Evaluation of the VA-876P Klystron for the 20-kW X-Band Uplink Transmitter

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Initial evaluation test results of the proposed 20-kW X-band uplink klystron are presented. Operating parameters are compared with the existing DSN 20-kW S-band klystrons. Measured differential RF phase sensitivities vs operating parameter changes are exhibited.

I. Introduction

A future requirement exists for a 20-kW X-band (7145-7235 MHz) uplink transmitter for utilization in the Deep Space Network (DSN). Efficient spectrum utilization, improved charged particle calibration, and precision doppler experiments for relativity investigation are the key drivers. A developmental model is being designed and built for installation at DSS 13. It will be evaluated in this test bed for possible application in the DSN. A key element of this new transmitter is a phase-stable, reliable, and long life klystron amplifier. A survey of available klystron amplifiers indicated that Varian Associates Model VA-876 is the only commercially available klystron meeting the potential requirements for the transmitter. This article discusses work to date on the evaluation of this klystron as a suitable power amplifier for future DSN transmitters.

II. General

A comparison of the operating parameters of the VA-876P klystron with the 5K70SG klystron currently used in the DSN 20-kW S-band (2110-2120 MHz) transmitters (Table 1) indicated that it would be practical to install an X-band klystron in one of the two transmitter test beds located at the Microwave Test Facility (MTF) at Goldstone. By utilizing the MTF, experience could be obtained with this klystron without impacting DSS 13 or an operational DSN station.

The major modification required to the MTF transmitter for installation of an X-band klystron is the addition of a crowbar circuit to protect the klystron body structure in the event of a klystron beam intercept. Crowbar protection is not provided on the 20-kW S-band transmitters because the body structure is relatively massive and not as susceptible to damage from electron beam interception. Since crowbar technology has been developed for the high-power transmitters (Ref. 1), the design from DSS 13 was incorporated in the power supply at MTF. As the beam voltage for the 20-kW transmitter is considerably lower (20 kV as opposed to 70 kV), only one deck of the quad ignitron crowbar assembly was installed at MTF. Also, it was not necessary to use the corona shields at the lower voltage. Figures 1 and 2 show the crowbar installation in the 20-kV power supply.

The RF circuitry for both drive and output had to be completely replaced to be compatible with the higher output frequency. Figures 3ab and 4 show the klystron installation in the MTF test transmitter. Figure 5 is a simplified block diagram of the test configuration.

Testing the VA-876P klystron at the Microwave Test Facility has two purposes:

(1) Gain operating experience with the klystron and obtain reliability information.

(2) Measure the phase stability of the klystron as a function of various parameters (beam voltage, drive, temperature, etc.).

Other users of the VA-876 klystron have been contacted to determine if any reliability problems had been encountered. Two users (Hughes Aircraft and the British Post Office Department) were informally contacted and their history of the use of this klystron discussed. Both organizations are using them as satellite ground station transmitters at nominal outputs of 3-5 kW, continuous duty. Occasionally, power output was boosted at 10 kW for short periods of time. Neither user could furnish complete documentation; they felt the klystron gave approximately 8500 hours of service.

Since August 13, 1979, when the Varian VA-876P klystron (S/N 344) was placed in service, it has acquired approximately 200 beam operating hours, with 65 on-off cycles. The klystron has been operated under a variety of conditions, from low-power swept output to 20 kW CW output for as long as 8 hours at a time. Each day, prior to operation of the klystron, the crowbar and arc detector are tested.

Although there have been system faults, none have been related to the klystron. In particular, the high-voltage rectifier has failed, and there have been component failures in the crowbar logic. These faults have presented no danger to the klystron.

III. Phase Measurements

A Hewlett-Packard Model 8410A/8411A Network Analyzer was connected to two electric-field probes placed directly on the output and input waveguide of the VA-876 klystron. The probes were connected to the Network Analyzer by equal-length semirigid cables, and the output of the Network Analyzer was connected to a chart recorder. Phase variation as a function of the following parameters was recorded:

(1) Beam voltage.

(2) Drive power (AM/PM conversion).

(3) Magnet (focus) current.

(4) Inlet coolant temperature.

(5) Heater voltage.

