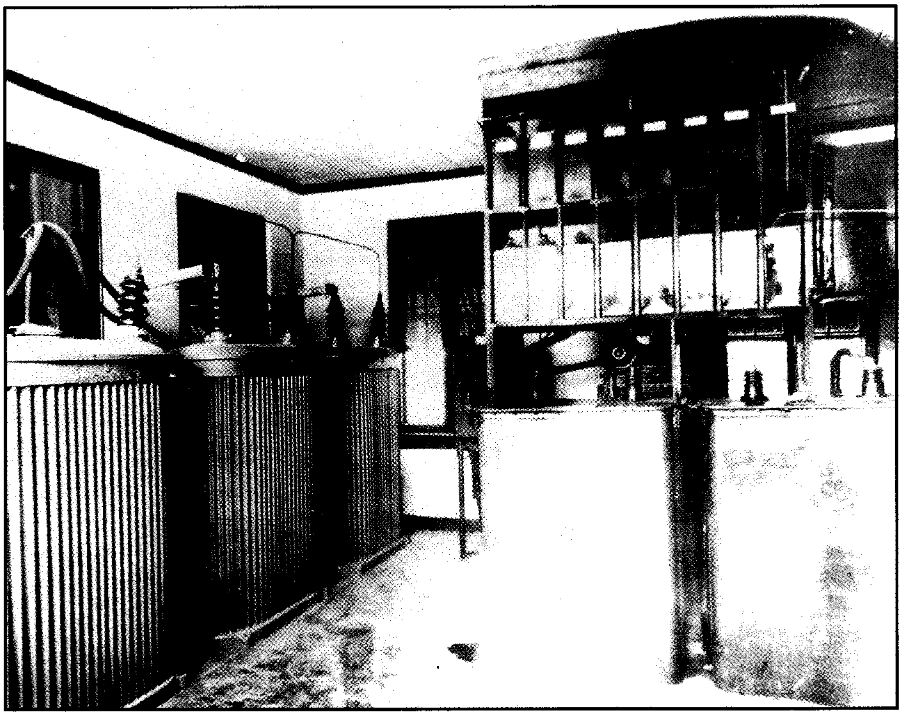

Figure 2. A portion of the power supply for the 180-kw station showing the filter capacitors in the upper right of the figure, and the filter chokes in the lower right foreground. Power transformers are along the left wall.

Institute of Radio Engineers as being approximately 3 feet in diameter, 5 feet high, and weighing 1,000 pounds.

Figure 2 above shows the new filter chokes, filter capacitors, and high-voltage transformers that were installed as part of the power supply modifications. The main transformer, manufactured by American Transformer Co., was fed from the 11,000 volt high-line through a motor-operated, high-speed, oil circuit breaker with an interrupting capacity of 100,000 KVA. The transformer had two six-phase secondaries, each supplying one of the Brown-Boveri rectifiers. Each of the six-phase systems supplied 9,000 volts, and the two were connected in series for a maximum output of 18,000 volts.

The output voltage of each six-phase rectifier could be set to any value by applying an arc-delay control voltage to each of the rectifier's six grids. Using this feature, each controlled grid of the rectifier on the 18,000-volt side was supplied with negative voltage, except for a single positive pulse, which was supplied once during each input cycle. By adjusting the phase position of the positive pulse relative to the positive half-cycle on each anode, Weldon made the power supply output voltage continuously variable from 9,000 to 18,000 volts. The positive pulses were supplied by a synchronous-motor commutation system, and the phase position of the pulses was adjusted by rotating the phase of the motor supply voltage. Two 100-volt motor-generator sets, one for each rectifier, supplied the grid voltage, and a Bakelite shaft-coupler isolated one of the generators from the 9,000-volt potential difference between the rectifier cylinders.

In case of backfire in the rectifiers, high-speed relays would reverse the polarity of their grid potential and thus interrupt the arc. The backfire would case within one-half cycle after the grids became negative, and the system would return to normal within eight to ten cycles.

Auxiliary equipment associated with each of the rectifiers included a high-vacuum and a low-vacuum pump, ignition and excitation set, water system to cool the high-vacuum pump, a cathode and condensing dome for each rectifier cylinder, and an interlocking protection system.

The Second Power Increase

After completing the power supply, Weldon modified the transmitter to increase its output power to 180 kilowatts. He changed the original final amplifier, eight W.E. 232A tubes, from class-B linear to class-C, and built

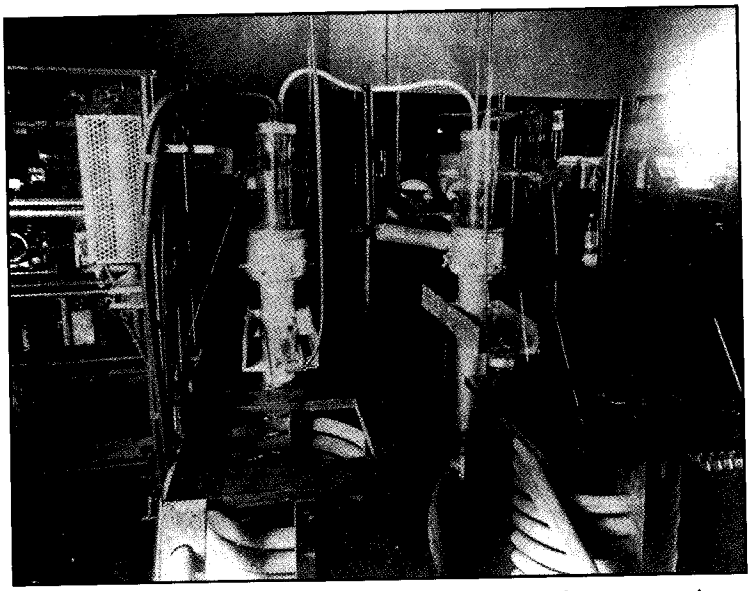

Figure 3. Part of the modulator for the 180-kw transmitter showing two of the modulator tubes, cooling-water coils and associated equipment. The front panel of the modulator is barely visible in the background.

a new modulator for the system. Writing in his paper about the 500-kw transmitter, Weldon described the new modulator as, "...a class-B modulator, using four RCA type UV-862 tubes... with modulating transformer, and condenser, and with parallel feed modulation reactors..." (3). A modulator driver containing two 848 tubes in a push-pull circuit was fed by a speech amplifier using a pair of 849 tubes, also operating in push-pull. The plate voltage for the audio and r-f driver tubes was the 9,000 volts obtained between the two series-connected rectifiers. A separate filter system was used for this lead. Two of the RCA UV-862 modulator tubes, cooling water coils, and associated equipment are shown in Figure 3. The resonating capacitor and coil that formed the push-pull output tank circuit for the eight W.E. 232A's in the final amplifier are shown in Figure 4. The coil, wound on a dried maple-wood form, had ceramic blocks in the grooves to hold the turns. The small coil in the foreground is the link that coupled the transmission line to impedance-matching equipment in the antenna tuning house.

Figure 5 shows the control panels for the 180-kw transmitter. The modulator tubes are behind the third and fourth panels from the left, and the power amplifier tubes are behind the eighth and ninth panels. The tank circuit for the final amplifier is on the other side of the wall in the far right of the Figure and is fed through the two feed-through insulators visible on the wall. The two panels to the right of the main panel contain controls that move the capacitor plates for fine tuning the tank circuit, and the meter in the top center of the left panel monitors the r-f tank current.

