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EBT-P 110 GHZ DEVELOPMENT PROGRAM

J. Shively, C. Conner, F. Friedlander, E. Galli,
H. Jory, D. Stone, R. Symons, and G. Wendell

Quarterly Report No. 1
through September 1979

Prepared by
Varian Associates, Inc.
Palo Alto Microwave Tube Division
611 Hansen Way
Palo Alto, California 94303

for
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830

operated by
UNION CARBIDE CORPORATION

for the
DEPARTMENT OF ENERGY

Contract No. W-7405-eng-26

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ABSTRACT

The objective of this program is to develop a microwave amplifier or oscillator capable of producing 200 kW CW power output at 110 GHz. The use of cyclotron resonance interacton is being pursued.

The early design phases of this three and one half year program are discussed.

I. INTRODUCTION

The objective of this program is to develop a microwave amplifier or oscillator capable of producing 200 kW of CW power at 110 GHz. Tunability or bandwidth is not considered an important parameter in the design, but efficiency is. Mode purity in the output waveguide is not a requirement for the device, but the circular electric mode is considered desirable because of its low loss properties.

With these objectives in mind, an approach based on a cyclotron resonance interaction between an electron beam and microwave fields is being pursued. The detailed arguments leading to this approach are contained in the final report of a preceding study program[1]. The device configurations of particular interest, called a gyrotron, have been discussed in recent literature[2-5]. They employ a hollow electron beam interacting with cylindrical resonators of the TE_{0m1} class. The experimental gyrotrons described have been of both the amplifier[3] and oscillator[2-5] type. At 28 GHz an amplifier with 76.0 kW peak output power and 41 dB gain has been reported[3].

The goal of this development program is to achieve an amplifier with 20 dB gain. Stability of an amplifier is a very important technical consideration. To capitalize fully on the advantages of the cyclotron resonance interaction, diameters large with respect to a wavelength are used. This exposes the device to the effect of microwave coupling between amplifier stages through the beam tunnel. Prevention of this coupling is an important consideration in the design.

The optimum beam for the cyclotron resonance interaction is one in which the electrons have most of their energy in velocities perpendicular to the axial magnetic field. Another requirement is that the spread in the axial components of the electron velocities be as small as possible. Electrons which have different axial velocities will not interact efficiently.

The approach chosen to generate the beam is a magnetron type of gun[6,7] as is used on the 28 GHz gyrotron, also developed for Oak Ridge National Laboratory. With this type of gun, the shaping of the magnetic field in the gun region becomes quite important.

The early phases of the 200 kW pulsed oscillator design are discussed in this report, including the electron gun, solenoid magnet, interaction circuit, output coupling schemes, collector, and output window.

The electron gun design is nearing completion with a cathode loading of 4 A/cm^2 and a maximum cold negative electric field gradient of <100 kV/cm.

The superconducting solenoid magnet computer design for the gun and main interaction regions is nearing completion.

A TE_{021} oscillator cavity for the pulsed tube has been designed and parts are on order.

Cold test hardware for evaluating various output coupling schemes in conjunction with the cold test oscillator cavities is available. Receipt of commercial cold test equipment components has been a limiting item.

An output window microwave design is nearing completion. Long lead time ceramic parts are on order.

The existing drive power facility has been analyzed and required modifications determined.

Waterload parts are on order. The power sampler and arc detector design is nearing completion.

II. 200 KW CW OSCILLATOR

A. ELECTRON GUN COMPUTER DESIGN

The design of the gyrotron gun was initiated taking into account previous gyrotron gun designs and analyses at Varian and elsewhere. For a cathode sloped 10° with respect to the axis, estimates were made of the effects of varying mean cathode radius and length to achieve given values of cathode loading (i.e., current density). The constants in the simple planar gun equations were adjusted to fit the results from a representative computer solution for a gyrotron gun. The simple equations used were:

$$h = 2.86 \frac{E_{\perp k}}{\eta B_K^2}$$

$$E_k = \frac{B_K^{3/2} \, B_o^{-1/2} \, \upsilon_{\perp o}}{1.265}$$

$$d = 1.25h$$

and

$$V_{a_1} = E_{\perp k} \, d/\cos\theta_k$$

where: θ_k = slope angle of cathode

d = spacing along normal from cathode to first anode

h = maximum spacing of outer beam envelope from cathode

B_k = magnetic field at cathode = $0.98\sqrt{\frac{r_o}{r_k}}\, B_o$

B_o = magnetic field in interaction circuit, 45 kGs

r_o = mean beam radius in interaction circuit, 0.798 mm

r_k = mean radius of cathode

$E_{\perp k}$ = electric field component at cathode that is normal to magnetic field

$\upsilon_{\perp o}$ = desired transverse velocity in interaction circuit, 1.35 x 10^8 m/s or 0.449 c (for 64 KeV transverse energy and 80 KeV total energy)

V_{a1} = voltage rise from cathode to first anode

η = charge/mass ratio for electron

Further study verified that for a given cathode length to mean radius ratio, the space charge limited current varies approximately as the inverse third power of the mean radius.

The maximum cathode loading considered was 7.5 A/cm^2 and the minimum was 3.0 A/cm^2. It was assumed desirable to operate as low as possible in this range, for stable reasonably uniform emission and for the maximum duration of useful cathode life.

It was further assumed that the space charge limited current should be at least three times the operating current, or 24 amperes, to avoid deleterious and severe effects due to space charge. In particular this assumption limited the maximum permissable cathode radius.

It was also assumed that the ratio of length to mean radius for the cathode should not be greater than about 1.75, to avoid deleterious variations in the beam. This and the limit assumed for cathode loading resulted in a lower limit for cathode radius. Another disadvantage of using a small cathode radius is the high electric field gradients in the gun that are required.

This study results in four initial cases worthy of further consideration. These are tabulated in Table I.

Table I
Early Cathode Cases Considered

Cathode Loading A/cm^2	Mean Cathode Radius Inches	Cathode Length/Radius	Space Charge Limited Current Amps	E_k kV/cm
3.0	0.192	1.76	25.0	21
7.5	0.150	1.15	42.0	44
5.0	0.150	1.73	49.5	44
7.5	0.125	1.66	87.5	76

Consideration of the high electric field gradient expected for the fourth case led to its elimination. As a reasonable trade off between minimizing cathode loading and maximizing space charge limited current, the third case above was chosen as the initial case for optimization on the computer. The initial magnetic field shape considered had a point of inflection in the flux lines at the plane tangent to the tip of the front focus electrode, and a slope of 6 degrees at that plane (for the flux tube threading the center-plane of the cathode at a radius 1% greater than the mean cathode radius). At the end of the cathode furthest from the circuit, the slope of the flux line was assumed to be zero. Experience has indicated this approximates an optimum field shape for a "short" cathode. For the "long" cathode studied initially, this did not appear to be true. In addition, it was found that this magnetic field shape could not be achieved with the relatively large diameter field coils required for this device.

Consideration was also given to trying an "inside-out" gun approach, for which the first anode would be inside a hollow conical cathode. It was determined that this approach had no advantage over the conventional gyrotron gun approach using a cathode of the same mean radius, and was, if anything, more difficult to design.

A number of electrode and magnetic field configurations were simulated by the computer for the 10° cathode case. One of the better cases is shown in Figure 1. The accompanying graph, Figure 2, shows the transverse energy as a function of trajectory number. The numbering starts at the rear of the cathode. The cathode loading for this case is 5.0 A/cm^2. Some trials had

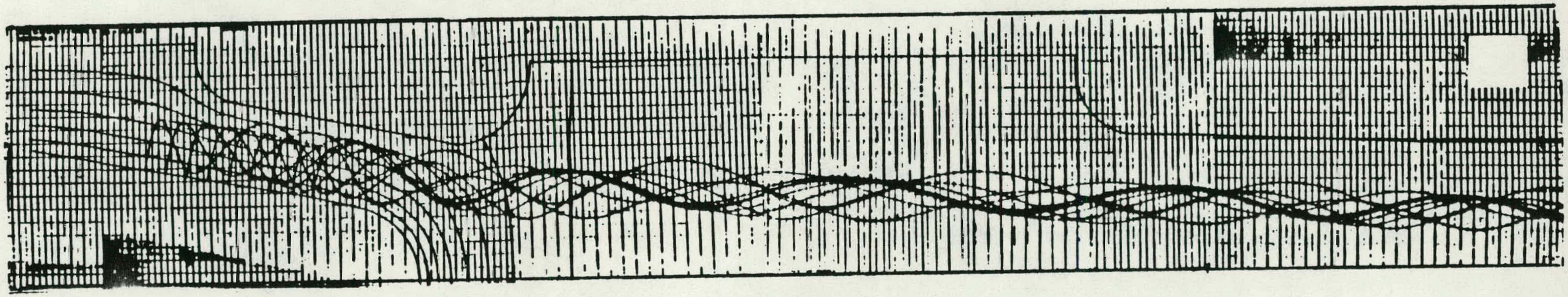


FIGURE 1 ELECTRON TRAJECTORIES FOR A TEN DEGREE CATHODE ANGLE

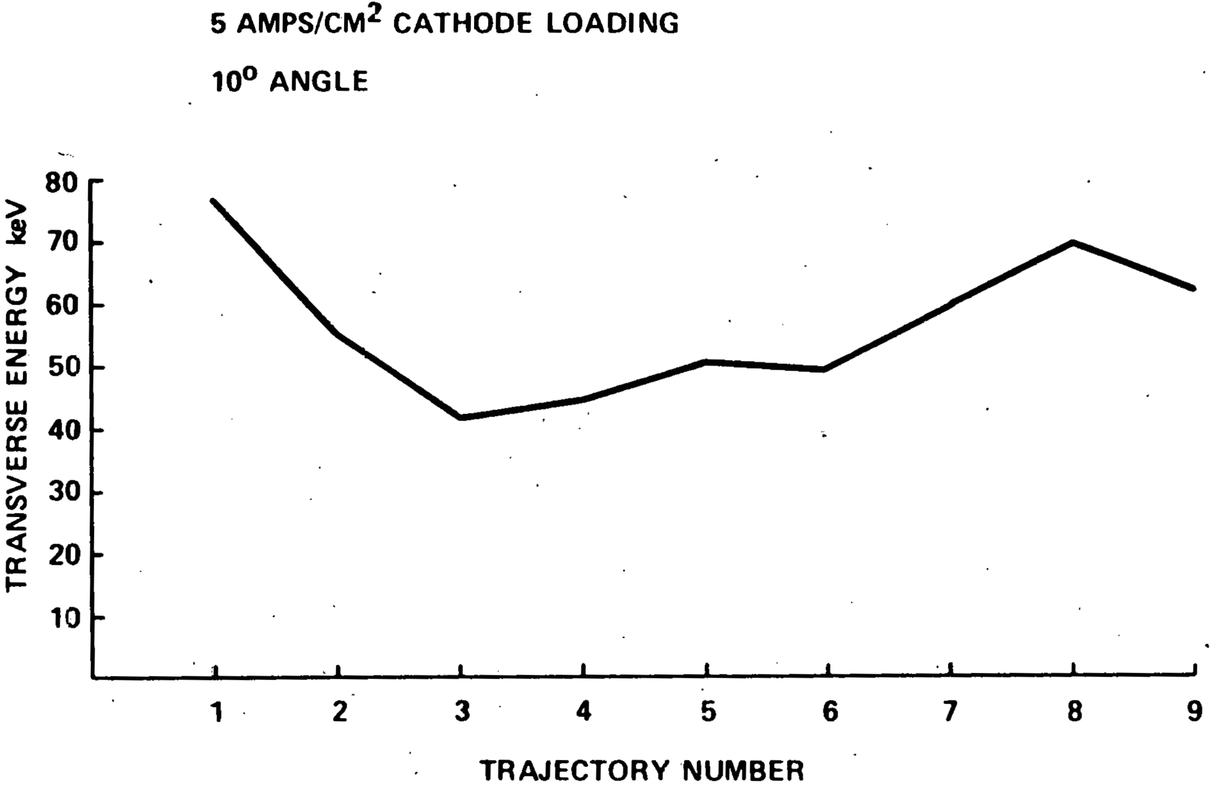


FIGURE 2 TRANSVERSE ENERGY PROFILE FOR 10° CATHODE WITH 5 A/CM² LOADING

been made for 7.5 A/cm^2 loading before it was decided that this high a loading was untenable.