Figures 6 through 10 show the measurement actual phase variations, and the results are summarized in Table 2.

Future reports will discuss transmitter centralized control overall design, control algorithms (saturation procedures, etc.), and further tests on phase stability. In addition, a report on X-band exciter design will be included.

Reference

1. Finnegan, E. J., "A New Dual Ignitron High Voltage Crowbar," Technical Report 32-1526, Vol. XVII, Jet Propulsion Laboratory, Pasadena, Calif., Oct. 15, 1973.

Table 1. Comparison of 5K70SG and VA-876P klystrons

Parameter	5K70SG	VA-876P
Tuning range	2100 - 2140 MHz	7145 - 7235 MHz
Bandwidth (– 1 dB)	14 MHz	45 MHz
Power output	20 kW	20 kW
Beam voltage	20 kV	19 kV
Beam current	2.3 A	2.6 A
Heater voltage	7.5 V	8.0 V
Heater current	12 A	8.0 A
Drive (20 kW saturated)	0.1 W	0.12 W
Coolant flows		
Collector	22 GPM	13 GPM
Body	1.5 GPM	2.0 GPM
Magnet	2.3 GPM	0.6 GPM

Table 2. Phase sensitivity of VA-876P klystron (S/N 344) (19-kV beam, 20-kW saturated output, 7190 Mhz)

Parameter	Sensitivity
Beam voltage	0.04 deg/v
Drive power	2.2 deg/dB
Focus current	–1.0 deg/A
Inlet coolant temperature	–1.3 deg/°C
Heater voltage[a]	4 deg/V

[a]Preliminary.