The Antenna System and Tuning Equipment

Figure 6 shows the coil and capacitor arrangement inside the antenna tuning house

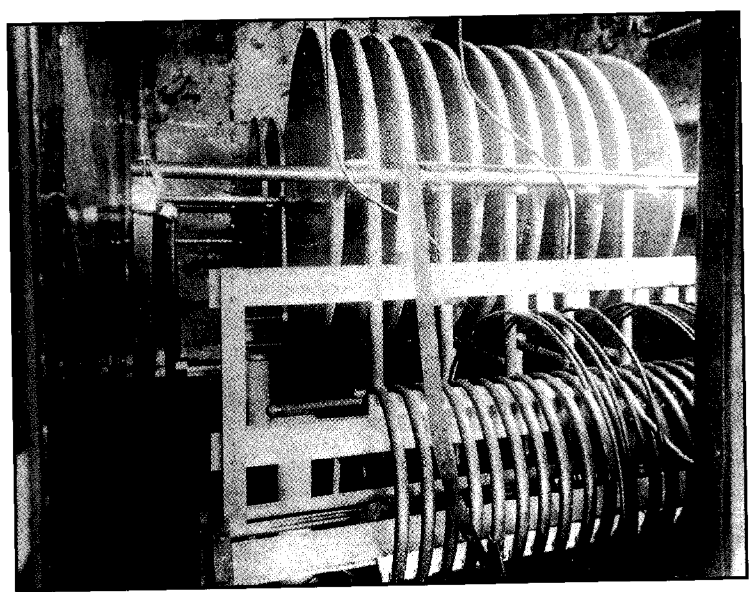

Figure 4. Tank circuit of the 180-kw final amplifier showing the resonating capacitor and part of the tank coil. The ceramic blocks within grooves to hold the truns are visibile inside the coil above and below the Maple-wood form. The small tubing in the foreground is the ouput link that drives the transmission line.

below the driven element of the array. The capacitors in the foreground are part of the push-pull tank for terminating the balanced line from the transmitter. The capacitor in the background is for series-tuning the antenna and is connected to the feed-line through the insulated bushing on the wall above the capacitor. The coil for the system is barely visible below the series-tuning capacitor. Each capacitor plate is constructed with two spun-aluminum plates, riveted at the center and sealed on the edges. Each plate is six feet in diameter and two inches thick. The transmission line from the final amplifier entered the tuning house from behind the camera.

Figure 5. Control panels for the 180-kw station. The modulator tubes in Figure 3 are behind the third and fourth panels from the left, and the power amplifier tubes are behind the eighth and ninth panels. The tank circuit in Figure 4 is on the other side of the wall at the far right in the figure. The plate leads connect to the tank circuit through the feed-through insulators that are visibile on the wall.

While the station operated with a transmitter power of 65 kw, the antenna system functioned without major problems. During that time, however, the weather had begun to cause oxidation on the surface of the multi-conductor lead-in cable. The oxidation increased the wire-to-wire resistance causing extensive heating of the lead-in when the power was increased to 180 kilowatts. A personal correspondence with Weldon in May 1989, finds that when operation at 180 kw started, the lower fifty feet of the half-inch copper cable feed line to the antenna became so hot that it turned black (1). He corrected the problem by slipping a five-eighths-inch diameter copper tube over the cable and connecting them at the top of the feed line. The larger outer diameter of the tubing provided a smooth, low-resistance conductor with sufficient surface area for current distribution and allowed the feed system to operate normally. With this arrangement the radiation resistance of the array measured 13 ohms, and the antenna current was about 118 amperes. Although an exact date is not known,

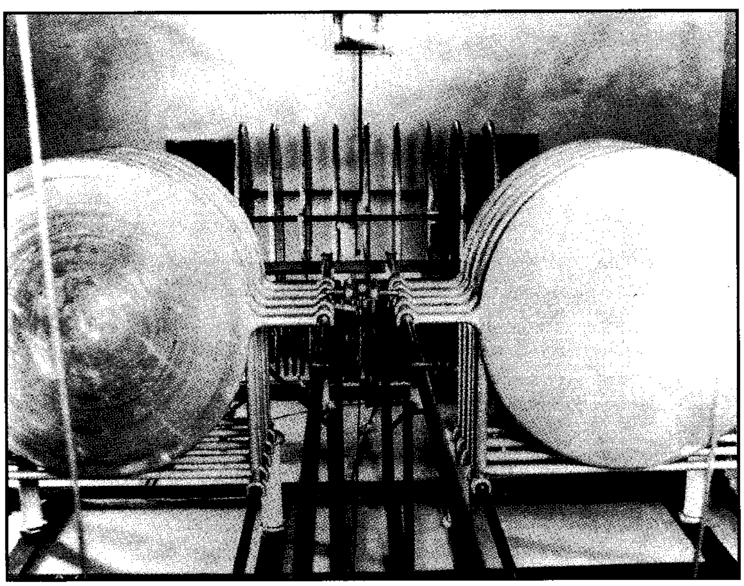

Figure 6. Resonating capacitors in the antenna turning house below the driven element of the array. The capacitors in the foreground are for resonating the push-pull tank that terminates the transmission line from the transmitter. In the background is the series-tuning capacitor for the antenna that connects to the feed-line through the insulated bushing on the wall just above the capacitor assembly. Each capacitor plate is six feet in diameter and two inches thick.

soon after the power increase to 180 kilowatts, engineering personnel converted the antenna system from a passive array to a phased array, with little or no effect on the radiation pattern.

The antenna system, however, was still not without problems. Writing in his paper, Weldon described one of the more potentially disastrous occurrences: "When the energy was divided and supplied to both antennas in proper ratio to give equal currents, these antennas were satisfactory. However, on one occasion all the energy was fed to a single antenna and corona discharge at the top and for perhaps fifty feet down the vertical lead was rather severe. Arc-overs across three, two-foot strain insulators, in series to the supporting messenger cables were experienced on some occasions" (23). Of course, this was not the normal operating mode of the antenna, and no arc-covers occurred when using the conventional hoop-up. It did indicate, however, that if a higher power transmitter were to be used, the station would require an antenna with greater capacitance to lower the r-f potential at the top of the array. Weldon eventually replaced the system with a new antenna (discussed later) when he increased the transmitter power to 500 kilowatts.

Brinkley Relocates in Texas

After Weldon corrected the feed-line overheating and developed a stable phasing system for the two antennas, the station operated without significant problems. Brinkley broadcast his lectures daily, made electrical transcriptions for re-broadcast, and frequently commuted to the border to supervise his broadcasting business. On a return trip to Milford, he discovered that one of his employees had started a rival clinic and was offering the Brinkley treatments for a substantially lower cost. Justifiably angered, Brinkley announced over XER that he had refined his surgical techniques for treating impotency and developed a new procedure for shrinking enlarged prostates. The Brinkley Hospital would also move to Del Rio he said, citing as justification the escalating cost of remote phone lines and commuting between the two cities.

In late October 1933, a caravan of thirty families of Brinkley employees plus trucks filled with hospital and office equipment began the journey to the Texas-Mexico border. Doctor, Mrs. Brinkley, and their son, John, followed a few days later by private plane and became permanent residents of Del Rio.