Although the velocity variation[*] for this case is of the order of ±5%, the trajectories are out of phase. Therefore, based on the results described in an article by the Russians[8], simulations were made using a cathode angle of 23°. The Russian results were achieved by assuming a desired flow, and from this, by analytic continuation, determining the electrode boundary parameters necessary. The magnetic field was assumed to be uniform.

---

[*] The velocity variation is calculated by scaling the transverse energies of each trajectory up to 45 kG from its value in the uniform field region at the right end of the trajectory plot. The inner trajectories are weighted by a factor of two by finding the statistics of a sample consisting of each inner trajectory counted twice and each outer counted once. The formulas used are:

$$\mu = \frac{1}{N} \sum_{n=1}^{N} E_n$$

$$\sigma = \sqrt{\frac{1}{N-1} \sum_{n=1}^{N} (E_n - \mu)^2}$$

$N = 2\,(N_T - 1)$ where N_T = number of trajectories

E_n = transverse energy associated with observation n.

The velocity variation is ± 1/2 σ, or more accurately $(\sqrt{1 + \sigma} - 1)$, $(\sqrt{1 - \sigma} - 1)$.

Figures 3, 4 and 5 show the trajectories for a 23° cathode with different lengths of front focus electrodes. The shorter the electrode the higher the transverse energy and the steeper the slope of transverse energy vs trajectory number, as can be seen in the plots in Figure 6.

The mean transverse energy and velocity variation at the magnetic field strength in the interaction circuit for these three cases, with 4 A/cm^2 cathode loading, is given in Table II:

Table II
Transverse Energy and Velocity Spread for Three Gun Designs

Front Focus Electrode	Mean Transverse Energy, eV	Velocity Variation
Short	74349	± 6.80%
Medium	61720	5.40%
Long	47806	3.25%

The trajectories for the best design with 5 A/cm^2 loading are shown in Figure 7. The variation of transverse energy among trajectories is shown in Figure 8.

The mean transverse energy for this case is 64904. The velocity variation is ± 2.1%.

Work is continuing to determine the optimum cathode angle and to see if the cathode loading can be reduced to 3 A/cm^2 while maintaining a velocity variation of ± 2.5%.

Once the best design is determined, several computer calculations will be made to resolve the sensitivity of the transverse energy characteristics to small changes in boundary and electric and magnetic field parameters. This will provide useful information for specifying production tolerances.

