LB-840

A CALIBRATED CONTINUOUSLY-VARIABLE SAMPLING-WAVE PHASE SHIFTER

RADIO CORPORATION OF AMERICA

RCA LABORATORIES DIVISION

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Approved

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Introduction

The phase shifter described in this bulletin is an instrument which has been developed to serve a specialized test requirement in research and development of sine-wave sub-carrier systems of color television, and in particular the RCA color television system. This phase shifter is continuously variable, calibrated in degrees from 0 degrees to 360 degrees, and operates at the color sub-carrier frequency (usually chosen to lie in the vicinity of 3.5 - 4.0 Mc). The dial has an adjustable indicator to facilitate measuring procedures.

General Discussion

The RCA color television system utilizes a subcarrier which is varied in phase and amplitude in accordance with the hue and saturation of the colors being transmitted. At the transmitter the color information in the three channels of a simultaneous-signal source is transformed to a subcarrier with its associated sidebands by a sampler, and an inverse process is used in the receiver sampler to transform the subcarrier information back to three simultaneous color video signals.

In one embodiment of the RCA color television system, the sampler circuitry, both in receiver and transmitter, utilizes a sine-wave sampling signal which is presented in a different phase to each of the three sampler tubes; these signals at the sampler tubes occur at phase angle separations of 120 degrees. Current practice is to use a single sampling-wave source and either lumped- or distributed-constant delay lines to obtain the necessary phase delay between successive sampling-wave inputs.

In order to adjust the sampling it is necessary to set the phase separations properly, and to this end the phase shifter has been developed for measurement of phase difference.

With the aid of a suitable oscilloscope it is possible to compare the phase of an unknown sine wave with a particular reference phase by means of the phase shifter and thus obtain the phase difference between the unknown and the reference signals.

Principles of Operation

The operation of the phase shifter will be discussed in terms of a 3.58-Mc (nominal) operating frequency, although the principles on which the phase shifter is based are equally applicable to any other specific frequency of the same order.

A schematic diagram of the phase shifter is shown in Fig. 1. The input signal which is to be shifted in phase is fed to the first tube, a triode-connected 6AC7. This tube has matched plate and cathode load resistors, and thus the plate and cathode signals will be equal in amplitude, but will differ in phase by 180 degrees. If the original input signal is considered to be at 0-degree phase angle, the cathode signal will also be at 0-degree phase angle and the plate signal will be at 180-degree phase angle.

The two signals drive four RC phase shift networks, each of which consists of a 390-ohm resistor and a 390-ohm capacitive reactance.