Brinkley rented three floors of the Roswell Hotel for his hospital and the entire basement for X-ray and laboratory facilities. He set up new remote studios for broadcasting over XER and bought a Spanish-style house on 16 acres just outside Del Rio. He soon enlarged his new home to accommodate a three-story pipe organ in the music room, and added a swimming pool, lush gardens with meandering walkways, and electrically operated fountains.

Brinkley loved Del Rio, and his business breathed economic life into the community during the depths of the Depression. He touted the recuperative powers of his new city over XER, citing the year-round warmth, fresh air, and the excitement of romantic Old Mexico. Del Rio, Brinkley quipped, was the place ". . . where summer spends the winter" (Fowler 40).

An increasing patient load for Brinkley meant more dollars for businesses on both sides of the border. Not everyone, however, was pleased with Brinkley, and plans were being implemented by the Mexican government to close XER. After initially granting Brinkley permission to broadcast in English, the Mexican authorities recanted the agreement and issued fines against XER. The fines were allegedly for violating Mexican laws by broadcasting in English from a remote location and continually breaching Department regulations in the content of the transmissions. On February 24, 1934, Federal troops from the Department of Communications closed the Sunshine Station.

While the station was off the air, Brinkley bought time on other border stations and on his old KFKB in Milford. Two months after closing XER, however, the Mexican Supreme Court ruled in favor of Dr. Brinkley and allowed the station to resume broadcasting. By the time of the court ruling, Weldon had changed the station's frequency to comply with new international regulations adopted by Mexico, and in April "The Sunshine Station Between the Nations" was reborn as XERA. The station now operated on a new frequency of 840 kilocycles, and the regular nightly broadcasts continued at 180 kilowatts until early 1938.

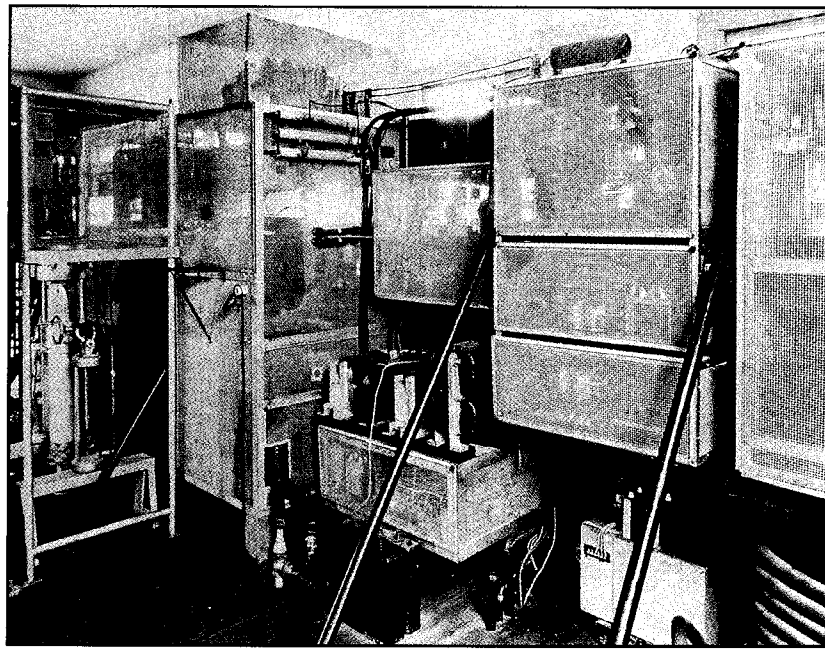
Figure 7. A portion of the modulator of the 180-kw transmitter.

Just after the first of the year, Brinkley decided to increase the station's power to 500,000 watts. In an effort to accomplish the increase in the most efficient manner, the station management developed a four-step plan to meet specific objectives. First, there could be no program interruptions during installation and change-over to the new equipment. Second, the new high-power equipment had to be in operation by early September, allowing slightly over eight months for design, construction, installation and adjustment. Third, as much of the existing equipment as possible had to be used in the new system. Fourth, since sufficient space was not available, an addition to the building had to be designed and built before the new equipment could be constructed.

To accomplish these objectives, Weldon began an in-depth study of published material relating to high-power work which had been done both in the United States and Europe on experimental and commercial equipment. Correspondence between Weldon and Brinkley in early 1930 shows that he initially planned to use some kind of a high-level modulation system. Later, however, he built 50-kilowatt transmitters for stations XEW in Mexico City and XEAW in Renosa, Mexico, using a new amplification system designed by W.H. Doherty. Weldon found the system to be more efficient than the conventional class-C amplifier and, therefore, more suitable for high-power applications (Doherty). Writing in his paper on the 500,000-watt transmitter, Weldon said that ". . . the most logical design for such a high-power transmitter lay in the use of the Doherty system of amplification" (5).

Having decided to use a Doherty amplifier, his choice of tubes was made easier by the development, in late 1937, of the Western Electric type 320A tube with a peak-power rating of 250 kilowatts. Until then, no tube had a peak-power rating greater than 100kw, but with the 320A, a 500,000-watt Doherty could be built using only eight tubes instead of 20 or more that would have previously been required.

In addressing the need to use as much of the existing equipment as possible, Weldon designed a system using the present transmitter, with modifications, as a driver for the Doherty amplifier. A new room was added to the transmitter building to house the 500-kw

Characteristic and Operating Data
320A Vacuum Tube

GENERAL

The 320A vacuum tube is a three element water-cooled tube designed for use as an oscillator, modulator or amplifier at the higher power levels and high frequencies.

Nominal filament voltage	35 volts
Nominal filament current	435 amperes, single phase or dc
Average thermionic emission	90 amperes

Average characteristics with a plate potential of 18,000 volts and a plate current of 8 amperes:

Amplifier factor	30
Plate resistance	965 ohms
Grid to plate transconductance	31,100 micromhos

OPERATING LIMITS

Maximum modulated direct plate voltage	12,500 volts
Maximum non-modulated direct plate voltage	18,000 volts
Maximum alternating plate voltage r-m-s	20,000 volts
Maximum direct plate current	15 amperes
Maximum plate dissipation	150,000 watts
Maximum grid dissipation	2,000 watts

Figure 8. Operating characteristics for Western Electric type 320A vacuum tube. Four of these tubes were used in each of the 250-kw Doherty amplifiers at XERA.

unit, its 50-kw r-f driver, and bias rectifiers. The room, constructed adjacent to the existing control room, was thirty by thirty feet with a full basement.

After completing the addition to the transmitter building, workers removed the wall separating the new structure from the old control room, and engineers began construction of the 500-kilowatt amplifier and its 50-kilowatt driver. In mid-July, with the 50-kw unit nearing completion, Weldon reduced the transmitter power from 180 kilowatts to about 80 kilowatts. He then removed two of the UV-862 modulator tubes and their sockets and used them to complete the new driver. The station remained on the air at 80 kilowatts for the nightly broadcasts until testing of the 50-kw unit had been completed.

The New 50-kilowatt Modulated Driver

The 50-kw driver consisted of two RCA UV-862 tubes, parallel-connected, in a tuned-grid-tuned-plate circuit. The amplifier occupied a space 48-inches wide by 54-inches deep directly behind its control panel. Plate voltage for the amplifier came from the 18,000 volt supply and the filament voltage from a d-c motor-generator in the basement. Two compressed-gas capacitors in a "double-ended" circuit formed the tunable portion of the plate tank and provided r-f energy for neutralization.