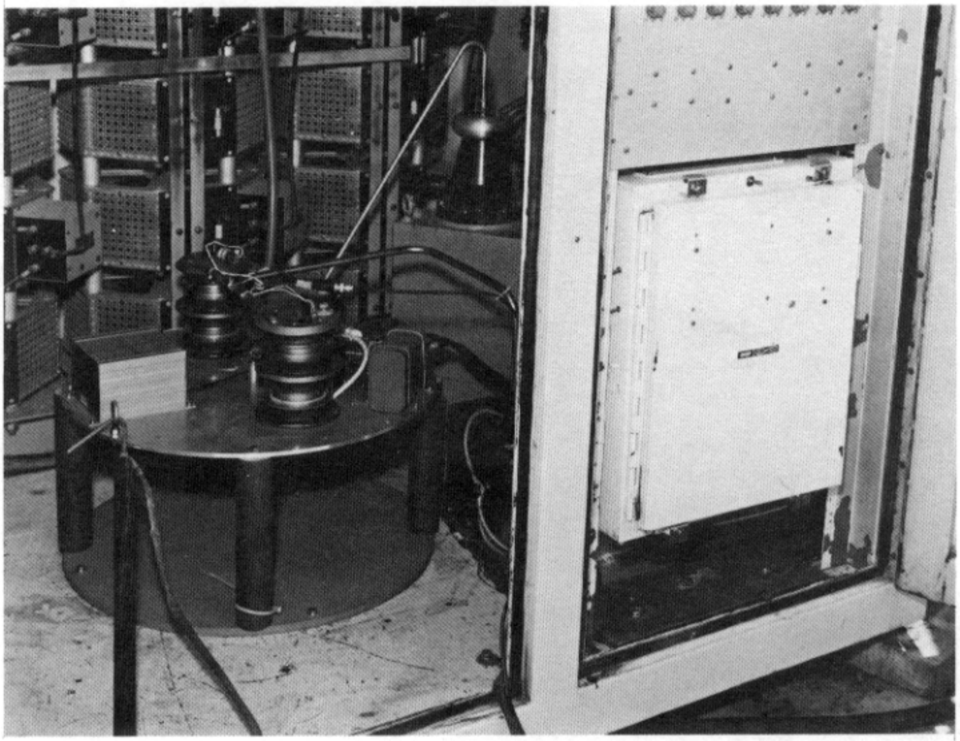

Fig. 1. Crowbar in high voltage power supply

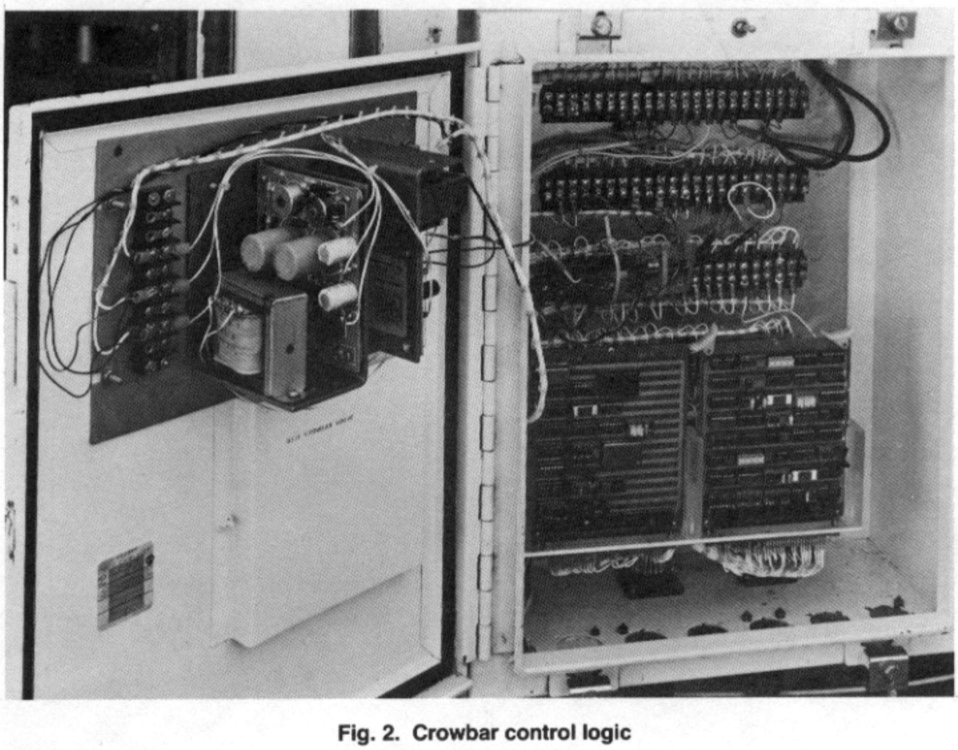

Fig. 2. Crowbar control logic

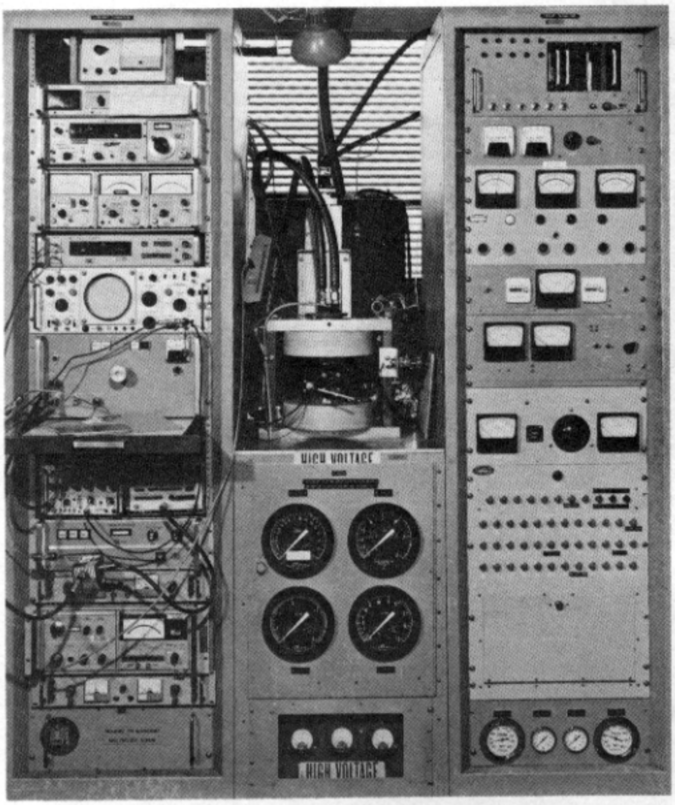