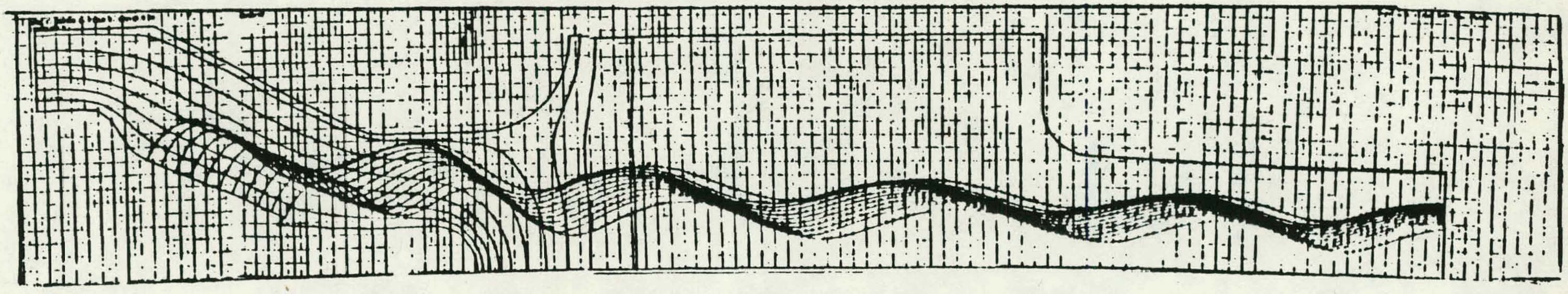


FIGURE 3 ELECTRON TRAJECTORIES FOR A TWENTY-THREE DEGREE CATHODE ANGLE WITH A SHORT FRONT FOCUS ELECTRODE

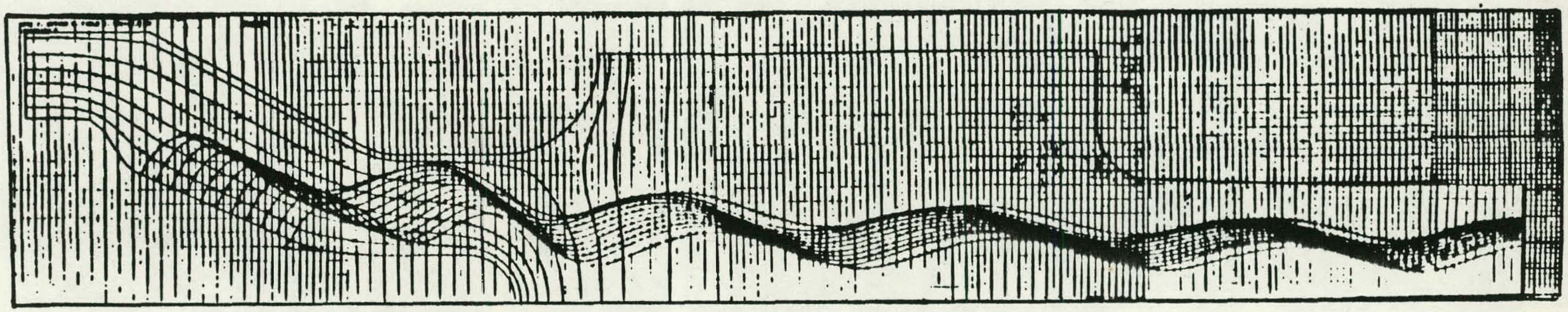


FIGURE 4 ELECTRON TRAJECTORIES FOR A TWENTY-THREE DEGREE CATHODE ANGLE WITH A MEDIUM FRONT FOCUS ELECTRODE

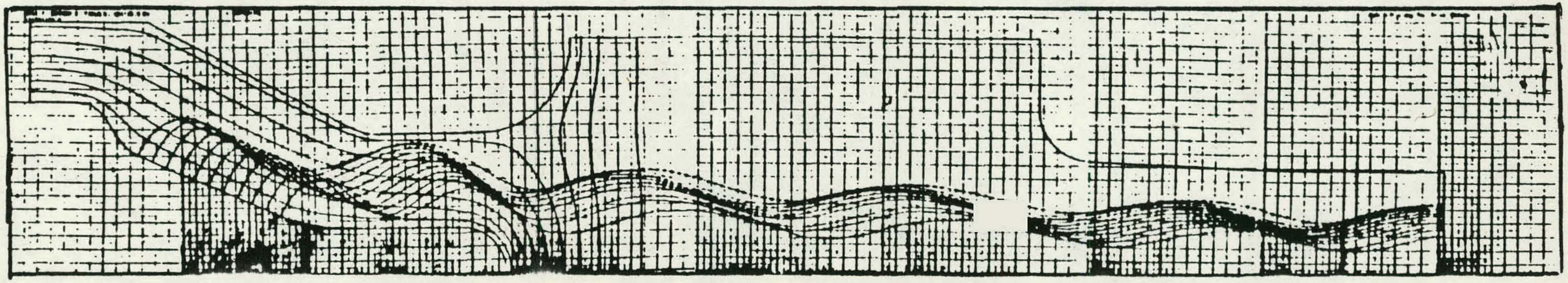


FIGURE 5 ELECTRON TRAJECTORIES FOR A TWENTY-THREE DEGREE CATHODE ANGLE WITH A LONG FRONT FOCUS ELECTRODE

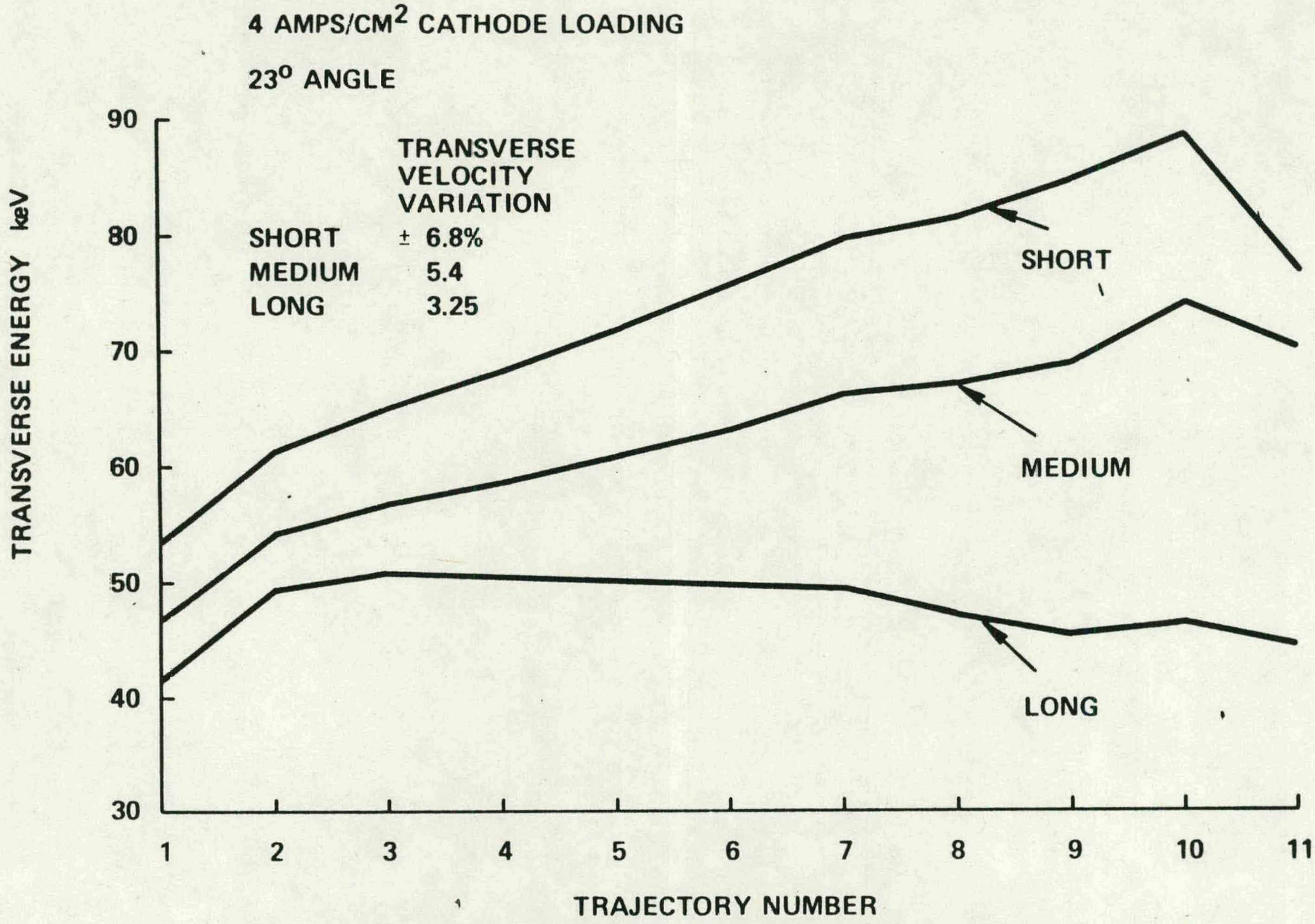


FIGURE 6 VARIATION OF TRANSVERSE ENERGY PROFILE WITH LENGTH OF FRONT FOCUS ELECTRODE

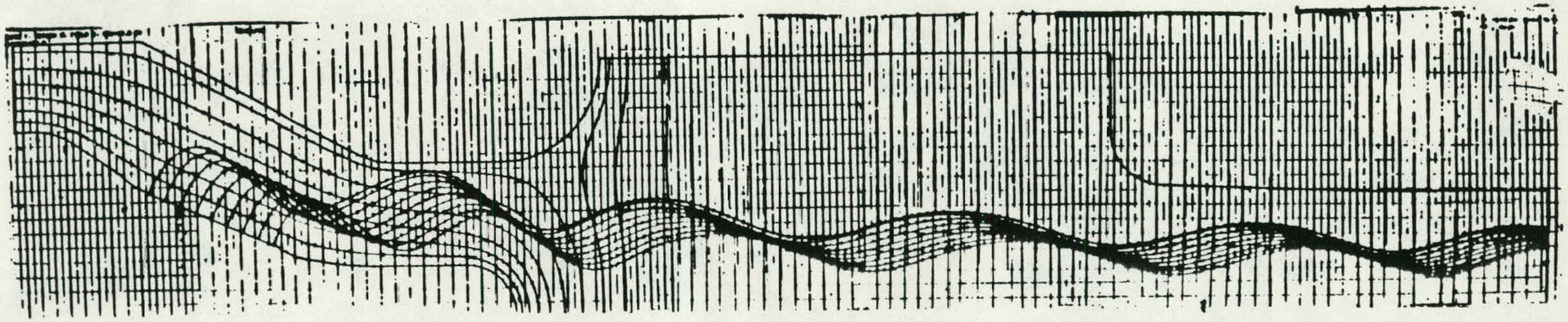
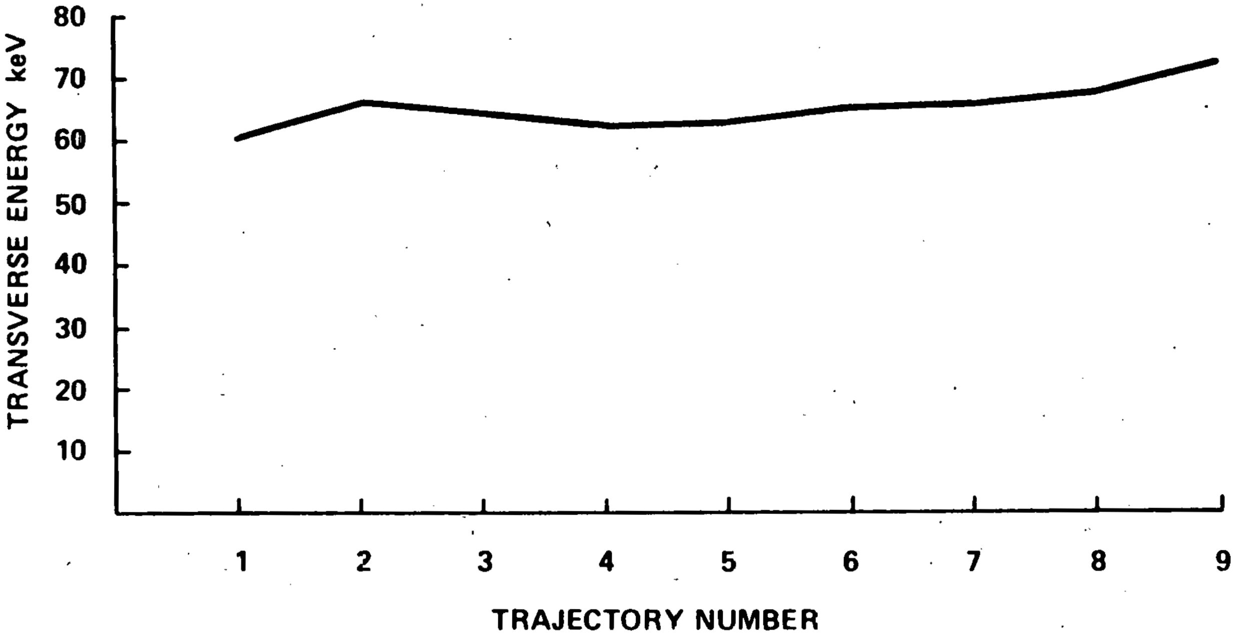


FIGURE 7   ELECTRON TRAJECTORIES FOR A FIVE AMPERE PER SQUARE CENTIMETER CATHODE LOADING DESIGN



5 AMPS/CM^2 CATHODE LOADING

± 2.1% TRANSVERSE VELOCITY VARIATION

23° ANGLE

FIGURE 8 TRANSVERSE ENERGY PROFILE FOR 23° CATHODE WITH 5 A/CM^2 LOADING

B. SUPERCONDUCTING SOLENOID MAGNET COMPUTER DESIGN

A superconducting magnet was designed using a .020 inch diameter wire of filamentary niobium-titanium (NbTi) embedded in a copper matrix with a copper to NbTi ratio of 1.8 to 1. The wire has the typical short sample characteristics shown in Table III.

Table III
Typical Superconducting Niobium-titanium Short Sample Characteristics

Field	Maximum Current Before Quenching
45 KG	131 AMPS
50	119
55	106
60	95
65	85
70	77

The magnet consists of a Helmholtz pair centered at the circuit to give a homogeneous (to ± 0.5%) field region at 45 KG 2 1/2 inches long. A small bucking coil is included as part of the coil system to give the desired field profile characteristics in the gun region. The calculated field profile is shown in Table IV.

The superconducting magnet has the specifications given in Table V.

Table V
Main Superconducting Solenoid Magnet Specifications

ID = 6" (winding)
OD = 8.25" (winding)
Length = 3" (per coil of Helmholtz pair)
Central Field = 45 KG
Peak Field = 67.6 KG (at winding ID)
Amp Turns = 315980 x 2
Current = 81 AMPS
Turns = 3900 x 2
Conductor = 0.020" Dia. Nb-Ti Multifilamentary 1.8:1 Cu Ratio
No. Layers = 52
Turns/Layer = 150

The magnet may be housed in a 4" warm hole dewar constructed from superinsulation. However, a hold time of greater than eight hours for the liquid

