Stanley Adams

WESTINGHOUSE RADIO STATION KDKA

50 KILOWATT AIR-COOLED BROADCAST TRANSMITTER

R. N. Harmon

June 27, 1940

Last November KDKA celebrated its 20th anniversary with the opening of a new transmitting plant containing a fifty kilowatt air-cooled transmitter. The new transmitter was the fourth fifty kilowatt set used and the ninth transmitter since the first broadcast on November 2, 1920.

Some of the features of the KDKA air-cooled fifty kilowatt transmitter are novel and since later models of this transmitter are now being manufactured for other broadcasters it is felt that a description of this transmitter is appropriate.

MAIN FEATURES

The KDKA transmitter, later models of which carry the title of fifty HG, is a fifty kilowatt high level modulated transmitter. The last radio frequency stage operates class "C" and is modulated by a class "B" audio modulator. Because of the high efficiency inherent in class "C" radio frequency amplifiers and class "B" audio amplifiers, it was found practical to use air cooling on all tubes in the entire transmitter. Detailed description of these new radiator type power tubes is to be given in a paper presented at this convention by Mr. W. C. Moran and Mr. I. E. Mouromtseff.

The following tables summarize most of the mechanical and electrical features of this transmitter:

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Features

1. All tubes air-cooled
2. High efficiency circuits.
3. Automatic spare tube changer.
4. Metal rectifiers.
5. Inductive neutralization.
6. Compressed nitrogen condensers.
7. Equalized feedback.
8. Complete automatic control and supervisory indication.
9. Low average plate voltages.
10. Conservative rating of tubes and equipment.
11. Simplicity of design and adjustment.
12. Unit construction with full accessibility.

Performance

1. Fifty kilowatt carrier with one hundred and five kilowatt input.
2. Fifty kilowatt carrier with one hundred percent modulation, one hundred and forty five kilowatt input.
3. Frequency stability plus or minus ten cycles.
4. Modulation capability one hundred percent.
5. Audio frequency response plus or minus one decibel, twenty to fifteen thousand cycles.

6. Carrier noise sixty decibels or more below one hundred percent modulation.
7. Audio distortion less than two percent - zero - ninety five percent modulation fifty to three thousand cycles, less than three percent thirty to ten thousand cycles.
8. Harmonic radiation at radio frequencies, none greater than seventy decibels below the fundamentals.

The transmitter proper is composed of eight steel cubicles each of which is eighty four inches high by forty eight inches wide by fifty four inches deep.

The installation of these units in a transmitter building is largely determined by individual preference. At KDKA the "in line" construction was used because the transmitter building was designed to house three fifty kilowatt equipments. All auxiliary apparatus including transformers, reactors, regulators and air blowers is located in the basement directly underneath the transmitter cubicles.

The various functions performed by the transmitter logically determined the disposition of the equipment into eight cubicles as follows:

Exciter

Modulator

Power Amplifier (3 cubicles)

Rectifier

Power Distribution

Power Control

POWER CONTROL CUBICLE

The transmitter operates from a twenty three hundred volt, three phase, sixty cycle power supply. The incoming supply cable terminates in the power distribution cabinet on a twenty three hundred volt bus to which is connected two oil manually closed, electrically tripped circuit breakers. One of these oil switches is connected to a step-down transformer bank having three phase secondary voltages of one hundred and fifteen volts. The secondaries of this transformer bank are connected in series with a three phase, motor operated, induction regulator having one hundred and fifteen volt series windings, thus giving one hundred percent regulation of a three phase voltage from zero to two hundred and thirty volts. This power supply feeds all low voltage equipment and is called the distribution service.

The second oil switch is connected to a step-up bank of transformers to which is connected the main rectifier. Two electrically operated step-start oil contactors are in the supply lines to the main rectifier transformers to permit connection of the rectifier to the supply line without undue surges.