To begin testing the new amplifier, Weldon disconnected the old class-C system and reduced the output of its exciter to about half power. Then using a three-quarter inch diameter concentric transmission line, technicians coupled the output of the exciter directly to the grid tank circuit of the 50-kw unit. Weldon obtained audio for modulating the new amplifier from the push-pull 848 tubes, previously used as the audio driver for the now-disconnected class-B modulator. He coupled the secondary of the output transformer from the push-pull stage with a 50-mfd dc-blocking capacitor to the grid lead of the UV-862 amplifier tubes. Two audio chokes connected in a T-filter arrangement provided audio isolation from the bias supply. By carefully designing the input circuits of the 50-kilowatt system, Weldon achieved a near-perfect impedance match to the audio transformer. The grid tank circuit presented a 600-ohm load in parallel with a 200-ohm resistive load across the transformer for an audio-input impedance of 150 ohms. Being much lower than any other load

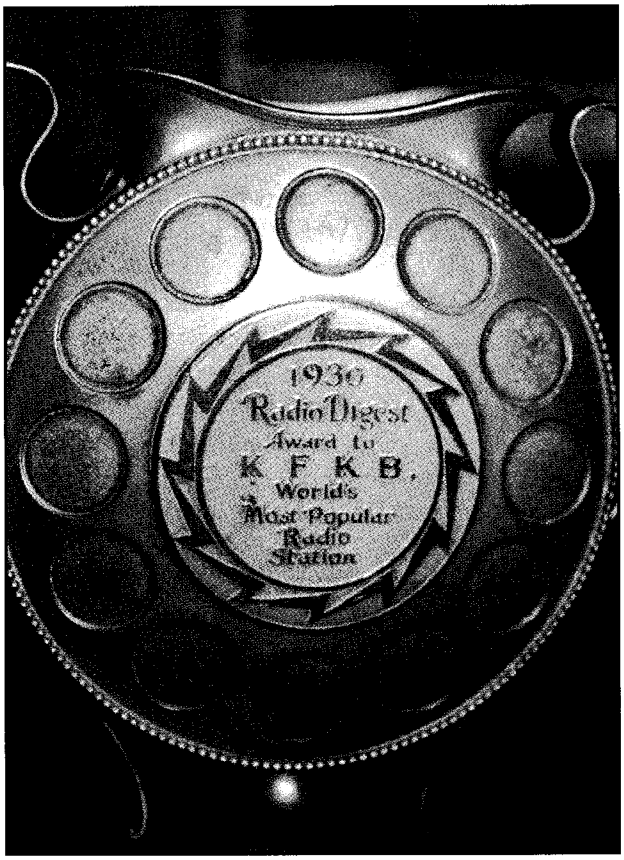

Figure 9. Gold cup awarded to KFKB in 1930 as the World's Most Popular Radio Station.

in the modulator, the 150-ohm impedance created a flat audio-frequency response with minimum phase distortion. The d-c output of an r-f rectifier in the 500-kw unit served as signal voltage for inverse-feedback control of the audio system, and transformer coupling throughout the high-power audio chain provided the necessary impedance matching and phasing within that feedback loop. The loop contained two transformers, but with the transformer technology of the time only 12 DB of feedback could be obtained. Although the feedback level was adequate for the initial start up of the 500-kw amplifier, the system was modified later to increase the amount of feedback in order to further decrease any audio phase distortion.

During the initial testing of the 50-kilowatt unit, a spurious oscillation or "singing" occurred as a result of the tuned-grid-tuned-plate circuit arrangement used in the amplifier. Weldon inserted a small inductor in the grid lead of the UV-862 tubes that detuned the circuit at the frequency of the oscillation and allowed the amplifier to function normally.

For a period of several weeks, the station broadcast the nightly programs at 50,000 watts. Since the station only operated during the night-time hours, all of the necessary equipment modifications for the 500-kw system were made during the day, when the station was off the air. Engineers installed a switching arrangement that allowed the 50-kw modulated driver to be alternately connected to either the new amplifier for testing or to the antenna for the nightly broadcasts.

More Power Supply Modifications

The power supply components and most of the r-f equipment had adequate power ratings for use with the 500-kw amplifier. Weldon, however, re-connected the power supply filter chokes and filter capacitors in order to accommodate the increased current requirements. The six-phase Brown-Boveri rectifiers were more than adequate for the new equipment; but the filter chokes, as connected, did not have sufficient current capacity. Each of the chokes had dual ratings and were re-connected in parallel to double their current capacity, which reduced the total inductance to one-fourth of the original value. To compensate for the reduced inductance, Weldon connected the audio reactors, which he had removed from the old class-C r-f amplifier, in series with the other filter chokes for a total inductance of 2.25 Henrys. As an economic measure imposed by management, technicians constructed a filter-capacitor assembly for the power supply consisting of the modulation capacitor from the old class-B modulator and additional capacitor units for a total of 70 microfarads. The capacitor assembly together with the 2.25 Henry inductance provided an L-C filter resonant frequency of slightly less than 13 cycles. While not adequate

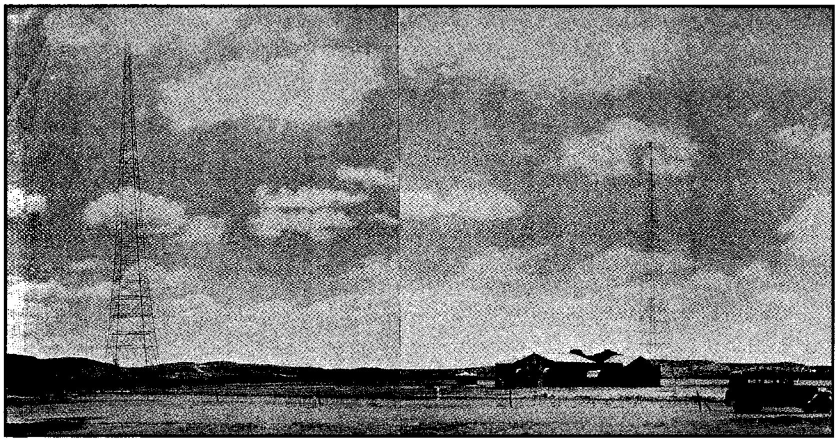

Figure 10. XER before the antenna was installed.

for the lowest audio frequencies, the 13-cycle filter did provide sufficient power-supply stability to begin testing of the 500-kilowatt amplifier.

The 500,000 Watt Amplifier

The 500-kilowatt amplifier consisted of two 250-kilowatt Doherty amplifiers that were operated in parallel to obtain 500,000 watts. Both of the Doherty units used four of the newly developed W.E. 320A tubes, each tube having a peak power rating of 250,000 watts.