TABLE IV

CALCULATED AXIAL FIELD

Z (inches)	H (Gauss)						
		6.0	518.18042	12.1	786.05615	18.2	17951.31250
0.0	249.50867	6.1	524.60010	12.2	817.81962	18.3	18648.34375
0.1	253.29094	6.2	530.56133	12.3	855.18799	18.4	19365.34375
0.2	255.02791	6.3	536.07495	12.4	898.05371	18.5	20101.75391
0.3	258.67725	6.4	542.94629	12.5	946.90186	18.6	20856.84766
0.4	261.34692	6.5	549.09814	12.6	1002.18628	18.7	21629.96484
0.5	264.66821	6.6	554.38916	12.7	1064.56519	18.8	22420.31250
0.6	267.61938	6.7	560.66406	12.8	1133.61328	18.9	23226.20703
0.7	271.21094	6.8	567.00879	12.9	1210.09497	19.0	24046.53125
0.8	274.21997	6.9	573.05542	13.0	1293.76196	19.1	24879.76953
0.9	277.86084	7.0	579.09766	13.1	1385.68115	19.2	25723.75391
1.0	280.28687	7.1	585.05640	13.2	1484.86670	19.3	26576.66750
1.1	285.30859	7.2	591.25635	13.3	1592.03882	19.4	27436.37500
1.2	287.07153	7.3	597.37256	13.4	1707.03296	19.5	28300.37500
1.3	290.39087	7.4	602.60767	13.5	1829.91870	19.6	29166.12109
1.4	295.14209	7.5	608.53687	13.6	1960.36255	19.7	30030.40625
1.5	297.80206	7.6	614.11523	13.7	2098.96926	19.8	30891.97266
1.6	302.23730	7.7	619.92651	13.8	2244.90479	19.9	31746.24609
1.7	305.89697	7.8	625.00195	13.9	2398.45410	20.0	32591.06641
1.8	309.90991	7.9	630.06982	14.0	2558.96828	20.1	33423.02641
1.9	313.13501	8.0	635.04956	14.1	2727.16577	20.2	34239.63672
2.0	317.59106	8.1	640.30176	14.2	2902.65696	20.3	35037.69531
2.1	320.84473	8.2	644.78862	14.3	3084.37842	20.4	35814.73047
2.2	324.39722	8.3	649.49414	14.4	3273.56010	20.5	36567.58594
2.3	328.81605	8.4	653.98340	14.5	3469.66020	20.6	37294.17188
2.4	332.54346	8.5	657.53540	14.6	3672.53052	20.7	37992.11719
2.5	337.02124	8.6	661.56812	14.7	3881.97266	20.8	38659.20703
2.6	341.06787	8.7	664.78491	14.8	4098.37109	20.9	39293.09141
2.7	346.14067	8.8	668.13550	14.9	4321.85547	21.0	39893.90575
2.8	349.94165	8.9	670.70435	15.0	4552.44141	21.1	40456.76172
2.9	354.44365	9.0	673.53076	15.1	4790.24219	21.2	40980.91406
3.0	359.19946	9.1	675.87524	15.2	5035.37891	21.3	41476.13281
3.1	362.98047	9.2	677.42041	15.3	5288.27344	21.4	41931.85547
3.2	368.41602	9.3	679.14063	15.4	5548.55078	21.5	42347.84766
3.3	371.85693	9.4	680.11548	15.5	5817.54297	21.6	42726.50797
3.4	376.89038	9.5	681.50879	15.6	6095.15625	21.7	43068.92578
3.5	381.67676	9.6	681.67554	15.7	6381.54297	21.8	43375.22266
3.6	386.56104	9.7	681.24121	15.8	6677.26172	21.9	43646.87891
3.7	391.19604	9.8	681.06421	15.9	6982.89453	22.0	43885.34375
3.8	395.53516	9.9	680.12671	16.0	7298.36261	22.1	44092.25000
3.9	401.24536	10.0	678.81274	16.1	7624.90438	22.2	44269.32422
4.0	406.13477	10.1	677.39014	16.2	7962.76563	22.3	44419.15359
4.1	410.75562	10.2	675.89233	16.3	8312.36328	22.4	44543.79297
4.2	416.54175	10.3	673.53271	16.4	8674.20953	22.5	44645.40625
4.3	420.93896	10.4	671.66504	16.5	9049.05078	22.6	44726.55550
4.4	427.07300	10.5	669.88623	16.6	9437.45438	22.7	44790.45313
4.5	432.53979	10.6	667.64624	16.7	9839.65234	22.8	44838.86719
4.6	437.41870	10.7	665.86426	16.8	10256.67891	22.9	44874.42188
4.7	443.00610	10.8	664.67749	16.9	10689.71875	23.0	44899.55859
4.8	448.30713	10.9	663.52026	17.0	11137.82422	23.1	44916.09141
4.9	454.06057	11.0	663.09497	17.1	11603.16750	23.2	44927.06466
5.0	459.84155	11.1	663.50982	17.2	12085.29538	23.3	44934.40625
5.1	465.10400	11.2	665.45313	17.3	12584.94531	23.4	44938.42969
5.2	470.80615	11.3	668.77661	17.4	13102.92578	23.5	44940.78125
5.3	476.86206	11.4	673.48853	17.5	13639.68359	23.6	44942.33984
5.4	482.85596	11.5	680.48877	17.6	14195.56641	23.7	44943.73438
5.5	488.64136	11.6	689.45215	17.7	14771.09766	23.8	44945.16016
5.6	494.93164	11.7	702.05493	17.8	15356.42188	23.9	44946.26563
5.7	500.09180	11.8	717.47363	17.9	15982.21094	24.0	44946.36719
5.8	506.59937	11.9	735.85986	18.0	16618.20953	24.1	44944.36719
5.9	512.39331	12.0	758.92896	18.1	17274.51953	24.2	44938.96484

helium would be highly desirable. The bore axis will be vertical. The dewar will be able to be filled from a horizontal fill line in order to obviate the need for access to the top of the dewar.

C. INTERACTION CIRCUIT

1. TE_{021} Cavity Design

The TE_{021} oscillator cavity dimensions have been scaled directly from the 28 GHz cavity. In anticipation of the tighter machining tolerances required at 110 GHz, we have built cold test cavities as well as actual cavity tube parts in order to investigate difficulties encountered with the requisite tolerances. We are also exploring optical techniques for checking the cavity parts after fabrication.

2. TE_{031} Cavity Design

A 110 GHz oscillator cavity operating in the TE_{031} mode is also under consideration for several reasons. First, the larger radius of a TE_{031} cavity simplifies mechanical design, machining, and allows larger tolerances for the cavity dimensions. Also as is shown in Figure 9, the figure of merit for tube operation with a TE_{031} cavity is 50% better than that for the TE_{021} cavity.

Cold test cavities at 28 GHz and 110 GHz and output tapers have been fabricated and are being tested for resonance characteristics and mode purity.

D. OUTPUT/COLLECTOR

Several different options are being pursued for the output coupling (see Figure 10) including (1) a gradual taper to a 2 1/2" cylindrical waveguide, (2) a gradual taper to a two-section compound taper to a 5" waveguide, (3) a single miter bend to a 2 1/2" waveguide, and (4) a triple miter bend to a 2 1/2" waveguide.

MAXIMUM FIGURE OF MERIT $\left(\frac{R}{Q}\right)\left(Q\frac{\delta}{\lambda}\right)\left(\frac{A}{\lambda^2}\right) = \left(E_\phi^2 \Big/ 2\frac{P_L}{A}\right)\frac{\delta}{\lambda}$

AS A FUNCTION OF MODE INDEX FOR TE_{ON1} MODES

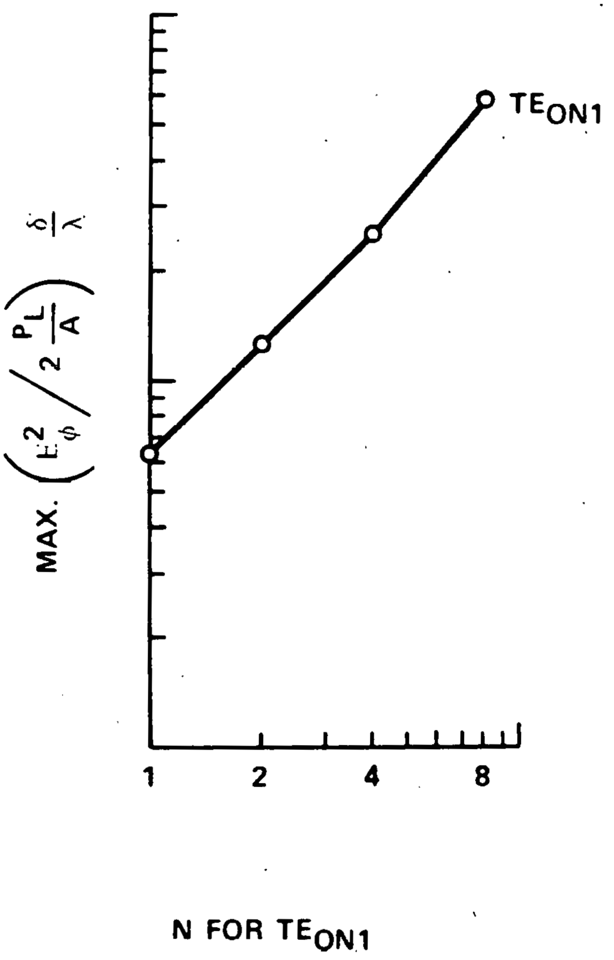
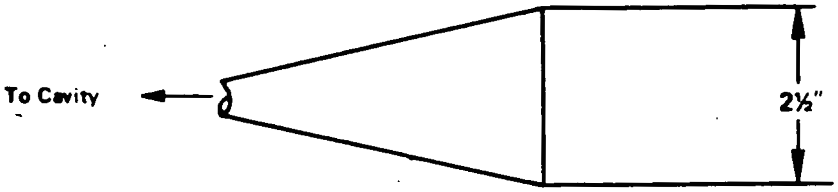
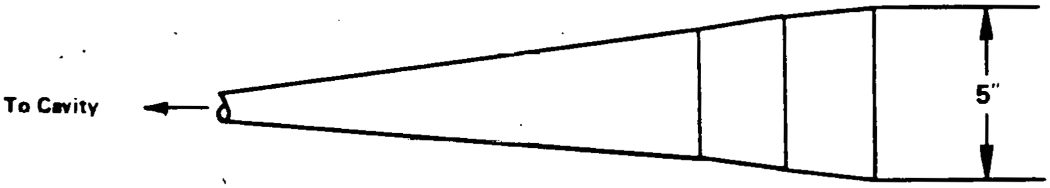


FIGURE 9 FIGURE OF MERIT FOR CIRCULAR ELECTRIC MODES

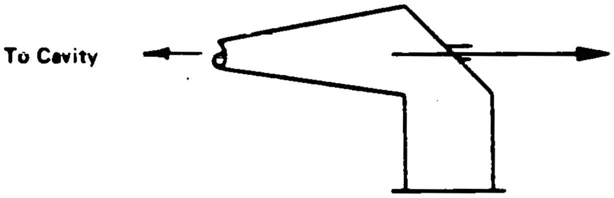
A) GRADUAL TAPER TO A 2.5 INCHES DIAMETER CYLINDRICAL WAVEGUIDE



B) GRADUAL TAPER TO A TWO SECTION COMPOUND TAPER TO A FIVE INCH DIAMETER WAVEGUIDE



C) SINGLE MITER BEND TO A 2.5 INCHES DIAMETER WAVEGUIDE



D) TRIPLE MITER BEND TO A 2.5 INCHES DIAMETER WAVEGUIDE

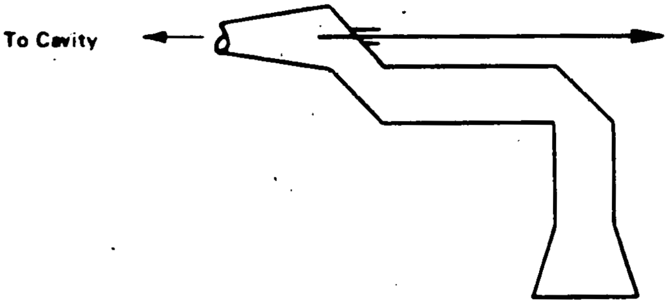


FIGURE 10 OUTPUT COUPLING OPTIONS BEING PURSUED

Strongest consideration is being given to the first two options at present although all four possibilities are being investigated in cold test. The straight through collector options (1 and 2) offer the best mode purity at the output and should allow less reflection back into the oscillator cavity than the miter bend output options (3 and 4). On the other hand, thermal design of the collector will be more difficult if options (1 or 2) are adopted as these designs will require a smaller surface area for electron beam collection.