Fig. 3a. VA-876P in MTF klystron test stand

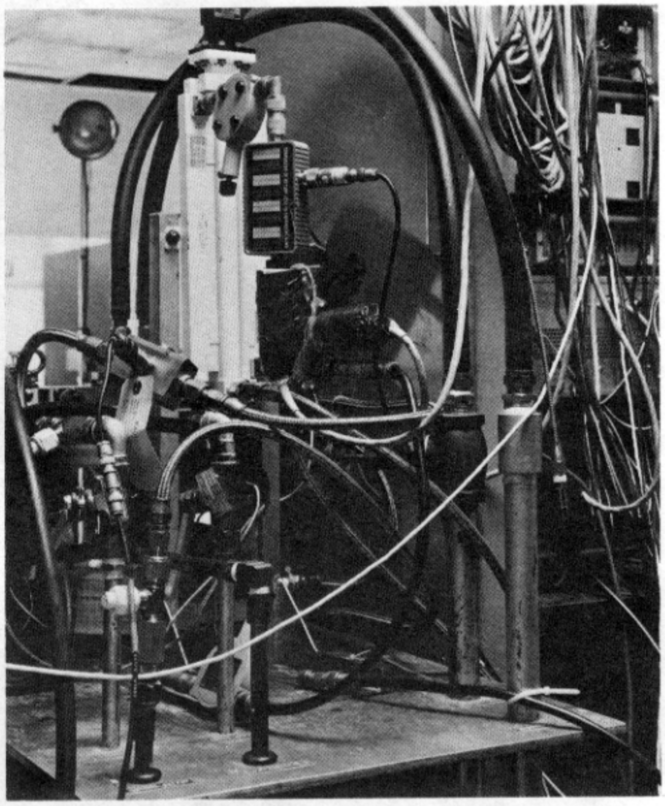

Fig. 3b. Rear view – VA-876P in klystron test stand

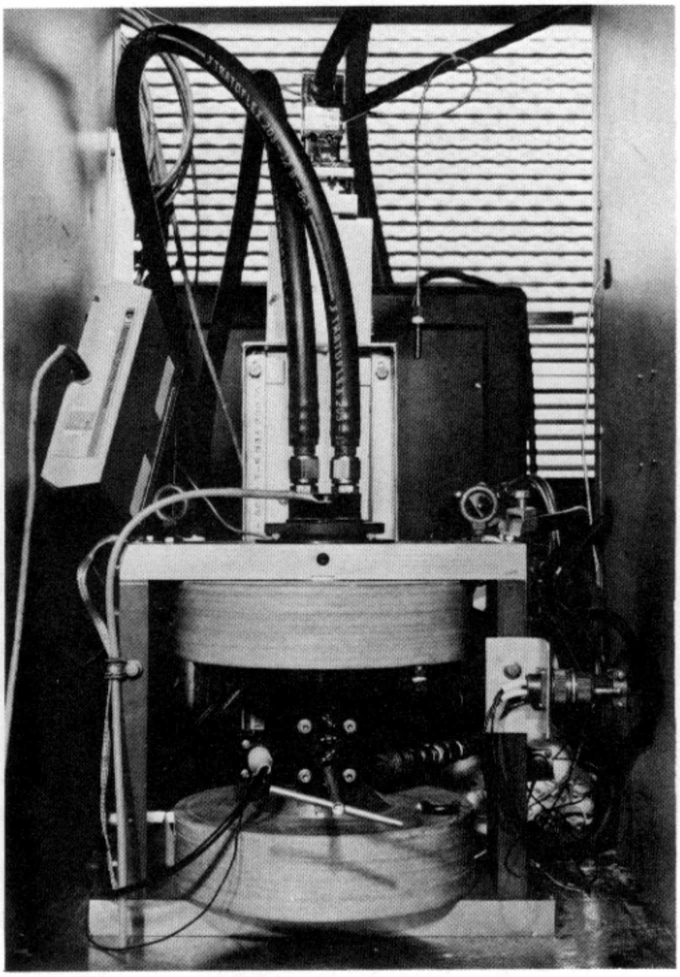