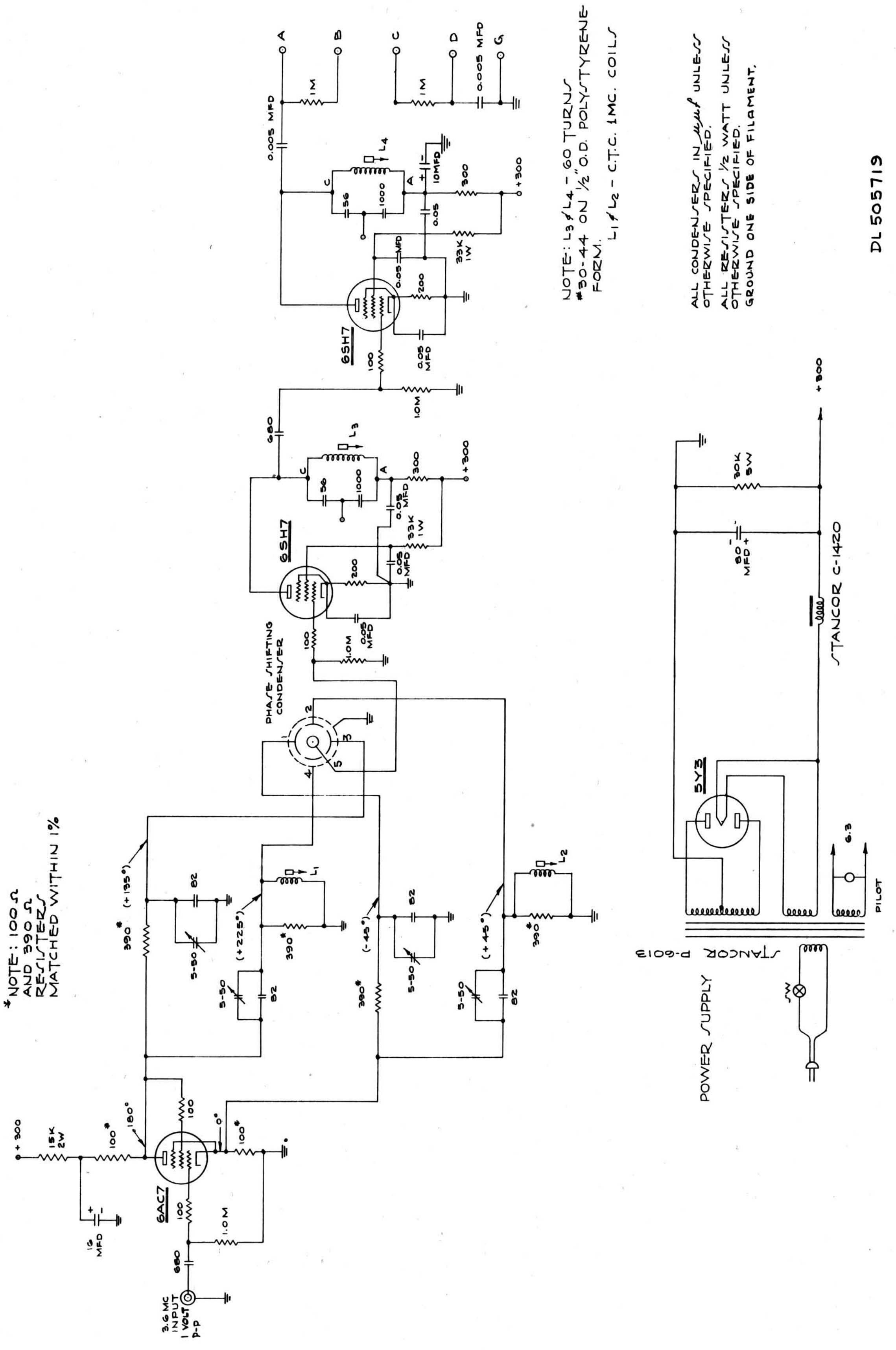

Fig. 1 – Schematic Diagram of calibrated, continuously variable phase shifter.

The two RC networks in the cathode circuit of the 6AC7 split the 0-degree sine-wave signal into two sine waves phased +45 degrees and -45 degrees relative to the input signal; the two RC networks in the plate circuit split the 180-degree sine wave into two sine waves phased 135 degrees and 225 degrees with respect to the input signal.

Coils L_1 and L_2 are intended to tune out the stray tube and wiring capacitances across the 390-ohm resistors to which they are connected. Since this capacitance is small, and because the circuit impedance at this point is low, the coils have little effect on the operation of the circuit, and have been omitted from later models with no observable difference in performance.

The four signals from the RC phase shifters, equal in amplitude and phased at 90-degree intervals, are then fed to a capacitive-type phase shifter. A vector diagram of the pertinent phase relationships in the phase shifter is shown in Fig. 2. The output from the capacitive phase shifter, a 3.58-Mc sine wave of constant amplitude and variable phase, drives a 6SH7 buffer stage, which is followed by a 6SH7 output stage.

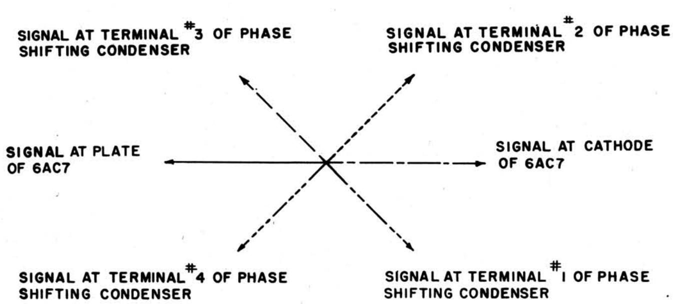

Fig. 2 - Vector diagram of pertinent phase relationships in phase shifter.