(1) Gradual Taper to 2 1/2" Waveguide

This is the most likely candidate for output coupling in the experimental pulsed oscillator, as it will provide the best mode purity with the simplest construction and permissible values of average electron beam power density at the collector walls. The problem of mode conversion from the TE_{02} to other TE_{on} modes which will occur at the junction of the conical taper and the cylindrical 2 1/2" guide has been analyzed. For a 5^{o} taper, roughly 30% of the TE_{02} mode power is converted to both the TE_{01} and TE_{03} modes, with 5% of the power going into the TE_{04} and higher order TE_{on} modes, as shown in Figure 11.[9]

(2) Gradual Taper to Compound Taper to 5" Waveguide

This option, which would be more compatible with the high average power collector wall loading in a CW tube, is a solution to the severe mode conversion which would occur in extending a simple taper to a 5" diameter guide. The fraction of rf power, P_{m2}, converted from the TE_{02} to other TE_{on} modes at a conical-cylindrical junction, scales according to,

$$P_{n2} \sim D^2 f^2 \Theta^2$$

for small taper angles Θ.[10] The wave frequency is f, and D is the cylindrical waveguide diameter. In going from a 2 1/2" to 5" diameter conical-cylindrical junction, the mode conversion increases by a factor of 4.

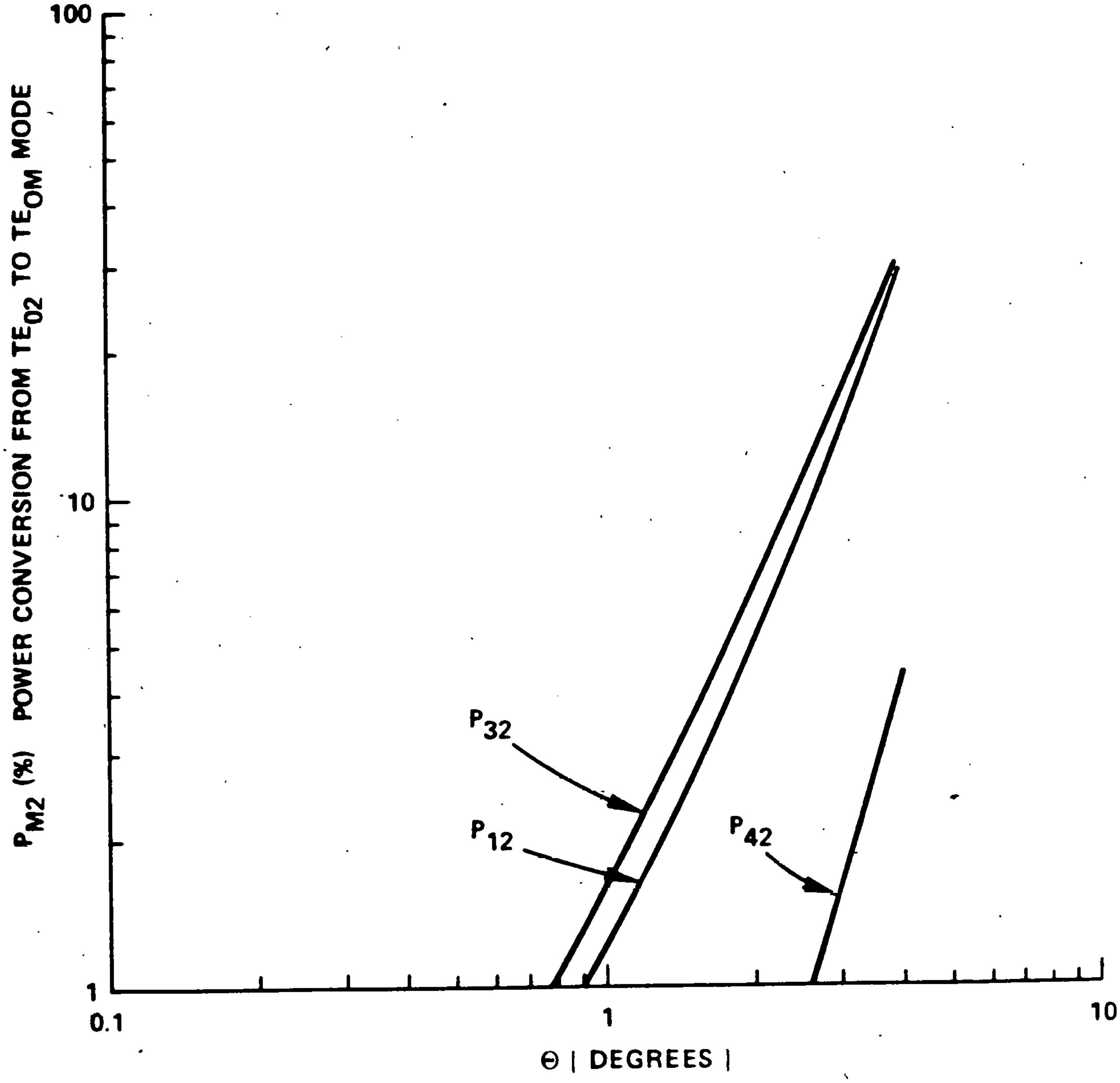


FIGURE 11 MODE CONVERSION AS A FUNCTION OF TAPER ANGLE

To correct the mode conversion, we have started design on a compound taper, shown in Figure 10b. One additional taper section is required for cancellation of each unwanted TE_{on} mode. A two-section compound taper is therefore necessary in this case because the simple conical-cylindrical junction tends to convert the TE_{02} mode predominantly into two other unwanted modes, the TE_{01} and TE_{03}. The angles in the compound taper are chosen to create specific mode conversion coefficients for these two unwanted modes. The lengths of these additional taper sections are then chosen so that upon superposition, contributions from the unwanted modes destructively interfere.

(3) High Power Mode Probe

Mechanical design of a high power mode probe is complete (see Figure 12), and parts are on order. This instrument will provide us with a complete picture of the gyrotron output rf field pattern. When mounted on a 2 1/2" or 5" waveguide, the device may probe the magnitude and direction of the rf field both radially and azimuthally across the guide. The probe mount has been designed to minimize wave reflection back down the waveguide. A piece of WR-10 guide with a coupling aperture on one end will be used as the probing element and will couple the sampled rf power into a broadband crystal detector. The coupling aperture size may be varied, depending on the peak rf power densities expected in the output waveguide of the tube. The instrument is designed to be operated by remote control during tests on live tubes, but of course, may be used in cold test experiments as well. We anticipate that our tubes may be tested with this device at full peak power and up to 1 to 2 kW average power.

E. OUTPUT WINDOW

Microwave designs for flourocarbon liquid face cooled double disc alumina and beryllia windows are nearly completed. The long lead time alumina and beryllia discs are on order. Deliveries are expected to begin in October. Mechanical design of the rest of the remaining parts is expected to be complete in October.

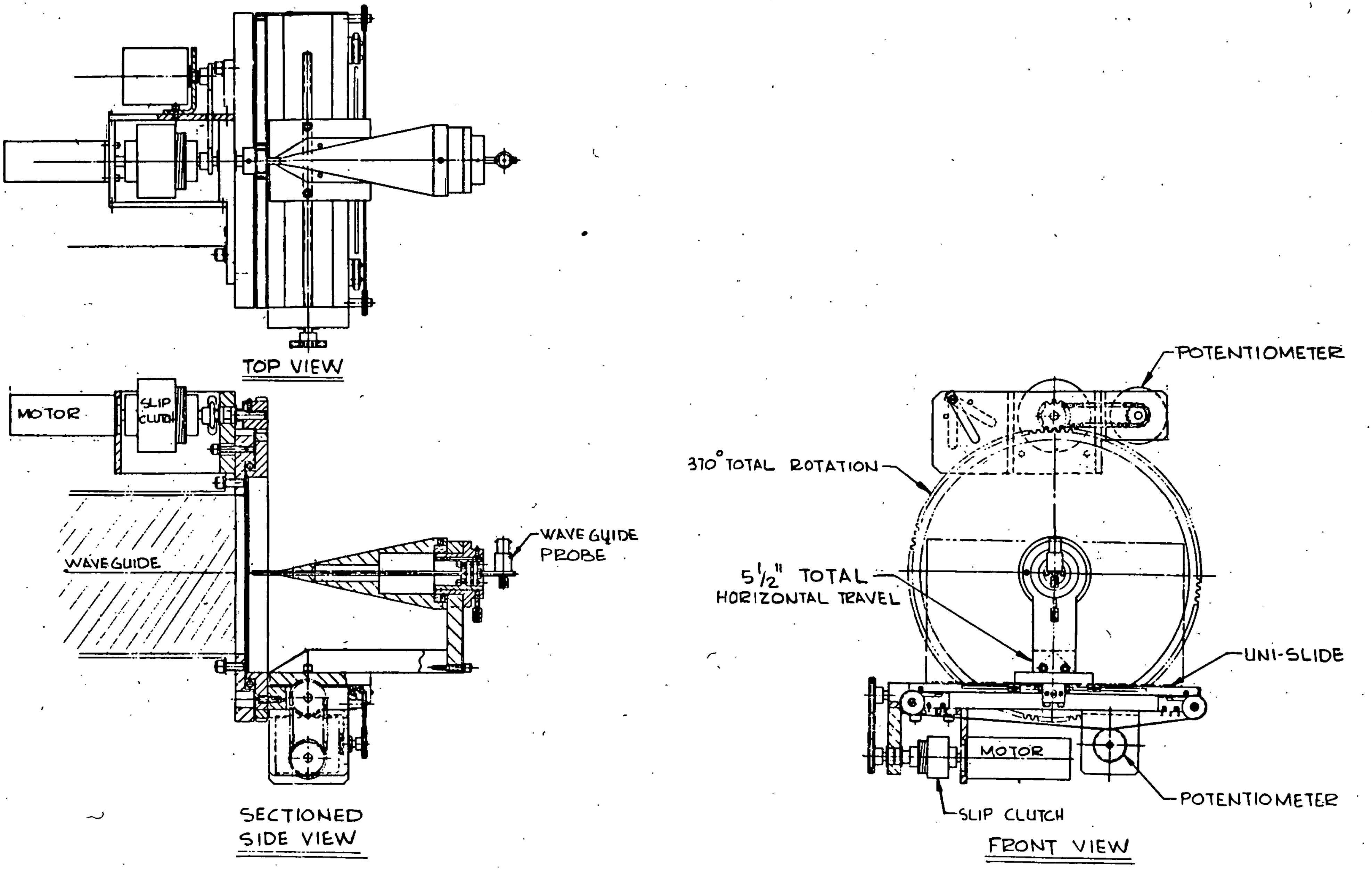

TOP VIEW
MOTOR
SLIP CLUTCH
WAVEGUIDE
WAVE GUIDE PROBE
SECTIONED SIDE VIEW
POTENTIOMETER
370° TOTAL ROTATION
5 1/2" TOTAL HORIZONTAL TRAVEL
UNI-SLIDE
MOTOR
POTENTIOMETER
SLIP CLUTCH
FRONT VIEW
varian
WAVEGUIDE PROBE

FIGURE 12

The design of the alumina window consists of a $5\lambda_g/2$ thick vacuum window, a half length of flourocarbon liquid and a $2\lambda_g$ thick air window.