Engineers made initial tuning adjustments in the amplifiers on August 1, 1938, using an r-f bridge to obtain coarse settings of all the resonant circuits. When power was applied to the first Doherty amplifier, a "singing" oscillation occurred that caused excessive plate current and opened the circuit breaker. To eliminate the oscillation, Weldon added additional mica capacitors, which he borrowed form the other amplifier, to increase the KVA/KW ratio of the grid-tank circuit. Because capacitors had been removed form the second amplifier, Weldon postponed the testing of the 500-kw system until additional parts could be obtained. During that time, however, engineers tested each of the Doherty amplifiers individually at a carrier output power of up to 320,000 watts. As part of the test, each amplifier was modulated at eighty percent with a single audio tone. On about August 10, XERA, The Sunshine Station Between the Nations, began regular nightly broadcasts using one of the Doherty units operating at an output power of 270,000 watts with 100-percent modulation.

When testing of the parallel operation for 500 kilowatts began, another spurious oscillation occurred at a frequency of 1370 kc. The oscillation resulted from the two pairs of Number 2 audio peak tubes acting as a push-pull oscillator when the output of each amplifier was paralleled. While trouble-shooting the system, Weldon discovered that, at 1370 kilocycles, a high-impedance, resonant, push-pull circuit was presented as a plate load to the audio peak tubes and that the distributed capacity of connecting lines to the grid tuning equipment functioned like a resonant push-pull tank at that frequency in the grid circuit. Together, these conditions caused the two units to operate as a high-power oscillator instead of an amplifier. He eliminated the problem by adding a three-turn damping coil in each grid lead to de-tune the tank at 1370 kilocycles. The coils were temporary, however, as any change in the tank tuning would require their re-adjustment. Later, when additional parts were available, each coil was replaced with a five-ohm resistor. The resistors presented a total of ten ohms to the oscillation in the tank, but only five ohms in the r-f drive lead to the amplifier. The ten-ohm impedance eliminated the oscillation with a negligible effect on the regulation of the r-f drive signal.

During a test at 500 kilowatts, the inadequacy of the 13-cycle power supply filter became apparent. While modulating the transmitter at 100 percent with a 50-cycle tone, Weldon discovered an audio voltage in excess of 3,000 volts across the 70-mfd power supply output capacitor. This voltage, alternately added to and subtracted from the plate voltage of the power-amplifier tubes, caused severe audio distortion and unnecessary stress on the new W.E. 320A tubes. As a stop-gap measure, he installed a high-pass audio filter with a roll-off of −6 db at 30 cycles. The filter was used until the recommended 120-mfd capacitor could be installed.

On September 15, 1938, XERA began regular nightly broadcasting with a 100-percent modulated carrier output power of 520,000 watts. With the 3 db gain in the antenna, XERA had an effective radiated power of slightly more than 1,000,000 watts. Dr. Brinkley boasted that he owned "...the world's most powerful broadcasting station" (Fowler 45).

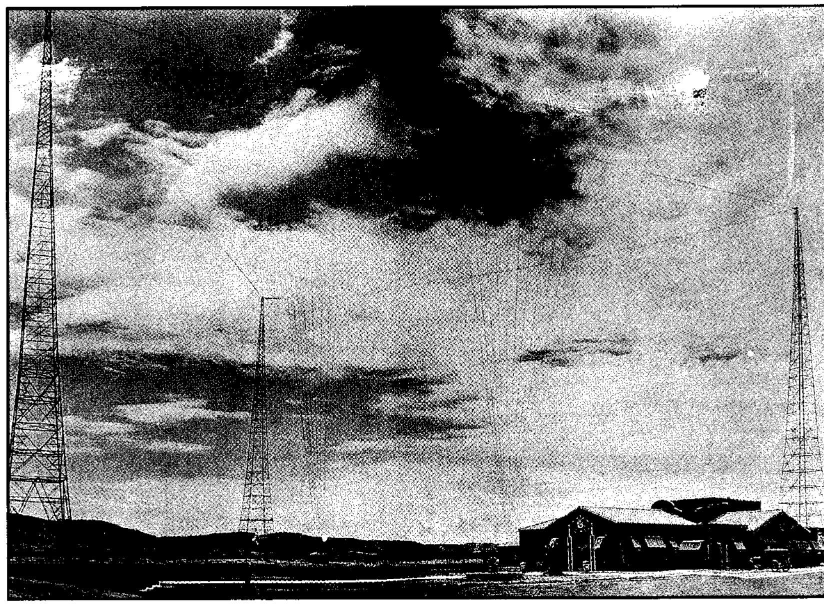

Figure 11. Station XER with the two-element flat-top antenna system that engineers installed while the station was operating at 65kw. The array had a forward gain of slightly more than 3 db and provided the station with an effective radiated power of more than 130kw to the north of the transmitting site. The flat-top portion of the system is not visible in the photograph; however, the group of wires nearer the building are the down-leads for the driven element of the array.

By skillfully designing the XERA equipment, Weldon accomplished a nearly impossible task; in less than eight months he had designed, constructed, tested, and put into operation the 500,000-watt station. He had used all but four parts from the existing transmitter, and he completed the entire project without program interruptions. After the power increase from 180 kw to 500 kw, the only parts of the old transmitter to be discarded were two tube sockets, one of the class-C stage assemblies and one high-level modulation transformer.

Touring the 500,000 Watt Amplifier[1]

Engineers positioned the control panel for the 500-kilowatt transmitter just inside the new room, facing the old operating position. Constructed of steel and glass office partition-material, the twenty-seven-foot-long panel spanned nearly the entire width of the new control room, with individual panels directly in front of the associated equipment.

Facing the new control board, one had a clear view of the complete in-line system of panels. A 48-inch wide panel in the center contained the controls for the 50-kilowatt modulated driver, and a door adjacent to each side of the panel provided access to the driver and one of the 250-kw amplifiers. A set of panels adjacent to the left access door contained the controls for one of the Doherty amplifiers, and an identical set of panels adjacent to the right access door formed the control system for the other Doherty unit. On the far right end of the main control system, stood a separate control panel for the bias rectifiers and filament starting circuits.

An array of eleven meters formed the first section of the monitoring panel for each Doherty unit. Included in this array was a plate-current meter for each of the four tubes and total plate-current meter for

[1]Photographs of the 500-kw system are not available.

the unit; a grid-current meter for each pair of tubes and an r-f tank current meter for each of the two grid-tank circuits; a filament-voltage meter that could be connected to any of the four tubes by a rotary switch and a time-meter for recording filament operating time. Four plate-current overload relays, each with an indicating flag, composed the second portion of the monitoring area. When plate-current overload occurred, one or more of the relays closed a 24-volt battery trip-circuit which in turn opened the high-speed oil-type circuit breaker to shut down the amplifier. When the relay closed, it set the indicating flag to show which of the four tubes had been drawing excessive current.

The controlling section of the panel for each Doherty amplifier contained an assortment of knobs, toggle-switches, and push-buttons for adjusting specific parameters of that unit. Among these were controls for adjusting the filament voltage for each of the four amplifier tubes and the 18,000-volt plate supply. Two push-buttons in the control area either removed the amplifier from service or re-connected it into service, as required. A system of shafts and gears allowed load impedance and grid-tank/plate-tank tuning adjustments to be made from the control panel.

By entering the amplifier compartment through either of the front panel access doors, one had a clear view of the Western Electric 320A power tubes. All eight tubes stood in a straight line, seven feet behind and parallel to the front panel, spanning its entire twenty-seven foot length. The four tubes to the left of the driver composed the 250-kilowatt amplifier, Number 1, and the four to the right composed the 250-kilowatt amplifier, Number 2.