POWER DISTRIBUTION CUBICLE

The distribution service terminates in the power distribution cabinet as a two hundred and thirty volt, three phase bus from which are connected various branch circuits supplying power to all apparatus in the transmitter except to the plates of the modulator and power amplifier tubes. The power distribution

cabinet contains all two hundred and thirty volt branch circuit contactors, de-ion switches, twelve hundred and fifty volt metal rectifier, three thousand volt metal rectifier and also all main control relays for overloads, under voltage, sequence, distribution regulator control, supervisory relays and metering for the metal rectifiers.

Having described briefly the equipment in the power distribution and power control cubicles, we are now ready to discuss the transmitter proper.

EXCITER CUBICLE

The exciter cubicle contains a radio frequency exciter for the power amplifier and an audio frequency exciter for the modulator. The radio frequency section contains two temperature controlled crystal oscillators each using one 802 tube. These oscillators may be switched into service by a crystal change switch located on the control panel of this cubicle. The crystal oscillator is connected to an 807 buffer followed by an 803 intermediate which excites two 833 tubes operating in push-pull. The output of the 833's is approximately two kilowatts and is connected to the grids of the power amplifier by two concentric lines.

The audio section of the exciter uses two 1620 tubes in push-pull resistance-coupled to two 807's, resistance-coupled to four 845's, push-pull paralled impedance-coupled to two 849's, push-pull transformer-coupled to the grids of the modulators.

Located in the exciter are metal rectifiers which provide plate supply for the crystal oscillators, bias supply for the 849's speech tubes and bias supply for the modulators. These rectifiers are completely controlled by variacs.

The control panel of the exciter mounts complete metering and controls for all stages of the aduio and radio exciter; OFF-ON switches for the metal rectifiers contained in the exciter cubicle, as well as OFF-ON switches for the twelve hundred and fifty volt and three thousand volt metal rectifiers located in the power control cabinet.

The more important meters for the 849's, 833's and 803's are mounted on the top of this cubicle to permit remote reading of these meters. All meters mounted at the top of all cubicles contain internal illumination for their dials.

Unusually complete controls for the apparatus in this cubicle are supplied. For ihstance, on the radio frequency section, grid and plate metering is furnished on each stage beyond the crystal. Grid and plate tuning and coupling from the front panel on the 803 and 833 permit easy and accurate adjustment of each circuit and tube while under power.

The audio frequency section has been carefully designed to permit inverse feedback to be used. Phase shift has been reduced to very small values: from five cycles to fifty kilocycles.

Two feedback loops are used; one around the 845's, and the other around the entire audio amplifier between the 807's and the output of the modulator.

MODULATOR

The modulator cubicle contains four 893-R tubes, two used in normal service and two as spares. The spare tubes may be connected into the circuit by grid and plate switches.

The filaments are multi-phase and are heated by current limiting transformers. The lower section of this cubicle contains the coupling condensers and resistors used in the feedback circuit and also serves as a plenum cham-

ber for the air supply for the 893-R tubes.

The modulation transformer is located in the basement directly under the modulator cubicle. Low capacity leads connect the modulator tubes to the modulation transformer. The design of the modulation transformer is an art in itself and usually ends up in a unit which is enormous in comparison to the power it handles. The chief reason for such a result is to avoid insofar as possible the detrimental effects of leakage reactance and shunt capacity. In order to effectively use inverse feedback, the response and phase shift of the entire audio system has to be excellent over a frequency range much wider than that actually used. This is necessary in order to neutralize high order harmonics of the higher audio frequencies.

POWER AMPLIFIER

The power amplifier is made up in three cubicles, two tube cubicles and one coil cubicle. The tube cubicles are located to the right and left of the coil cubicle.

Each tube cubicle contains two 893-R tubes which are a temporary situation until new 895-R tubes are available. At the present time four 893-R tubes are used but when replaced by 895-R, only two tubes will be used with one spare on each side. The power amplifier tubes are operated in push-pull and inductively-coupled to a balanced Pi section filter which is connected in turn to the transmission line. The following equipment is located in the tube compart ment: two air-cooled tubes, grid condenser and coil, grid leak and choke, filament transformers, neutralizing coil, plate blocking condenser, plate

tuning condenser and output coupling circuit. The plate and grid condensers are variable condensers operating under several atmospheres of nitrogen. All controls for these condensers are terminated in the coil cubicle in the center.