The design of the beryllia window consists of two $2\lambda_g$ thick windows separated by one-half wavelength of flourocarbon liquid.

These designs will allow at least sixty pounds per square inch absolute pressure capability for the vacuum windows.

Assuming a loss tangent of 0.006, a loss of 3.7 kilowatts is expected in the flourocarbon liquid. Total loss in the two discs is expected to be 0.5 kilowatts for alumina and 1.0 kilowatt for beryllia. It should be possible to handle these losses with a flow of four to six gallons per minute of FC-75 flourocarbon liquid.

III. 200 KW CW AMPLIFIER DRIVE POWER FACILITY

An investigation was initially made to determine which test station could be used most expeditiously on this program. The stations having the capabilities required were evaluated along with their usage based on existing schedules and the amount of floor space available, since the drive facility had to be in proximity to the amplifier facility. The decision was made to utilize the super power facility which was being used for the development of the 28 GHz gyrotron. The latter project will be moved to a new location.

Following this decision, it was determined what modifications and new equipment would be required to produce a complete driver facility based on the project requirements.

The basic requirements for the gyrotron driver socket are a high voltage beam power supply source with properly interfaced interlock protection and a multichannel crowbar logic scheme to divert the capacitor banks energy storage in the event of a load fault. Also required is accurately calibrated instrumentation to properly monitor the parameters of the beam power supply voltage and load currents.

A new crowbar logic assembly will be interfaced to the existing power supply which allows accurate read-out of the fault signal's trip levels in each of three available input channels. The unit will provide protection against excessive peak pulse or average current levels from sensors placed in the circuits of concern.

Another power supply will be retrofitted to provide both the pulse voltage parameters in the first stages of development and later the dc voltages required for the modulating anode of the gyrotron device. Accurately calibrated instrumentation for both modes of operaton will be installed to properly evaluate the drivers performance.

The gyrotron socket will be in an oil filled tank which will be designed and built to also interface to the superconducting magnet dewar. The tank will also contain the pulse instrumentation components.

High level terminations will be ducted between the power supply cabinet and the oil tank.

For convenience in servicing the tube or components within the oil tank, the tank will be plumbed to interface to an oil fill and drain system.

A separate water manifold will be designed and built to properly channel and control the driver's coolant. This includes flow instrumentation and flow interlock protection. A special heat exchanger utilizing FC-75 will also be interfaced into the coolant system to provide output windows' coolant.

For protection against waveguide arcs, a new arc-detector will be installed in the drive waveguide and interfaced to the electronic fault protection. The cryogenic system required for cooling both the amplifier and driver magnet assemblies will also have to be designed and installed.

The magnet power supplies will be specified, procured and installed to properly interface with the associated magnets and the necessary fault protection.

Based on the outlined tasks, an estimate of the manpower required to accomplish the work has been determined so that available personnel can be scheduled accordingly.

IV. WATERLOAD, POWER SAMPLER AND ARC DETECTOR

The waterload planned to be used on the 110 GHz tube is identical to that used on the 28 GHz tube and is shown in Figure 13.

Design of a combination power sampler and arc detector is expected to be completed in October.

REVISIONS					
ZONE	LTR	DESCRIPTION	EO	DATE	APPROVED
	A	REV DIMS PER EO 10-85494		10-10-79	WL

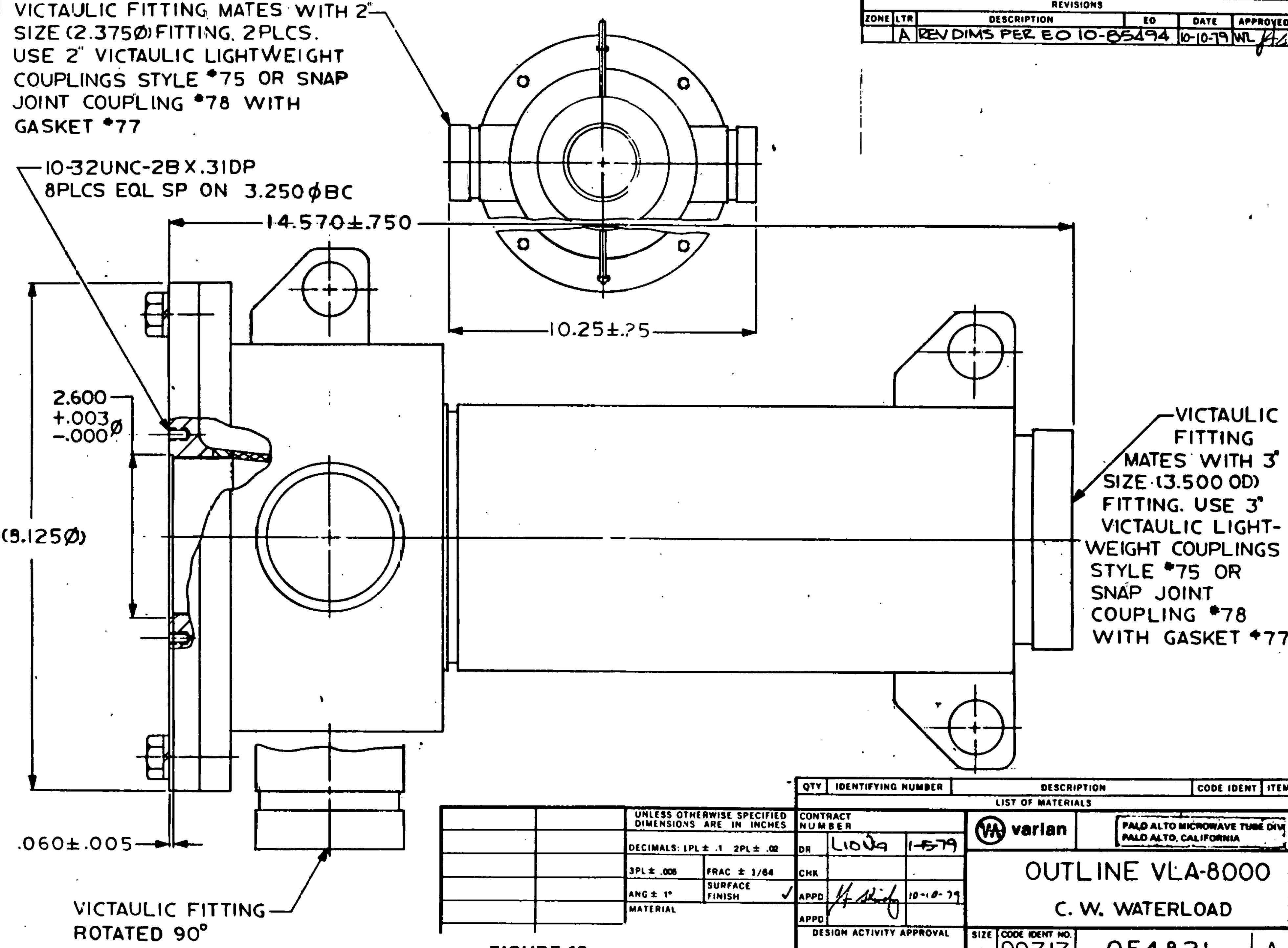


FIGURE 13

QTY	IDENTIFYING NUMBER	DESCRIPTION	CODE IDENT	ITEM
LIST OF MATERIALS				

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES		CONTRACT NUMBER	
DECIMALS: 1PL ± .1 2PL ± .02		DR	L10Q9 1-5-79
3PL ± .005	FRAC ± 1/64	CHK	
ANG ± 1°	SURFACE FINISH ✓	APPD	10-10-79
MATERIAL		APPD	
		DESIGN ACTIVITY APPROVAL	
PEC NO.		CUSTOMER APPROVAL	
INISH			

varian

PALO ALTO MICROWAVE TUBE DIV
PALO ALTO, CALIFORNIA

OUTLINE VLA-8000
C. W. WATERLOAD

SIZE	CODE IDENT NO.		
C	99313	054821	A
SCALE 1/2		SHEET	OF

V. PROGRAM SCHEDULE AND PLANS

The program schedule is shown in Figure 14. All facets of the program are on schedule with the exception of those requiring 110 GHz cold test equipment.

During the next quarter the electron gun computer and mechanical design and drawings will be completed. Gun parts will be ordered for the first two tubes. The superconducting solenoid magnet and room temperature collector solenoid magnet designs and specifications will be completed. The first unit will be ordered. The interaction circuit cold tests will be completed. The cold testing of output coupling schemes will be well under way. The output window parts will be ordered. The drive power facility design will be complete. The power sampler and arc detector drawings will be complete.

MILESTONE CHART AND STATUS REPORT

○ ORIGINAL START
☐ REVISED START
△ MAJOR MILESTONE
▽ INTERMEDIATE OR DECISION POINT
◇ PROPOSED SCHEDULED DEVIATION FOR A MAJOR MILESTONE
▼ STATUS REPORT TIME
— ACTIVITY SCHEDULED
▬ ACTIVITY COMPLETED