Fig. 4. VA-876P klystron and magnet

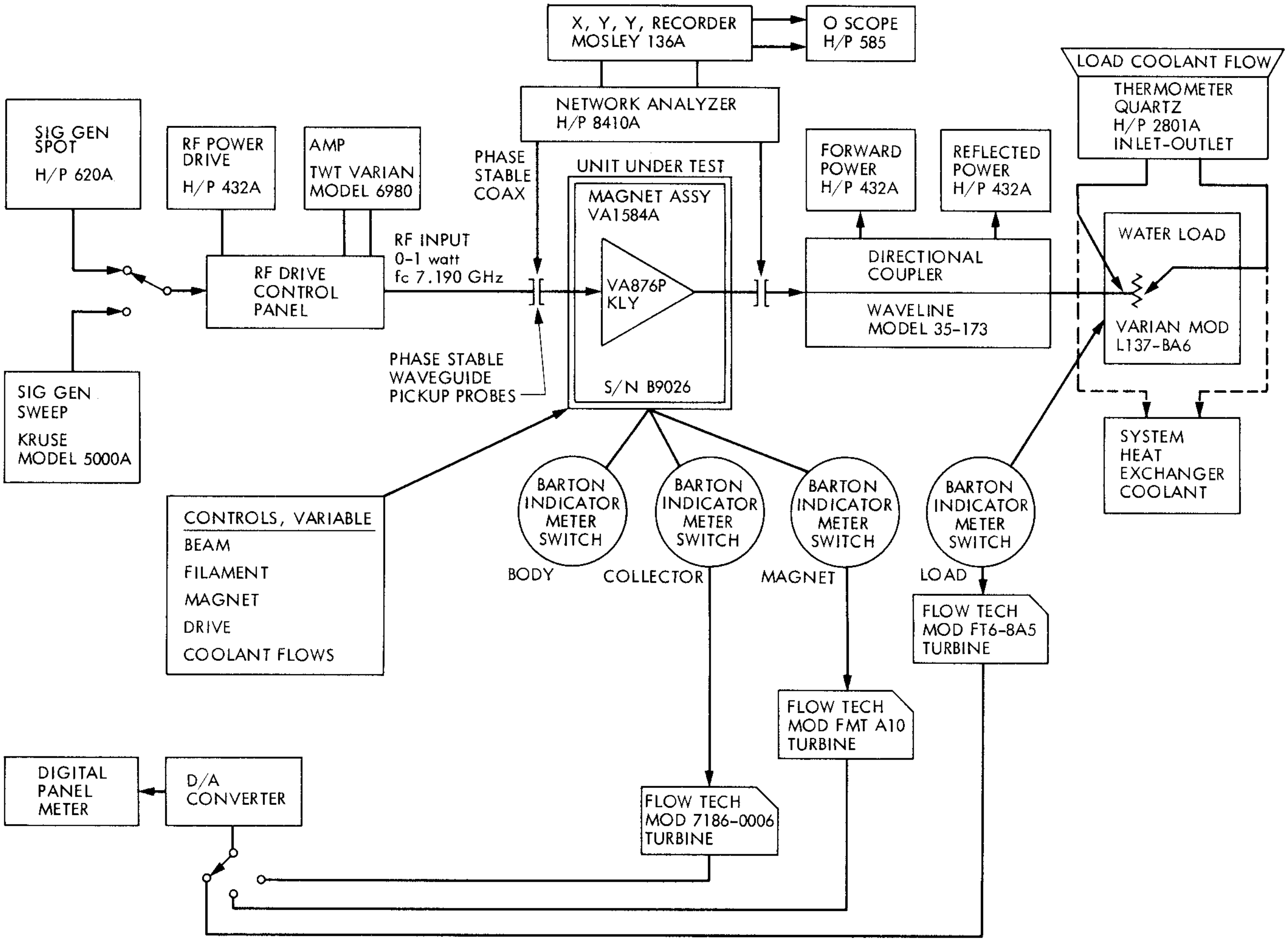

Fig. 5. System test configuration

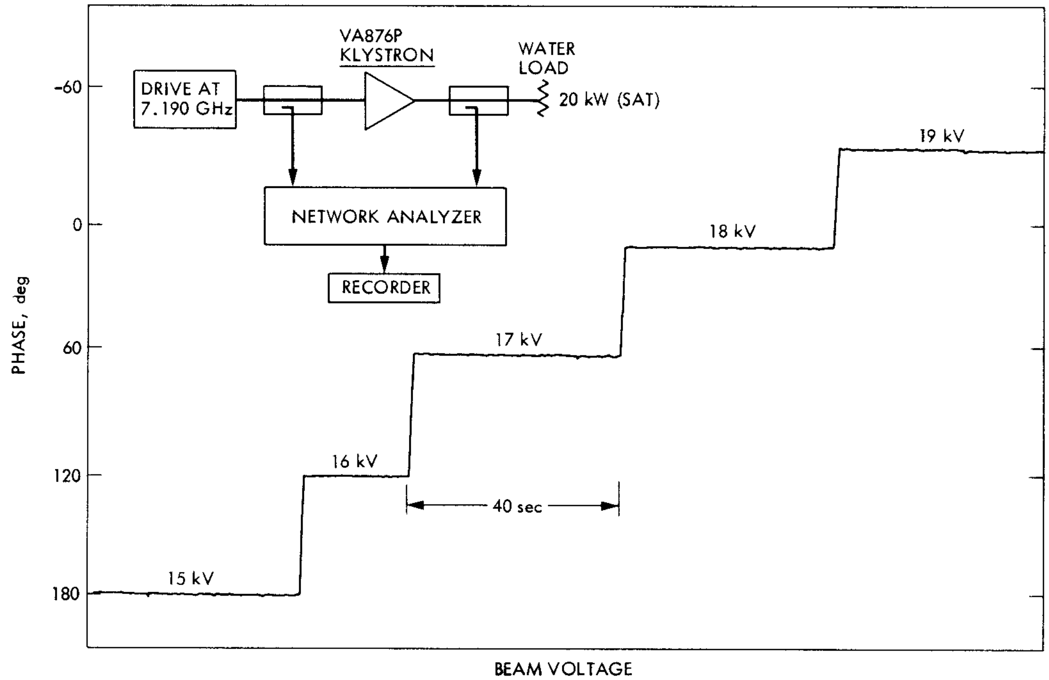