The output of the phase shifter is available at terminal A. The two 1-megohm resistors, the 0.005-µf condenser, and the additional terminals B, C, and D have been provided merely as an operating convenience to be used when the output of the phase shifter is connected directly to the deflection plates of an oscilloscope; the resistors provide a d-c path for the oscilloscope centering voltage. Fig. 3 shows the unit connected to a Tektronix oscilloscope and illustrates the method of connection to the deflection plates.

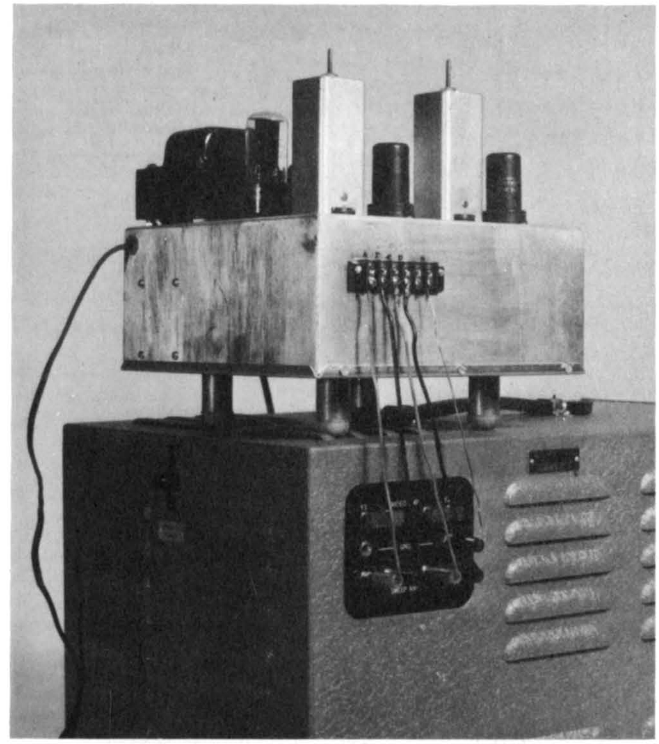

Fig. 3 - Phase shifter connected to deflection plates of Tektronix oscilloscope.

Construction

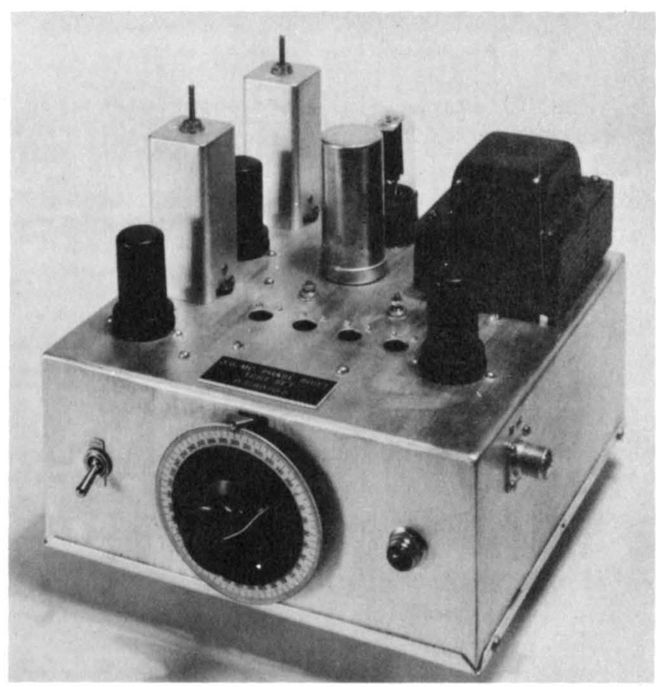

Fig. 4 - Top perspective view of phase shifter.