In his paper on the 500,000-watt transmitter, Weldon described the functional placement of each amplifier tube: "In each 250-kilowatt amplifier, the two tubes farthest away from the driver stage are the "Number 1" or carrier tubes and the two tubes nearer to the driver stage are the "Number 2" or modulation peak tubes of the Doherty system. The 250-kilowatt units are identical in every detail and the following description applies to either" (11).

Each 250-kilowatt amplifier contained four of the Western Electric 320A tubes; two tubes connected in parallel for the carrier amplifier and two connected in parallel for the audio peak amplifier. A 17.5 KVA filament transformer and induction-voltage regulator hung on the basement ceiling directly below each of the tubes. The transformers supplied single-phase a-c power to the filament of the associated tube, with the filaments of each pair being supplied 90-degrees out of phase. A system of shafts and gears allowed adjustment of the voltage regulators from the control panel located on the floor above.

Cabinets mounted at floor level and eighteen inches behind the 320A tubes contained the grid inductors, mica condensers, and variable condensers for adjusting the grid-circuit phasing and tuning. An air duct mounted directly above the cabinets extended the full length of the two amplifiers and then extended outside the building. The duct served as housing and cooling system for the grid-load resistors in each Doherty amplifier. The resistors generated approximately thirty kilowatts of heat, and air supplied by a blower in the basement removed the heat at each end of the system.

Weldon designed the grid-tank circuit for the Number 1 and Number 2 tubes as a "built-out" or "double-ended" circuit, so that neutralizing voltage could be obtained from the built-out end of the tank. The neutralizing condensers consisted of a group of mica units, with a small, air-insulated variable condenser connected in parallel for trimming. The trimming condenser was located above the air duct and connected to the plate-blocking condensers at that point. In his paper Weldon said that he found this method of neutralizing unsatisfactory because any adjustment of the tank condensers could result in the need to re-adjust the neutralizing condenser. "Although instability never developed as a result of changing adjustments of the grid tuning without re-neutralizing, it was made a routine to re-check neutralization after such adjustments and practically always a slight readjustment was found necessary" (Weldon 14).

At the center of the air system containing the grid-load resistors, the duct extended forward toward the front panel. Here the duct functioned as a conduit for the wires that connected the driver through a phase-shift network condenser to the input circuits of the Number 1 tubes. In the center of the duct engineers installed part of the isolation system that disconnected either or both of the 250-kw units form the driver amplifier.

Compressed-gas condensers mounted on the floor of the amplifier compartment, behind the grid equipment cabinets, resonated the amplifier output circuits. A system of shafts and gears allowed the condensers to be adjusted from the front panel. As an economy measure the station management required that compressed air, rather than dry nitrogen, be used to operate the condensers. Under normal conditions this method proved to be more economical; however, in his paper on the high efficiency transmitter, Weldon noted that it "...has a disadvantage in that oxygen is present in the condenser tanks to support combustion in case of an internal arc over." As a precaution, safety gaps were installed across each condenser; but Weldon also noted that "...conditions may develop wherein these do not provide protection" (14, 15).

To help prevent moisture condensation in the air lines, and thus in the condensers, a ten-foot vertical pipe was run from the compressor tank. This allowed any moisture that condensed in the line to drain back into the tank. Engineers removed the moisture daily by opening a drain cock at the bottom of the tank. To test the efficiency of the system, and to check on the danger of moisture condensation in the condensers, Weldon left the drain cock closed for several months until the tank became half-full of water. At random intervals during that time, some of the condensers were opened and found to be completely dry. Weldon, however, states in his paper that "...in general, the weather conditions prevailing in the locality where the transmitter is situated present lower humidity values than may normally be expected in most parts of the country. Although no difficulties have been experienced in this case, the use of air is not to be recommended above the use of dry nitrogen" (15). Weldon used a 300-psi compressor as an air source to operate the condensers, and a pressure switch controlled the compressor and maintained a line pressure between 250 and 255 psi.

Directly above the compressed-gas tuning condensers, a shielded cabinet containing the plate phase-shift networks and output tank coils associated with the tuning condensers spanned the length of both amplifiers. This cabinet had a steel and aluminum frame and used copper sheets to form separate internal compartments.

Above the output-inductance cabinets another air duct, attached to the ceiling, ran the full length of the control panel and then out of the building. In addition to functioning as a hot-air exhaust, the duct served as a housing for the 18,000-volt supply lead, which entered the system near the center and connected directly to the driver plate-choke. Before the driver choke, the high-voltage line went through two contacts of the isolation system and then to the individual plate-current limiting resistors of the two Doherty amplifiers. Another air duct mounted directly above the 320A tubes contained the limiting resistors, each positioned above the associated tube. The duct spanned the full length of the two amplifiers and functioned as the cooling system to remove the heat generated by more than 13 kilowatts of power radiated from the resistors. A blower in the basement supplied air at the center of the duct and the heat was removed from the system through an external exhaust at each end of the building.

A feed-through bushing carried the 18,000 volts from the limiting resistor to the plate r-f choke for each of the eight 320A tubes. The chokes were mounted vertically on top of each tube assembly. In his paper Weldon describes the chokes as having been wound with number ten wire on a seven-inch diameter, three-foot-long Bakelite form. Every twentieth turn was firmly attached to the form to prevent the turns from piling up due to heating or magnetic force which might be caused by high plate current (16).

At the rear of the amplifier, engineers positioned the two T networks used for matching the output circuits of the 250-kilowatt amplifiers. The output leads of the networks connected, through the contacts of an isolation switch, to a dual-impedance T network in the basement. Weldon describes the T network as consisting of two inductive series elements and one capacitive shunt element. Each element had leads connected to contacts of the isolation switch in order to adjust the impedance match to the final amplifier (17).

The Isolation System

Weldon designed this system so that it would automatically isolate either or both of the Doherty amplifiers when an electrical fault occurred. As part of the isolation procedure the switching system adjusted load impedances and re-routed signal paths as necessary to keep the station on the air while repairs were made to the isolated equipment.

On the control panel of each amplifier, a switch labeled "Automatic" or "Manual" set the operating mode of the isolation system for that unit. In the manual mode an operator had to initiate an isolation sequence, but in automatic, when an electrical problem occurred, the system removed that amplifier from the air without operator intervention. A two-position switch on the control panel set the time required to disconnect a specific unit. In the "Instantaneous" mode isolation procedures occurred immediately, but in the "Delayed" mode two interruptions within one minute were required to isolate an amplifier.

The isolation switch selected specific taps on the dual-impedance T network that fed the antenna in order to alter the load impedance presented to the amplifier output circuits. Under normal operating conditions the network presented an impedance between 50 and 60 ohms to the 500-kilowatt amplifier. When one of the Doherty amplifiers had been disconnected, however, the system readjusted the network and presented an impedance between 100 and 120 ohms for operating at 250 kilowatts. In the event that both amplifiers were isolated at the same time, the system would automatically connect the 50-kilowatt modulated driver to the transmission line through a separate network. Engineers only used this feature during initial adjustments and eventually removed it from the system. Although not used during the first year of broadcasting at 500-kilowatts, the feature that removed either of the Doherty amplifiers from service became a prominent part of the system during a period of financial instability at the station. During that time Weldon operated the station at 250-kilowatts as an economic measure and used the feature daily to alternate the amplifiers.