PROGRAM	JOB NO.	STATUS REPORT DATE
EBT-P 110 GHz DEVELOPMENT		28 SEPTEMBER 1979

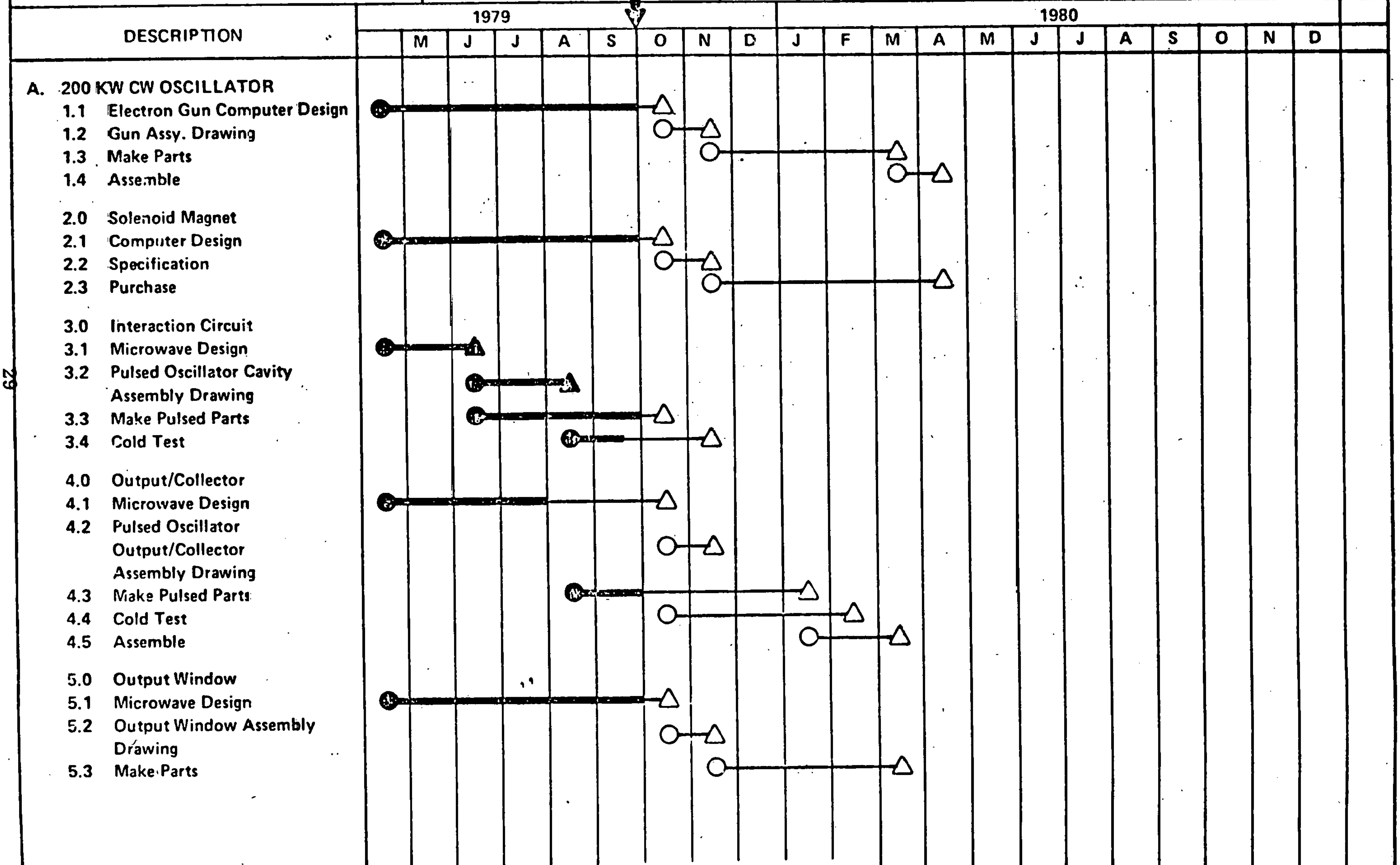


FIGURE 14

MILESTONE CHART AND STATUS REPORT

○ ORIGINAL START ☐ REVISED START △ MAJC LESTONE

▽ INTERMEDIATE OR DECISION POINT ◇ PROPOSED SCHEDULED DEVIATION FOR A MAJOR MILESTONE

⇩ STATUS REPORT TIME — ACTIVITY SCHEDULED ▬ ACTIVITY COMPLETED

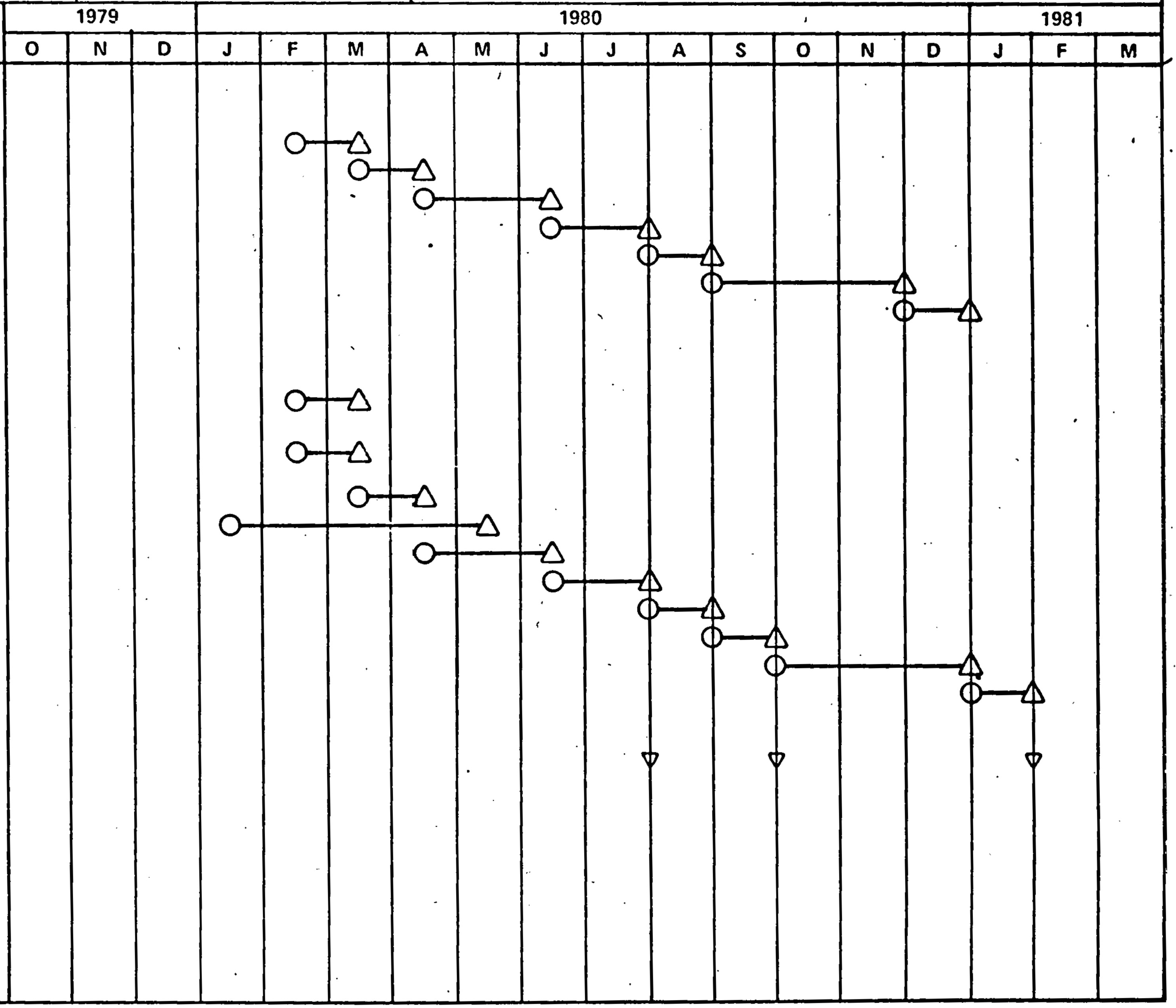
PROGRAM EBT-P 110 GHz DEVELOPMENT	JOE NO.	STATUS REPORT DATE 28 SEPTEMBER 1979

DESCRIPTION

A. 200 KW CW OSCILLATOR (Cont.)
- 6.0 Experimental Tube
- 6.1 Final Assembly Drawing
- 6.2 Assemble
- 6.3 Pulse Test
- 6.4 Modify & Reassemble I
- 6.5 Retest I
- 6.6 Modify & Reassemble II
- 6.7 Retest II

- 7.0 CW Test Oscillator
- 7.1 CW Oscillator Cavity Assembly Drawing
- 7.2 CW Oscillator Output/Collector Assembly Drawing
- 7.3 CW Final Assembly Drawing
- 7.4 Make Parts
- 7.5 Assemble
- 7.6 Test
- 7.7 Modify & Reassemble I
- 7.8 Retest I
- 7.9 Modify & Reassemble II
- 7.10 Retest II

- 8.0 Oscillator Delivery Decision



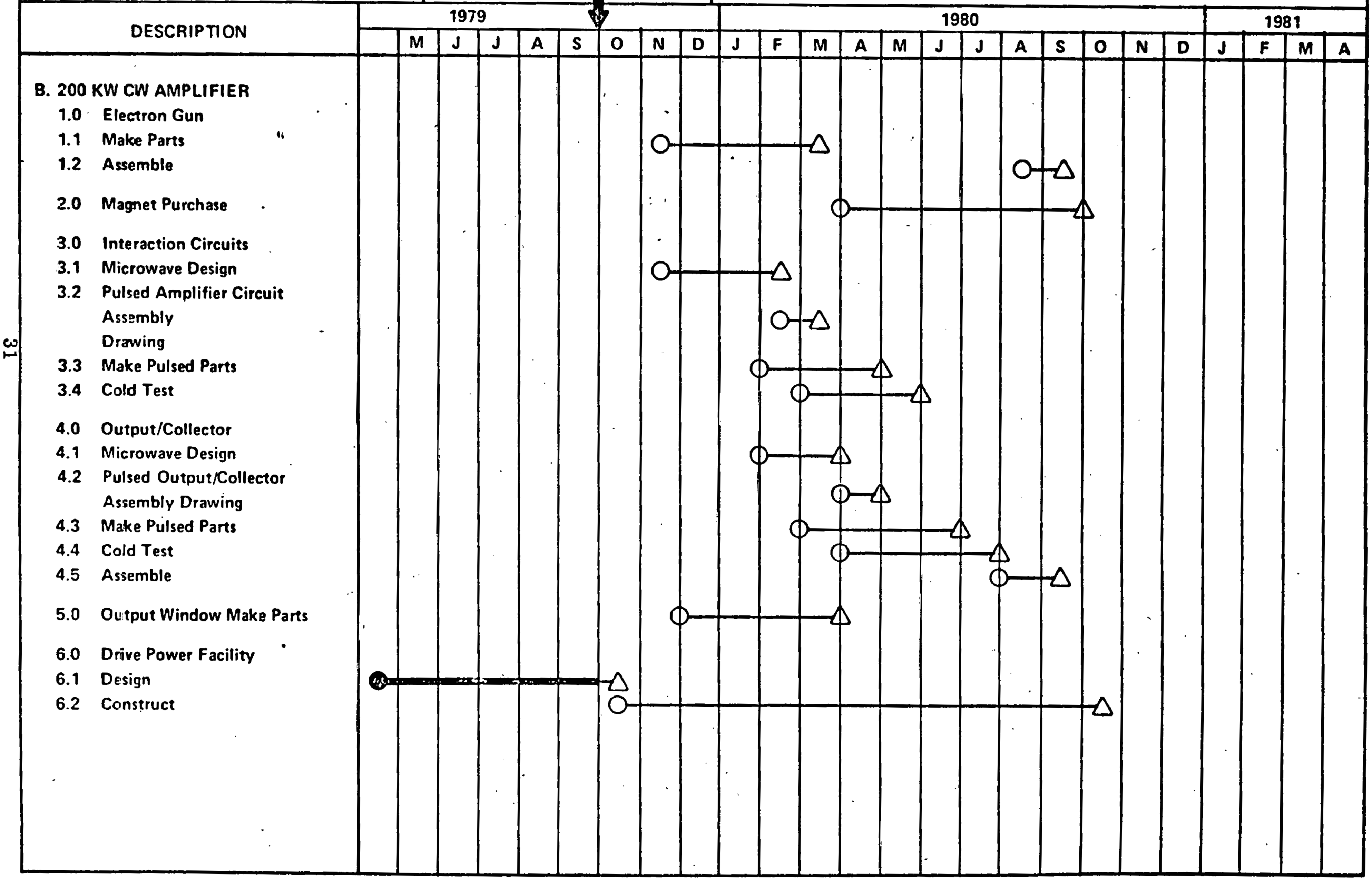
MILESTONE CHART AND STATUS REPORT

○ ORIGINAL START
□ REVISED START
△ MAJOR MILESTONE
▽ INTERMEDIATE OR DECISION POINT
◇ PROPOSED SCHEDULED DEVIATION FOR A MAJOR MILESTONE
▼ STATUS REPORT TIME
— ACTIVITY SCHEDULED
▬ ACTIVITY COMPLETED

PROGRAM
EBT-P 110 GHz DEVELOPMENT

JOB NO.