Fig. 6. Phase difference as a function of beam voltage changes

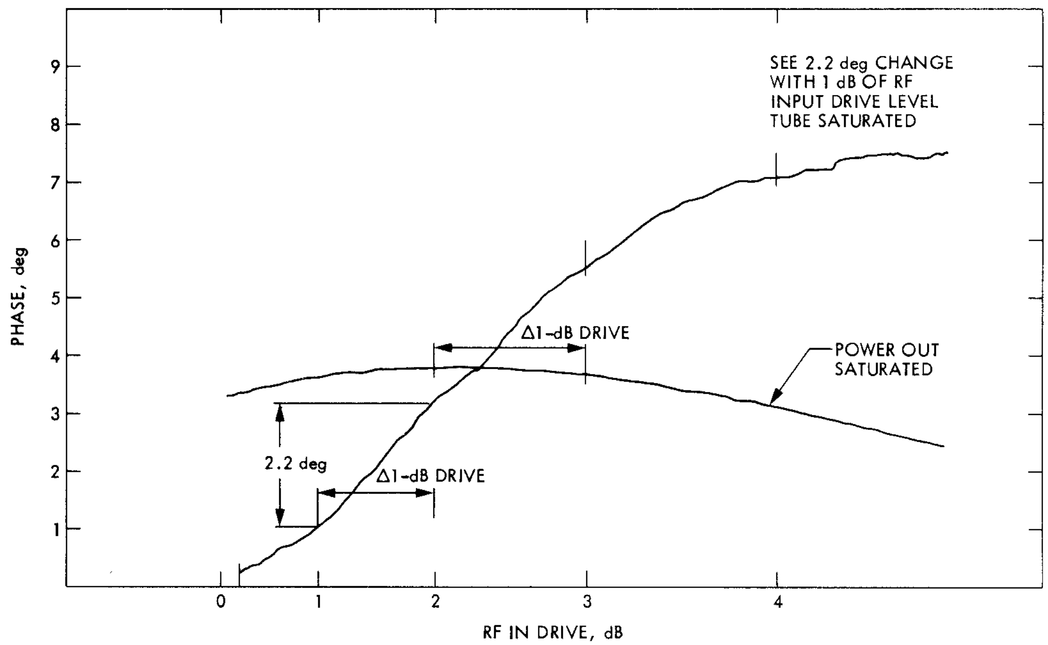

Fig. 7. Varian VA-876P X-band klystron phase change at saturation with 1 dB of input drive change