The coil cubicle contains in its lower half the plate tuning inductance and coupling coil, and in its upper half a balanced Pi filter and coupling network. This filter contains four gas condensers similar to those used in the plate circuit of the power amplifier but of different rating and manufacture.

The coil cubicle of the power amplifier is the control center. It contains grid and plate tuning for each tube cubicle and four condenser controls for the balanced Pi network. It also carried OFF-ON controls for the main rectifier as well as raise and lower controls for the same rectifier.

Two metal rectifiers with variac control are also mounted in this cabinet to furnish fixed bias for the grids of the power amplifier tubes.

Duplicate grid and plate meters are mounted alongside the grid and plate tuning controls to facilitate tuning and balancing the tubes in the power amplifier. Large seven inch meters are mounted at the top of the three power amplifier cubicles permitting reading of plate current, grid current, grid voltage, plate voltage transmission line current and antenna current. Unusually high efficiency is obtained by careful design of the various circuit components and by adjusting the circuits so that plate current flows only when plate voltage is low.

MAIN RECTIFIER CUBICLE

The main rectifier cubicle houses seven mercury vapor tubes; six in active use in a three phase full wave circuit, and the seventh tube, with filament heated, connected to a transfer bus ready for automatic transfer by relays to any of the other six positions. This rectifier cubicle also contains the filter condensers and the power factor correcting condensers for the transmitter. The power factor condensers are connected across the three phase supply to the rectifier tubes and not only correct the power factor of the transmitter but also remove some of the steep wave fronts from the power circuit.

The filter choke for this rectifier, main rectifier plate transformer and induction regulator are mounted in the basement directly underneath the rectifier. The rating of the rectifier is twelve thousand and five hundred volts at twelve amperes.

AIR BLOWER SYSTEM

Two air blowers are located in the basement, one of which is a standby. The transmitter requires approximately ten thousand cubic feet of air per minute at a two inch head of water. The outlet air from the blowers is conducted to a large duct mounted on the ceiling of the basement directly under the transmitter cubicles. Small risers from this duct are connected to each cubicle requiring air.

The air is led into the bottom of each cubicle which forms a plenum or pressure chamber. The large air-cooled tubes are mounted on insulating jackets directly on top of the plenum chamber which has an opening to match

the tube jackets. Air is blown from the plenum chamber through the tube jacket and tube radiator and out the top of the cubicle into an exhaust duct formed by a drop ceiling above the transmitter.

In the other cubicles where no large tubes are used, air is supplied to cool the smaller tubes and aparatus in addition to cooling the several metal rectifiers.

In actual operation the pressure drop across the cubicle is slightly more than one inch of water, the majority of which occurs across the large tube radiators.

In the winter time the air is recirculated to keep the building warm. In the summer, hot air is exhausted outdoors and fresh air drawn in.