The method of construction is illustrated in Figs. 4 and 5, top perspective and bottom views, respectively. The phase shifting condenser is of the type used in some radar applications, and was obtained from Dubin Electronics Company, 103-02 Northern Boulevard, Corona, Long Island, New York.

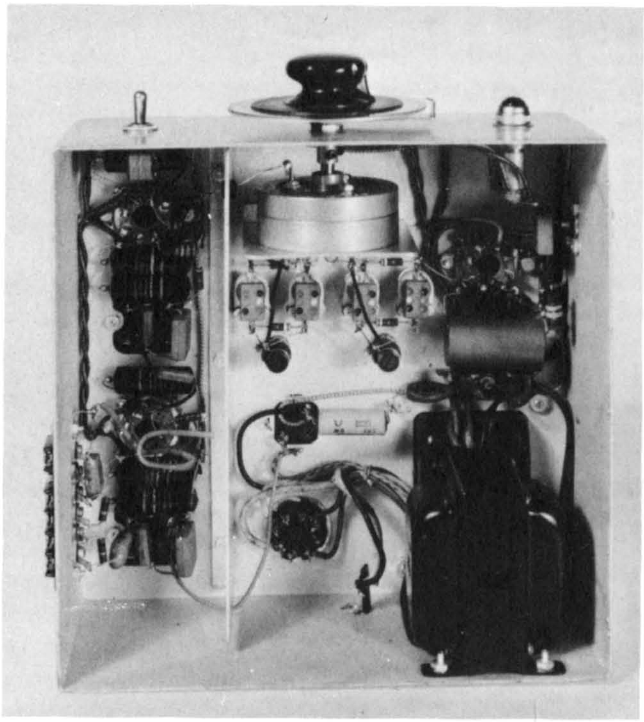

Fig. 5 – Bottom view of phase shifter.

The 360-degree dial was constructed from a 360-degree protractor, two aluminum plates, and a bakelite knob. Constructional details of the special adjustable indicator are shown in Fig. 6.

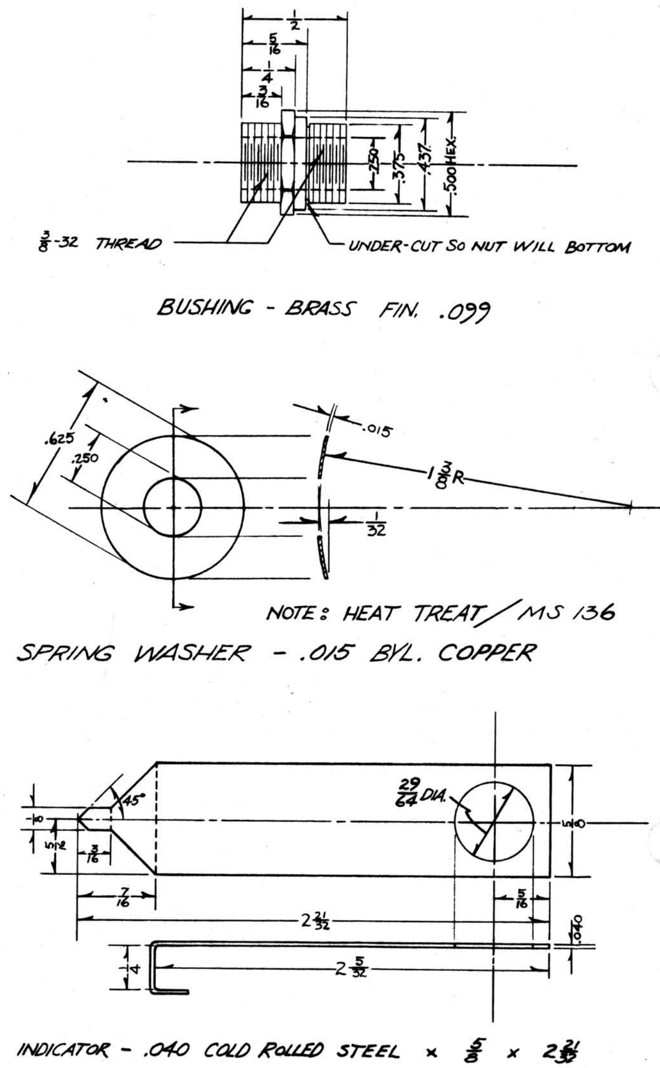

Fig. 6 – Constructional details of special indicator.