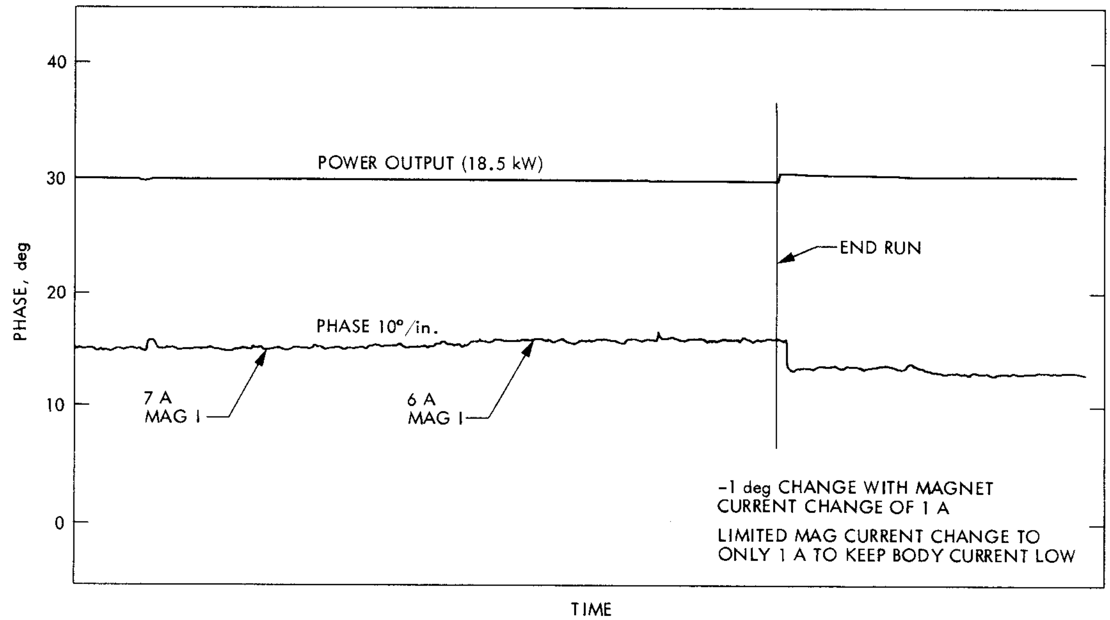

Fig. 8. Phase change vs magnet current, Varian VA-876P klystron S/N 334

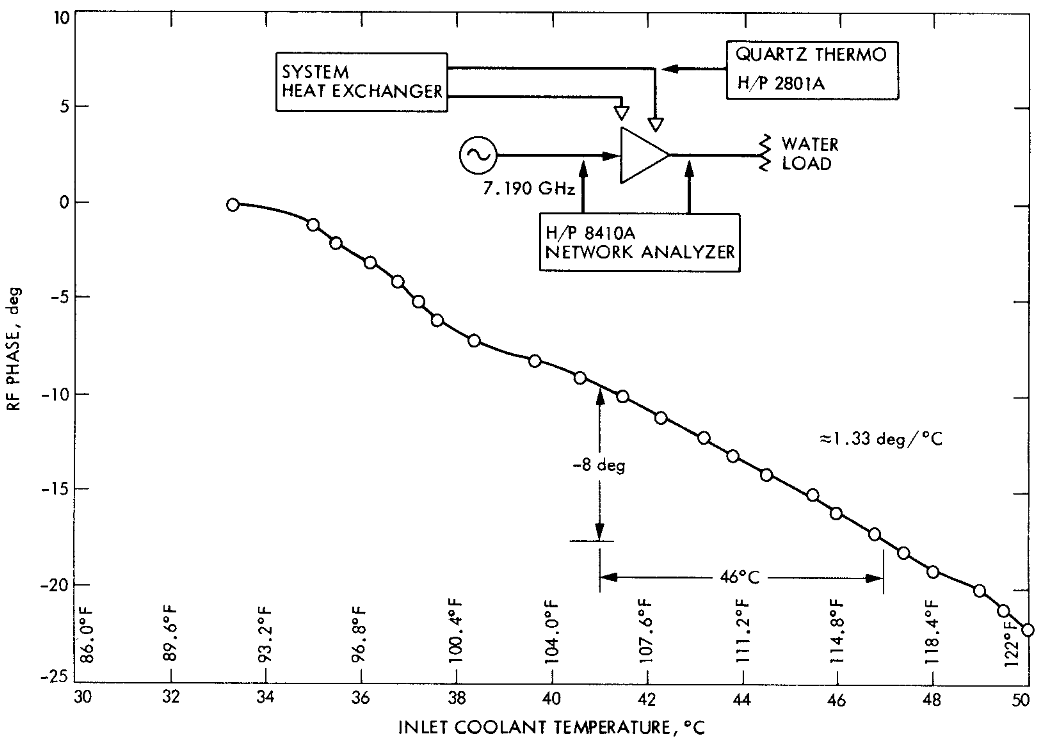