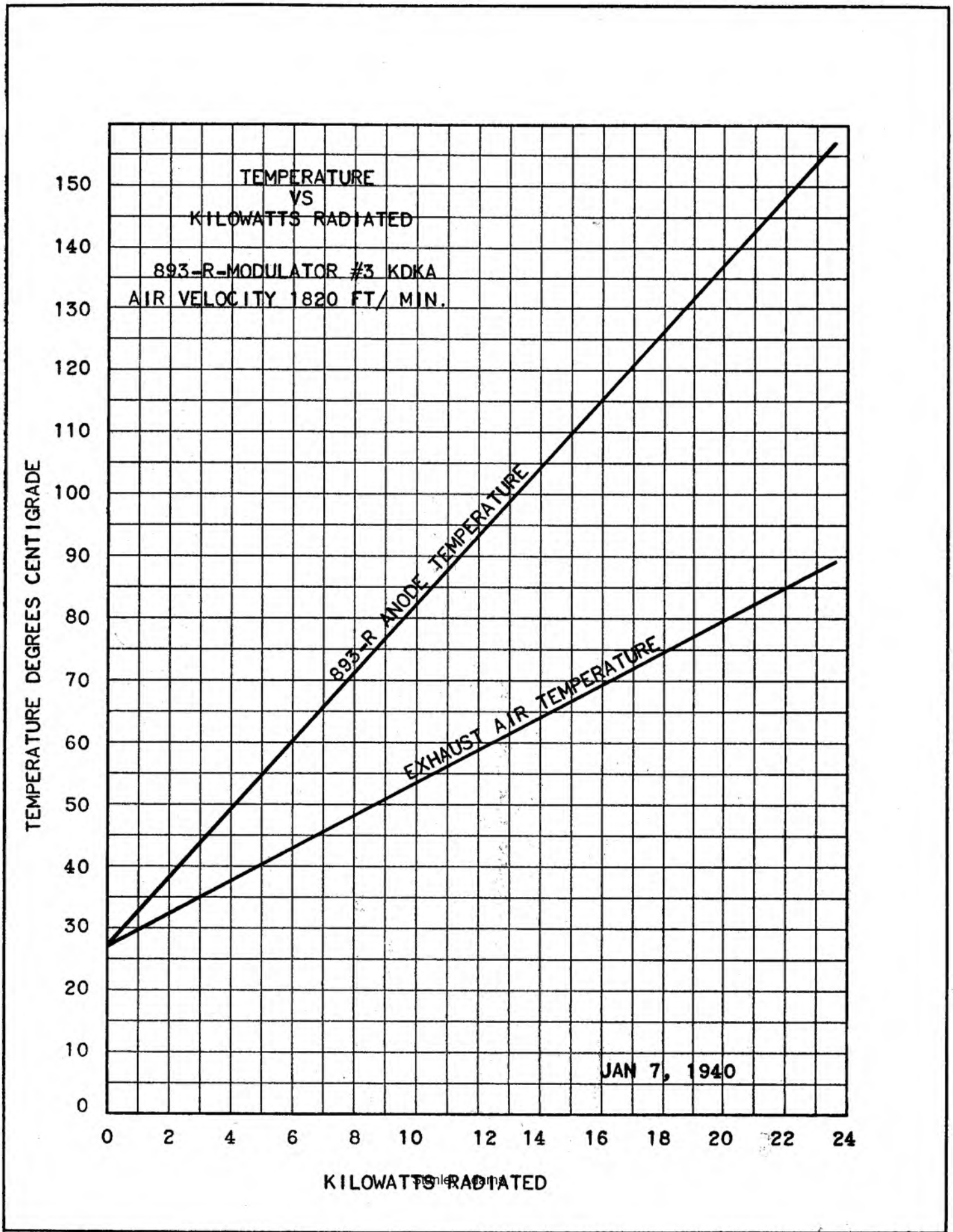
CONTROL SYSTEM

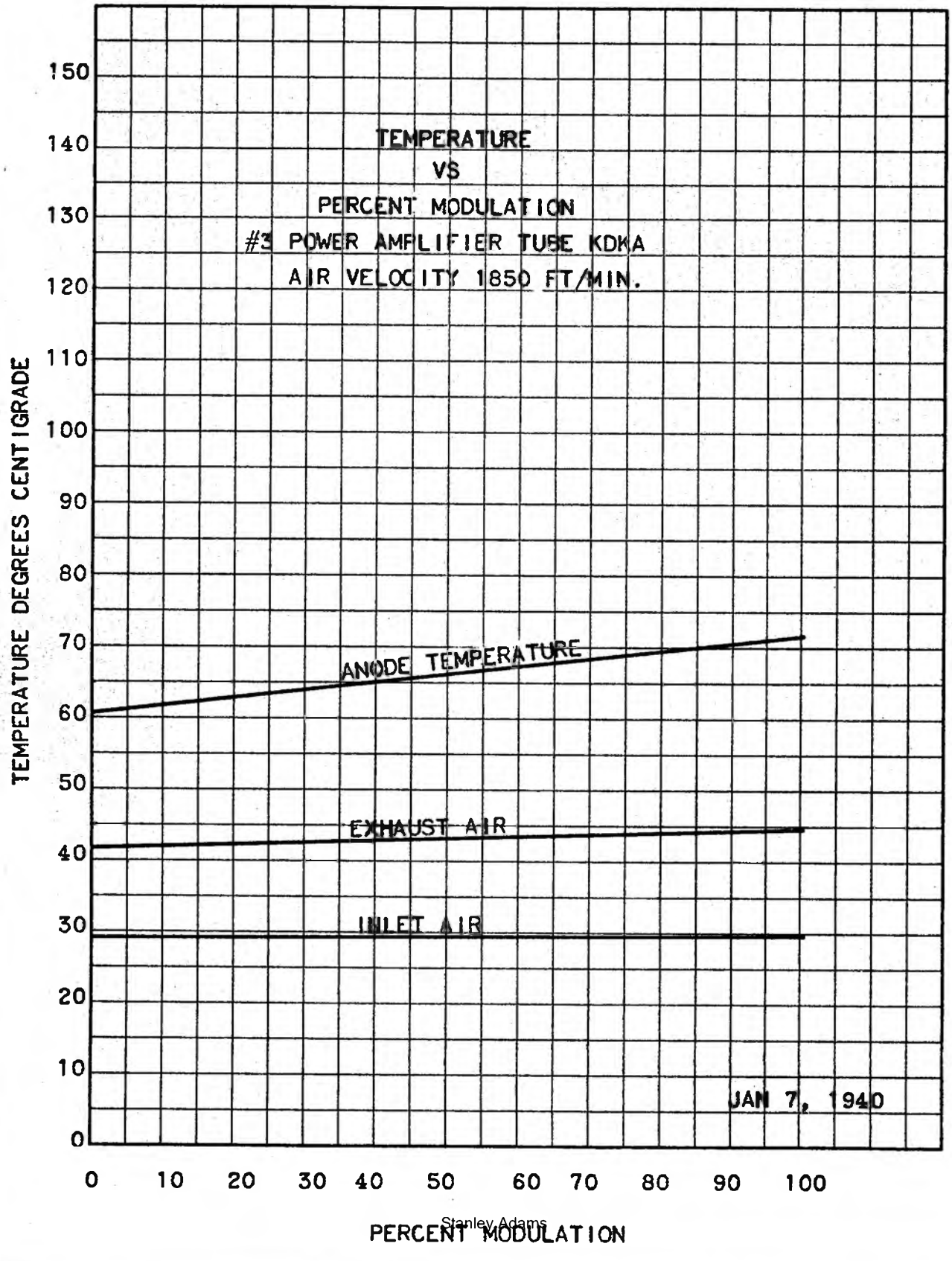
The control system is unusually complete. The transmitter may be controlled from two different locations if so desired. The control circuit is set up to operate manually or automatically. This permits easy test and adjustments as well as complete control under adverse conditions.

The controls are designed to operate in sequence starting with air flow relays, filaments, bias, door inter-locks, intermediate plate, excitation, and main rectifier plate supply. Complete overload protection is supplied by individual overload relays in the cathode circuits of all tubes having more than four hundred volts plate supply.

All relays may be set for manual or automatic return and have separate supervisory relays which lock up a light giving tell-tale indication. In the case of the main rectifier automatic return will occur two times before lock-out occurs. On all other circuits automatic return will occur indefinitely un-

less the de-ion backup breaker opens if on automatic return, or only once if on manual return. For the latter condition, the OFF-ON switch for the circuit in question must be reset before the circuit can be re-energized.