Method of Use

There are a number of ways in which this phase shifter may be used in the measurement of phase delay. One method, which has been found to be simple and reliable, is to connect the output of the phase shifter to the horizontal deflection plates of an oscilloscope.

This oscilloscope should be one which has a vertical amplifier response extending beyond the operating frequency of the phase shifter. A low-capacitance, high-impedance probe (see LB-794, "Shielded Low-Capacitance Video Frequency Oscilloscope Probes") should be used on the input to the vertical amplifier. Connect the input of the phase shifter and the oscilloscope probe to the sine wave which is to be used as the reference phase, and adjust the dial of the phase shifter until a straight line pattern is observed on the oscilloscope. Next, without moving the dial, move the adjustable dial indicator until it points to the zero degree point. Now move the oscilloscope probe to the signal of unknown phase and again rotate the dial of the phase shifter until a similar straight line is observed. The indicated reading will be the phase difference between the unknown and the reference signals, expressed in degrees.

Alignment

Alignment of the phase shifter requires proper adjustment of L_4, L_3, and the four RC phase-shift networks. L_4 and L_3 are adjusted first, followed by the four trimmer condensers in the RC phase-shift networks.

Connect a source of sampling frequency sine wave of one volt peak-to-peak amplitude to the input of the phase shifter, turn on the power switch, and allow a few minutes for warmup. The bottom cover should be on the chassis. Then connect an oscilloscope to the output terminals (A and G). If an oscilloscope having a vertical amplifier bandwidth of about 5 Mc is available, the regular y-axis input of the scope may be used. If such an oscilloscope is not available, the output of the phase shifter may be connected directly to the deflection plates of any oscilloscope which will permit such a connection to be made without introducing excessive loading of the output signal.

Connect the x-axis amplifier to the input of the phase shifter and adjust the x and y gains of the scope for approximately equal horizontal and vertical amplitudes. Now rotate the dial of the phase shifter until a single line at an angle of approximately 45 degrees is observed on the scope. Adjust L_4 for maximum output from the phase shifter, observed as a maximum deflection in the y direction. Similarly, adjust the tuning slug of L_3 for maximum output from the phase shifter. It is possible that this 6SH7 buffer stage may overdrive the 6SH7 output stage, and a distorted output waveform will result. This is evidenced as a curvature of the line on the oscilloscope. Should this curvature occur, detune L_3 until the line is straight.

Inasmuch as the phase shifter contains two 6SH7 amplifier stages which operate at the same frequency, and at relatively high gains, self-oscillation may occur. This self-oscillation has been prevented by judicious placement of a short piece of wire, one end of which was soldered to a ground point near the socket of the 6SH7 output stage; the wire was bent in close proximity to the grid terminal connection on the socket of this stage.

The four RC phase-shift networks should be aligned next. The preliminary adjustment is based on the fact that a phase shifter of this type is a constant-amplitude device. A convenient oscillographic representation for this adjustment is one in which the y-axis amplifier of the scope is connected to the output of the phase shifter, as described above, and a sawtooth sweep (any convenient frequency) from the internal sweep generator is applied to the horizontal deflecting plates.

Rotate the dial of the phase shifting condenser and observe the output signal on the oscilloscope. If the amplitude of this output signal varies as the condenser dial is rotated, the trimmer condensers in the four RC phase-shifting networks should be adjusted until the output amplitude no longer varies with condenser rotation. Trial and error will indicate which condensers relate to the various portions of the dial. The following method, however, has been found useful in systematizing this procedure.