In addition to the preceding actions, the isolation switch performed the following functions in a single operation (Weldon, 18-20):

1. Disconnected the 18-kilovolt supply and grounded the high-voltage positive terminal of the isolated unit.
2. Disconnected the grid-drive lead and substituted resistance loading so that the driver-stage load remained unchanged.
3. Opened the 500-volt bias supply and grounded the 500-volt bias terminal of the isolated unit.
4. Opened the 1,200-volt bias supply and grounded the 1,200-volt bias terminal of the isolated unit.
5. Applied a short-circuit across the door switches of the isolated unit so that this unit could be entered without interrupting the plate and bias supplies to the other unit.

6. Applied a short-circuit across the filament time-delay circuit and the plate-interlock relay so that the filament voltage of that unit could be removed without interrupting the plate voltage supply to the other unit.

7. Applied plate voltage to the other unit when the isolating operation was complete.

When an electrical fault occurred, the time required for the isolation system to perform the preceding functions and return the operating portion of the transmitter to the air was less than two seconds. "The mechanism of this switching system is driven," Weldon wrote, "by the slow speed shaft of ratio-motors, one motor controlling the switching for each of the units. Interlocking prevents operation of the switch while the rectifier oil circuit breaker is closed and also prevents the circuit breaker closing while the isolation or re-connecting is in progress" (18).

The Cooling System

A system of porcelain pipes hung on the ceiling of the basement by stand-off insulators supplied distilled cooling water to the tubes in the amplifier on the floor above. In his paper Weldon described the hookup of the water system to the 320A tubes of the 500-kilowatt amplifier: "A two inch pipe brings water to the pair of 'Number 1' tubes with their jackets in parallel. Their outlet water passes through suitable lengths of porcelain pipe to the jackets of the 'Number 2' tubes and from them through 28 feet of porcelain to the outlet manifold" (19). Water circulated at a rate of sixty gallons per minute through each of the 320A tubes.

Weldon used coils of porcelain pipe to supply water for cooling the 848 and 863 tubes in the lower-power stages. A similar system using a one and one-half-inch diameter porcelain pipe supplied water, from the same source. to the 50-kilowatt driver. Each tube assembly had a water cutoff valve to interrupt the supply water and another valve to drain the water jacket when it was necessary to remove a tube.

Two 3,000-gallon cypress-wood tanks served as storage for the distilled water that circulated through the system. A 25-horsepower, 3,600-RPM centrifugal pump circulated the water through a closed loop that included all the water-cooled tubes and a heat exchanger. The hot raw water form the exchanger was cooled in a fifty-by-sixty-five-foot pond through a system of ten spray nozzles.

The Bias Supply

A power supply using six UV-872A rectifier tubes in a three-phase, half-wave, double Y connection supplied the bias for the Number 2 tubes of each amplifier. The system supplied 1,200 volts at 7.5 amperes. The motor-generator that supplied bias for the Number 1 tubes is described by Weldon in his paper as being "...separately excited so that in case of an arc over within one of the tubes, from plate to grid, the plate voltage will not cause reversal of the polarity of the machine [motor-generator]" (22). A standard single-phase, full-wave rectifier supplied the bias voltage for the 50-kilowatt modulated driver.

The 500-kilowatt Antenna

Until the fall of 1938, when the testing of the 500,000-watt amplifier began, all of the antennas used at the station were variations of a multi-wire flat-top system. When operation with the 500,000-watt amplifier began, brilliant corona would, at times, appear on the flat-top and over about 50 feet of the down leads. Weldon stated that the corona 'talked' so loud that you could hear the Doctor's voice on the main street in downtown Villa Acuna (Correspondence 27 May 1989). The corona caused audio distortion on modulation peaks greater than 75 percent, but both problems were corrected when Weldon installed the new antenna system for the 500-kilowatt transmitter. The new antenna had higher capacitance than the old one, which prevented corona from forming on the array.

A sixteen-wire tapered cage 36-feet in diameter at the top and 3-feet in diameter at the bottom constituted each element of the new antenna. Using a 1,000-cycle bridge, Weldon measured the capacitance-to-ground of the new system as being 2.6 times greater than the old one. With a 100-percent-modulated 540-kilowatt signal applied to the new array, no visible or audible corona was present on the system. Figure 12 is a photograph of XERA with the new cage antenna. Someone apparently tried to enhance the antenna wires, which were barely visible in the original picture; and although the enhancement is obviously poor, the photograph does show the general appearance of the 500,000-watt system.

In his paper on the transmitter Weldon describes the phasing and coupling equipment for the antennas as having inductors made of large-diameter copper tubing and supported by 10-inch stand-off insulators attached to each alternate turn. The resonating condensers were a series of air-insulated aluminum plates, two inches thick and five feet in diameter, similar to those used in the 180-kilowatt amplifier. The output of the transmitter was connected to the phasing equipment by a 75-ohm concentric transmission line made of a two-inch diameter copper inner conductor and a seven-inch diameter copper outer conductor. The line was sealed and kept at a constant air pressure of 20 psi. Under normal operating conditions, r-f current in the line measured approximately 83 amperes or slightly less than 520,000 watts. A three-conductor, unbalanced, open-wire line connected the phasing circuits of the reflector and the driven element.