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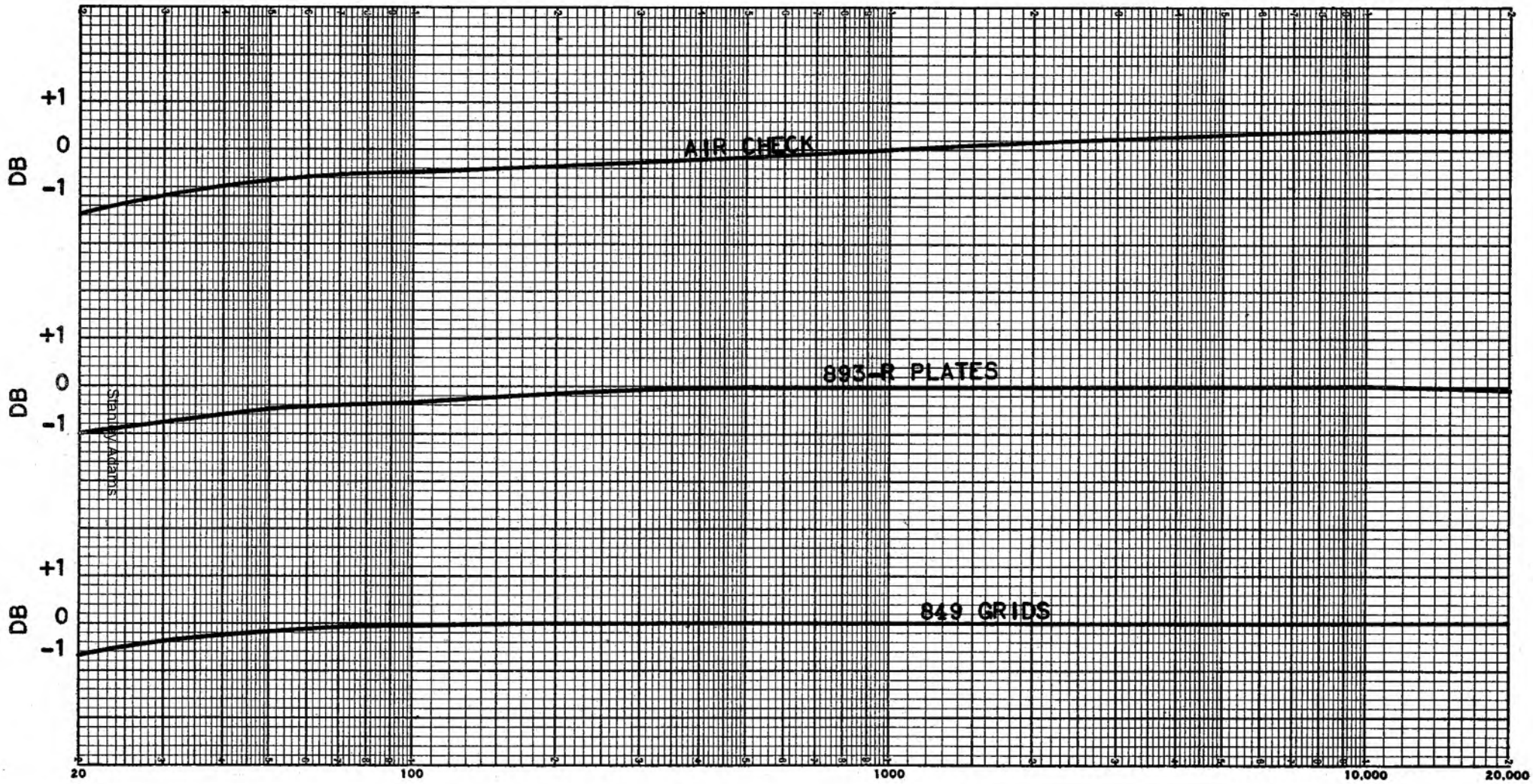
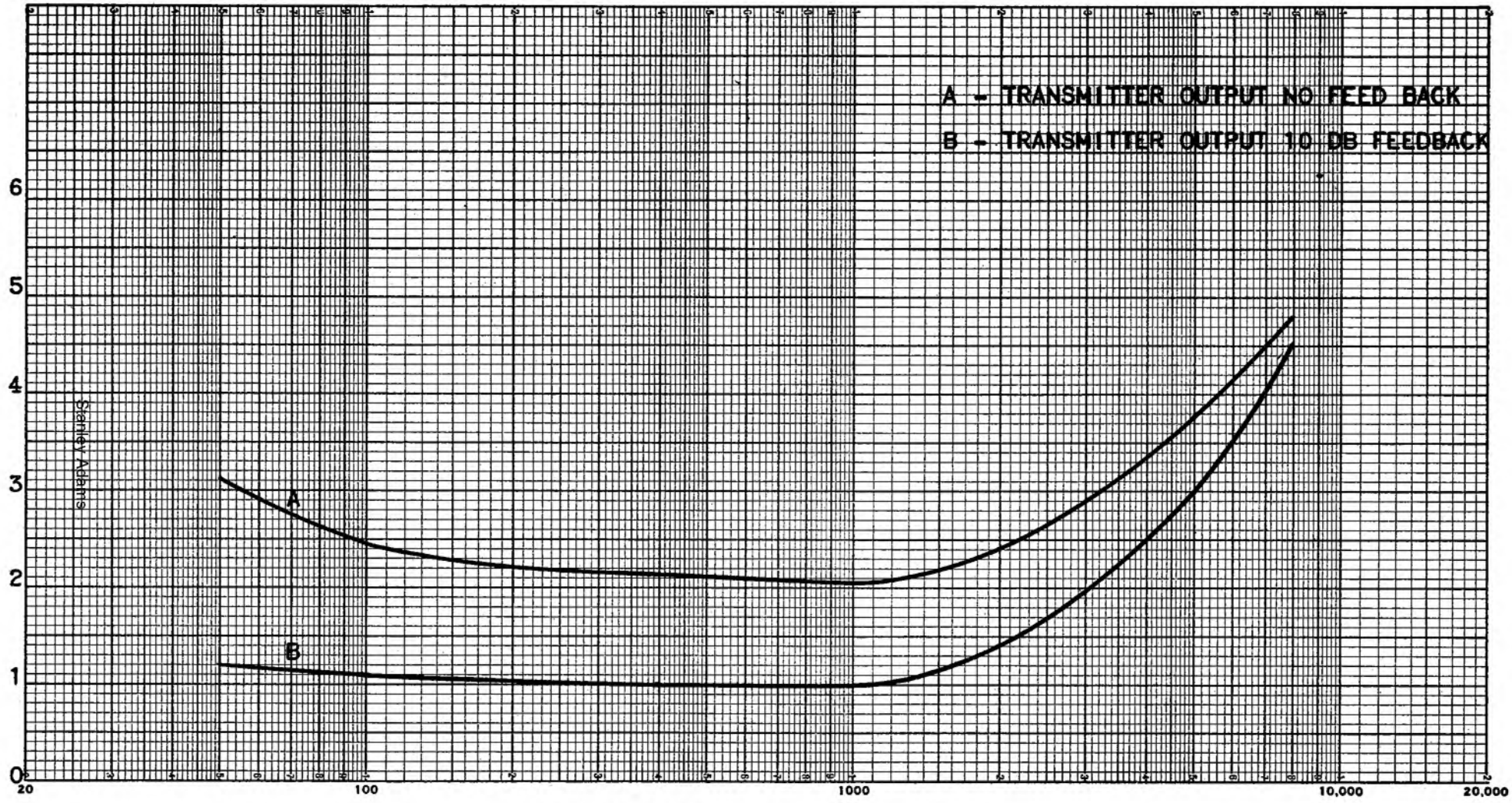
FREQUENCY RESPONSE



FREQUENCY - CYCLES PER SECOND

APPARATUS. 50 HG		
S. O.	REF. KDKA	FIG. BOOK. 19259
INPUT CONSTANTS. 110 A - 500 OHM		
OUTPUT CONSTANTS. 11.5 KV - 5.7 AMP		
SIGNATURE.		DATE. 6/9/40

FREQUENCY RESPONSE



FREQUENCY - CYCLES PER SECOND

APPARATUS. 50 HG		
S. O.	REF. KDKA	FIG. BOOK. 19259
INPUT CONSTANTS. 110 A - 500 OHM		
OUTPUT CONSTANTS. NORMAL 11.5 KV - 5.7 AMP		
SIGNATURE.		DATE. 6/15/40

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