There is a slot cut in the shaft of the phase-shifting condenser and in the bearing in which the shaft turns (rear of condenser). In addition there is a small flat filed at the end of the shaft. The slot and flat on the shaft are at right angles to each other, and may be considered to constitute an "arrow" with the slot as the shaft of the arrow and the flat as the tip. This is shown in Fig. 7, where the "ar-

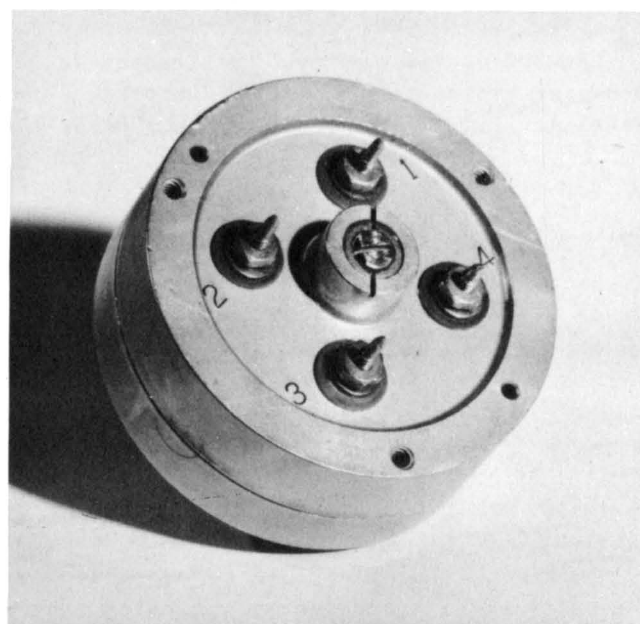

Fig. 7 - Rear view of phase shifting condenser, showing alignment "arrow" pointing to terminal 2.

row" points to terminal 2. The "arrow" is used in alignment in the following manner. When the "arrow" is pointing to a particular terminal, (such as terminal 2 in Fig. 7), the trimmer condenser which is connected to that terminal is the one which will have the greatest control of the output amplitude. Since these adjustments must be made with the bottom cover on the phase shifter (which makes it impossible to see the "arrow") it will be necessary to correlate the position of the "arrow" with the dial markings before the bottom cover is in place.

Rotate the shaft of the phase shifting condenser until an amplitude maximum is observed on the oscilloscope, and adjust the trimmer to which the "arrow" is pointing so as to reduce the amplitude slightly. By manipulation of this sort it should be possible to obtain a substantially flat amplitude-phase characteristic.

This completes the first step in the adjustment of the phase shifter. The dial indications will now be within about ten degrees of the true value. The next stage in adjustment requires a source of sine-wave signal which is the third harmonic of the sampling frequency signal. In the case of a 3.58-Mc sampling frequency, this may be obtained from an auxiliary non-linear amplifier which is connected to the 3.58-Mc source, and has a plate tank circu tuned to 10.8 Mc. Connect the 10.8-Mc signal . the horizontal deflection plates of the oscilloscope. Accurate check points are now available at 60-degree intervals by observance of Lissajous figures on the oscilloscope. The four trimmer condensers in the RC phase-shift networks should now be readjusted slightly until the 60-degree check points are correct within one or two degrees. The readings of the dial on the phase shift condenser will now be within ±2 degrees of the true value over t entire 360-degree range. This completes th adjustment procedure.

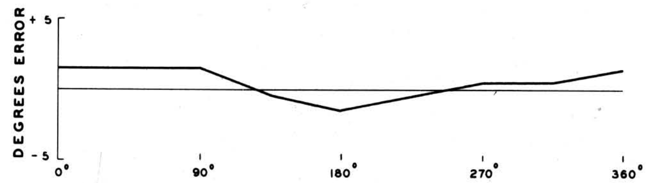

Fig. 8 - Calibration curve of a typical phase shifter unit.

As an alternative to the third harmonic signal, a source of second harmonic sine wave signal may be used in the adjustment procedure. A higher harmonic signal is preferred, howeve because it provides a larger number of Lissajou check points. A calibration curve for a typical unit is shown in Fig. 8.

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