Fig. 9. RF phase change vs inlet coolant temperature

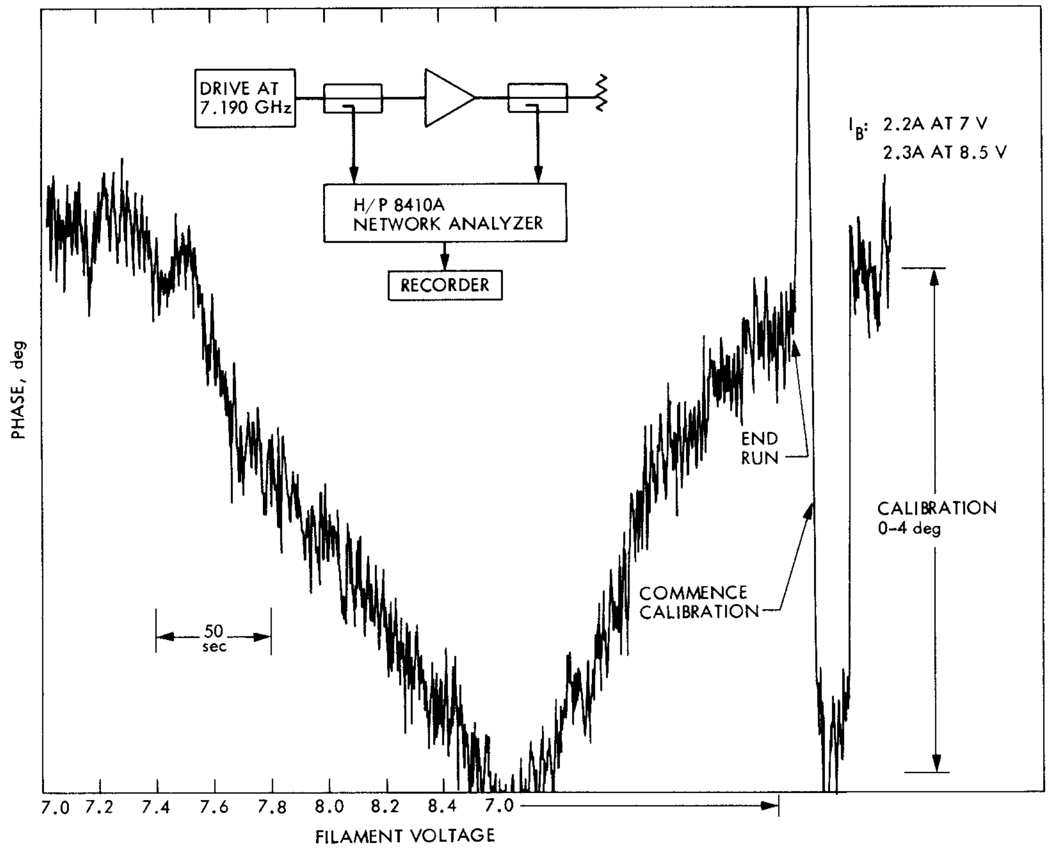

Fig. 10. Phase change vs filament voltage