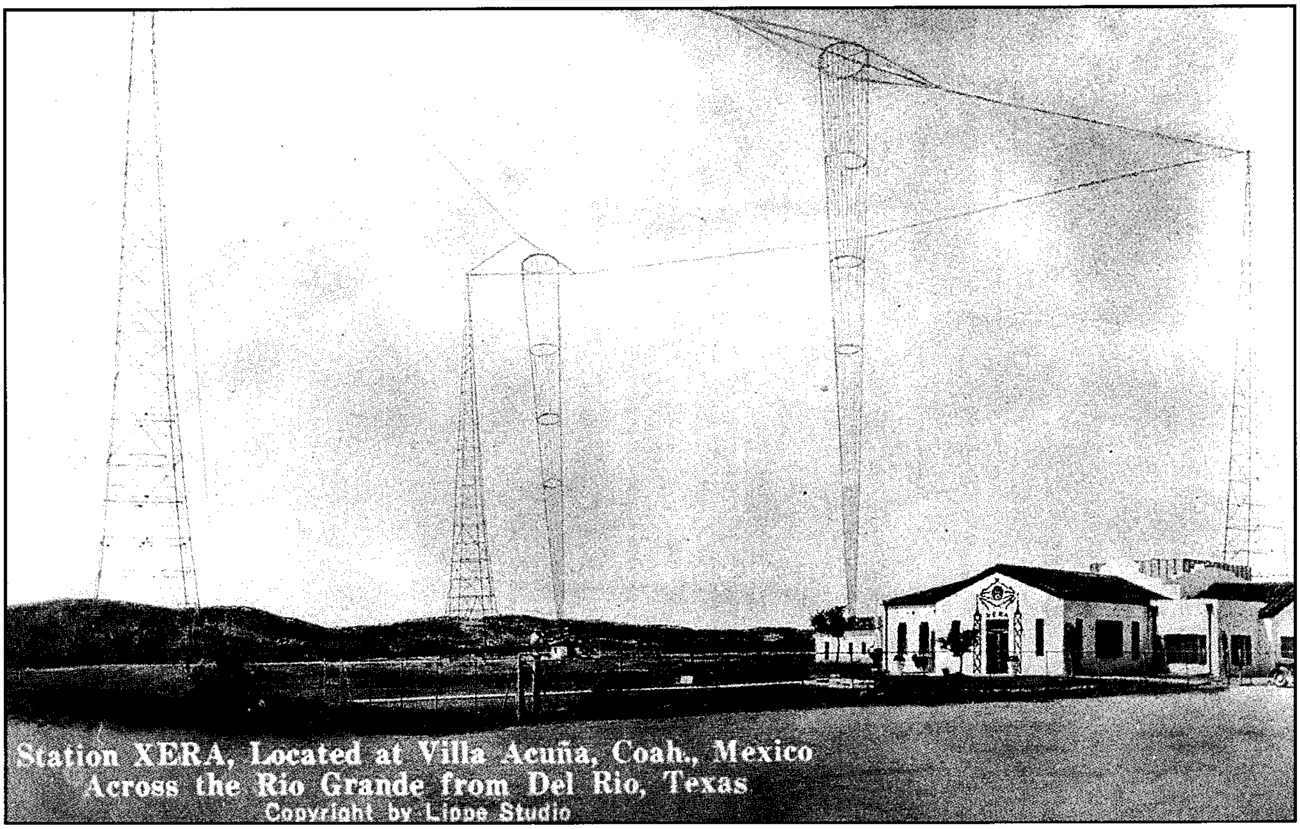

Figure 12. XERA with the cage antenna used with the 500-kw transmitter. The wires of the cage and flat-top, which were barely visible in the original picture, have been poorly enhanced by someone, but the photograph still shows the nature of the system.

While operating the station at 500,000 watts, engineers made field-strength measurements in the 180-degree maximum-signal area to the north of the transmitting site. In his paper on the transmitter, Weldon said that when converted to "fundamental strength" the measurements showed 6.65 volts at a distance of one mile. Additionally, he reported that this figure agreed closely with the predicted strength for 1,000,000 watts of power in an antenna one quarter wave high, and would be the expected strength from the directive system with a transmitter output power of slightly more than 500 kilowatts (28).

As described earlier, the ground system for the flat-top antennas consisted of an array of parallel wires laid out on a grid. When the new antennas were installed, engineers overlaid the old system with a set of 120-half-wave radials spaced at three-degree intervals. They installed one such system under each element of the antenna and connected the two systems at points where the radial wires crossed.

Figure 13. XERA designer, James O. Weldon, next to one of the 250 kw Western Electric 320A tubes at his company, Continental Electronics, in Dallas.

Lightning Protection

The antenna and equipment was protected from lightning and other flashovers by a system described by Poppele, Cunningham, and Kishpaugh in their August 1936 paper published in the *Proceedings of the Institute of Radio Engineers*. They describe the protection system as "...a device which functions to remove the carrier for an instant succeeding a flashover in any part of the circuit" (1074). The detection part of the circuit depended on the grid and plate voltages, in the final amplifier, being proportional in magnitude but opposite in phase when the amplifier is in normal operation. To form the detector circuit, two reactors were connected between the grid and plate circuits and their common point connected, through a detector, to ground. With the reactance of each coil critically adjusted and the system operating normally, the output of the detector remained zero. When lightning or other flashovers occurred in the antenna system, however, the grid-to-plate phase and/or magnitude relationship became unbalanced and the detector output increased to a level that operated a relay. The relay removed the carrier by interrupting the plate supply voltage to a buffer amplifier just after the crystal oscillator. According to Poppele, "...plate voltage is restored after a delay of approximately a fourth of a second, which permits the arc to clear in the antenna system with an almost unnoticeable interruption of the program" (1074).

Overall Specifications

Table I lists the overall specifications for the XERA 500,000-watt system. It should be noted, however, that the second harmonic level of -72 db below the 500-kilowatt carrier was not satisfactory, and Weldon reported in his paper that the design would allow the use of several methods of reducing the level further. One such method, he said, would be the use of a quarter-wave concentric harmonic shunt connected in the matching network (28). Even though the value of the harmonic signal

Table 1. Overall Specifications for the XERA 500,000 Watt System

Plate Voltage on 320A final tubes:	18,000 volts
Plate current (no modulation):	45 amperes
Plate input power:	810,000 watts
Output power to antenna:	500,000 watts
Second harmonic:	−73 db below 500-kw carrier
Efficiency (Doherty amplifier only):	approx. 61%
Maximum power demand:	1,340,000 watts*
Overall station efficiency:	approx. 37%
Audio frequency response:	30-30,000 cycles plus or minus 1 db

*Using an integrating demand watt meter. Includes transmitter power, building lights, and loss on one mile of 11,000 volt power lines from the U.S. side of border.

remained above one millivolt at a distance of one mile, it caused no interference and engineers made no attempt to reduce it further. Measurements of other harmonics showed their levels to be well within good engineering practice.

Closing XERA

XERA operated at 500,000-watts until early summer 1941. Two years earlier Mexico had ratified the provisions of an international agreement with the United States that cleared the way for action against all controversial border broadcasters. In late spring 1941, the newly elected President of Mexico ordered the expropriation of XERA, saying that the station was controlled by foreigners and that it had transmitted "...news broadcasts unsuitable for the new world..." (Border Radio, 44). In early July *Federales* closed XERA.

In an attempt to revive the station, Dr. Brinkley flew to Mexico City for an ill-fated conference with the Mexican authorities. On his return trip to Del Rio, Brinkley suffered a heart attack from which he never fully recovered, and on July 21, 1941, Mexican authorities began dismantling XERA. During the next year his health continued to deteriorate, and on May 26, 1942, he had a second heart attack and died.

After removing the equipment from Brinkley's station, the Mexican authorities installed the XERA transmitter at station XEX in Mexico City. It is not known if the transmitter was ever put on the air or whether any portion of the station still exists. One of the Western Electric 320A final tubes, however, did find its way to Weldon's company, Continental Electronics, in Dallas and is currently on display in the lobby.

Works Consulted

Brighton, Ivan. Personal video tape interview. 19 April 1990. Author's collection.

Brinkley, John R. Telegram to Howard Wilson. 10 October, 1932. Author's collection.

Doherty, W.H. "A New High Efficiency Power Amplifier for Modulated Waves." *Proceedings of the Institute of Radio Engineers* 24.9 (1936): 1163-1182.

Duran, S.R. "Steel-Cylinder Grid-Controlled Mercury-Arc Rectifiers in Radio Service." *Proceedings of the Institute of Radio Engineers* 23.4 (1935): 372-379.

Evening Radio Broadcast. By John R. Brinkley. XERA, Del Rio. c. 1838. Author's collection.

Fowler, Gene, and Bill Crawford. *Border Radio.* Austin, Texas: Texas Monthly Press, 1987.

Gonzalez, Arturo. Personal video tape interview. February 1989.1 Author's collection.

KFKB Broadcasting Association, Inc. *Souvenir Album of the Artists and Others at Radio Station KFKB.* Kansas: KFKB Broadcasting Association, 1930. Author's collection.

Munal, H.L. Letter to Dr. Brinkley. 5 October, 1932. Author's collection.

Munal, H.L. Letter to Dr. Brinkley. 7 October, 1932. Author's collection.

Continued on page 39