STATUS REPORT DATE
28 SEPTEMBER 1979



MILESTONE CHART AND STATUS REPORT

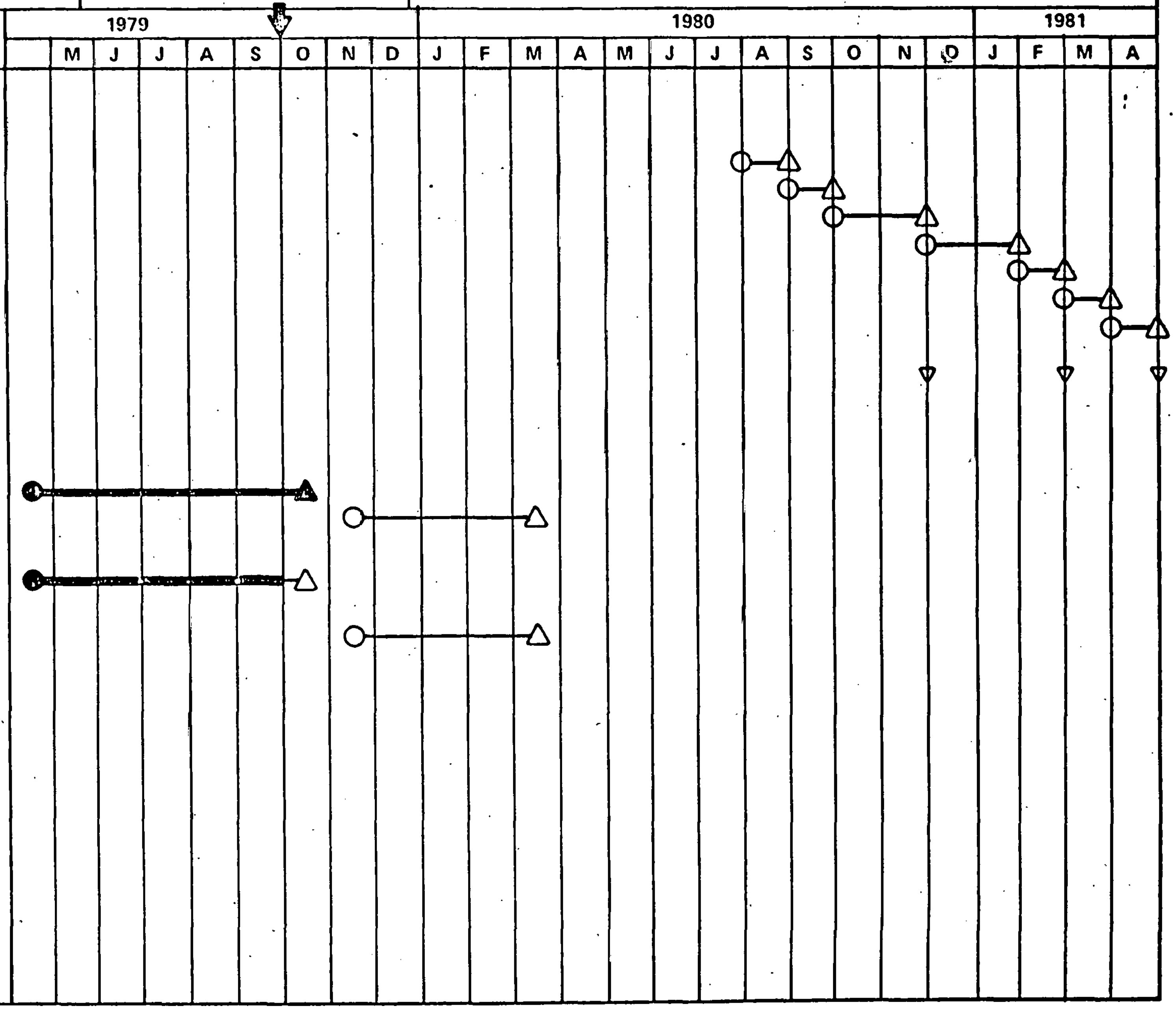
○ ORIGINAL START
☐ REVISED START
△ MAJOR MILESTONE
▽ INTERMEDIATE OR DECISION POINT
◇ PROPOSED SCHEDULED DEVIATION FOR A MAJOR MILESTONE
⇩ STATUS REPORT TIME
— ACTIVITY SCHEDULED
▬ ACTIVITY COMPLETED

PROGRAM: EBT-P 110 GHz DEVELOPMENT
JOB NO.:
STATUS REPORT DATE: 28 SEPTEMBER 1979

DESCRIPTION

B. 200 KW CW AMPLIFIER (Cont.)
- 7.0 Experimental Tube
- 7.1 Final Assembly Drawing
- 7.2 Convert From Oscillator
- 7.3 Test
- 7.4 Modify & Reassemble I
- 7.5 Retest I
- 7.6 Modify & Reassemble II
- 7.7 Retest II
- 8.0 Amplifier Delivery Decision

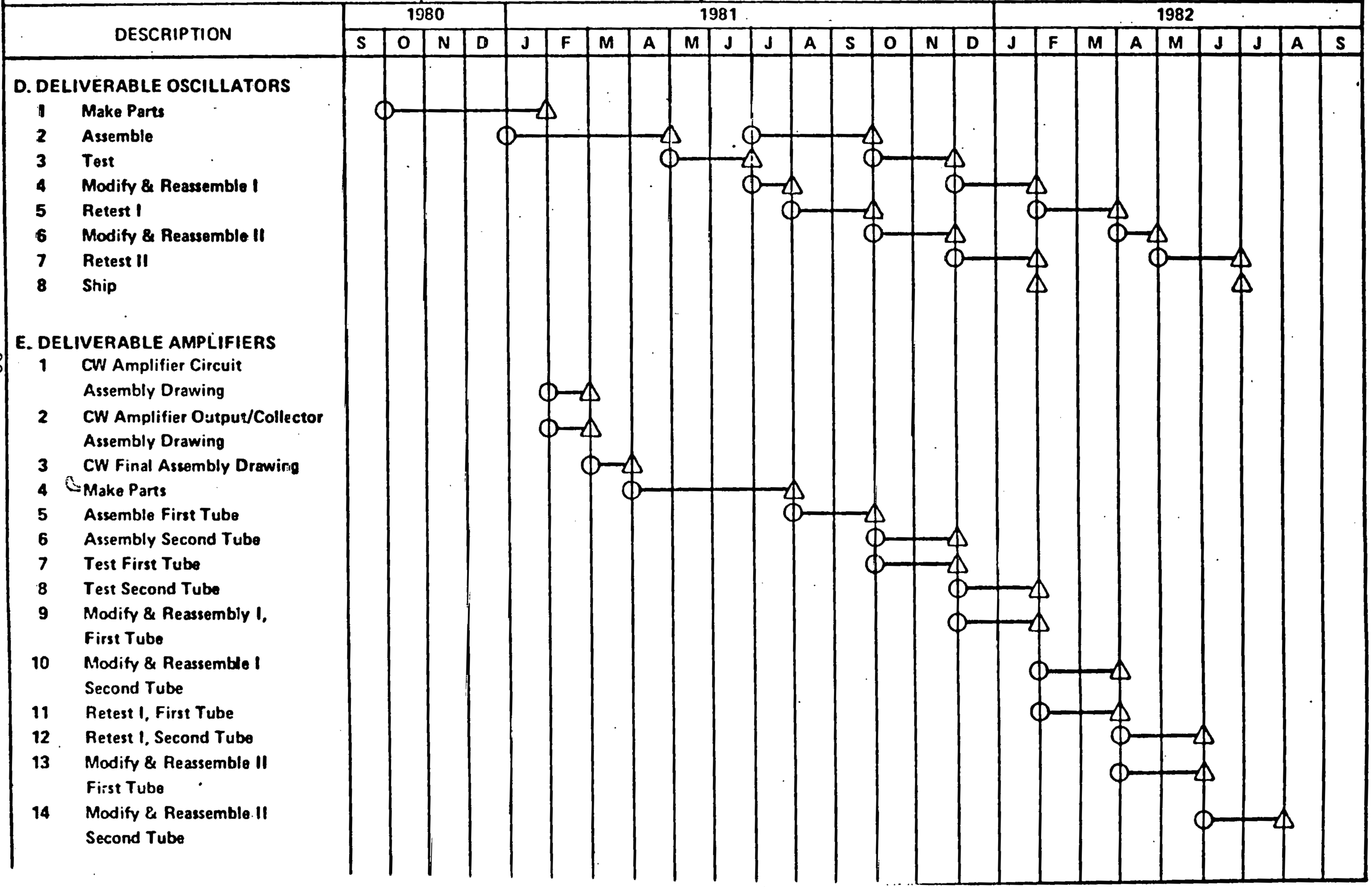
C. WATERLOAD, POWER SAMPLER AND ARC DETECTOR
- 1.1 Waterload Assembly Drawing
- 1.2 Build one Waterload
- 2.1 Power Sampler and Arc Detector Assembly Drawing
- 2.2 Build one Power Sampler and Arc Detector



MILESTONE CHART AND STATUS REPORT

○ ORIGINAL START
□ REVISED START
△ MAJOR MILESTONE
▽ INTERMEDIATE OR DECISION POINT
◇ PROPOSED SCHEDULED DEVIATION FOR A MAJOR MILESTONE
STATUS REPORT TIME
— ACTIVITY SCHEDULED
▬ ACTIVITY COMPLETED

PROGRAM EBT-P 110 GHz DEVELOPMENT	JOB NO.	STATUS REPORT DATE 28 SEPTEMBER 1979



MILESTONE CHART AND STATUS REPORT

○ ORIGINAL START
☐ REVISED START
△ MAJOR MILESTONE
▽ INTERMEDIATE OR DECISION POINT
◇ PROPOSED SCHEDULED DEVIATION FOR A MAJOR MILESTONE
⇩ STATUS REPORT TIME
— ACTIVITY SCHEDULED
▬ ACTIVITY COMPLETED

PROGRAM
EBT-P 110 GHz DEVELOPMENT

JOB NO.

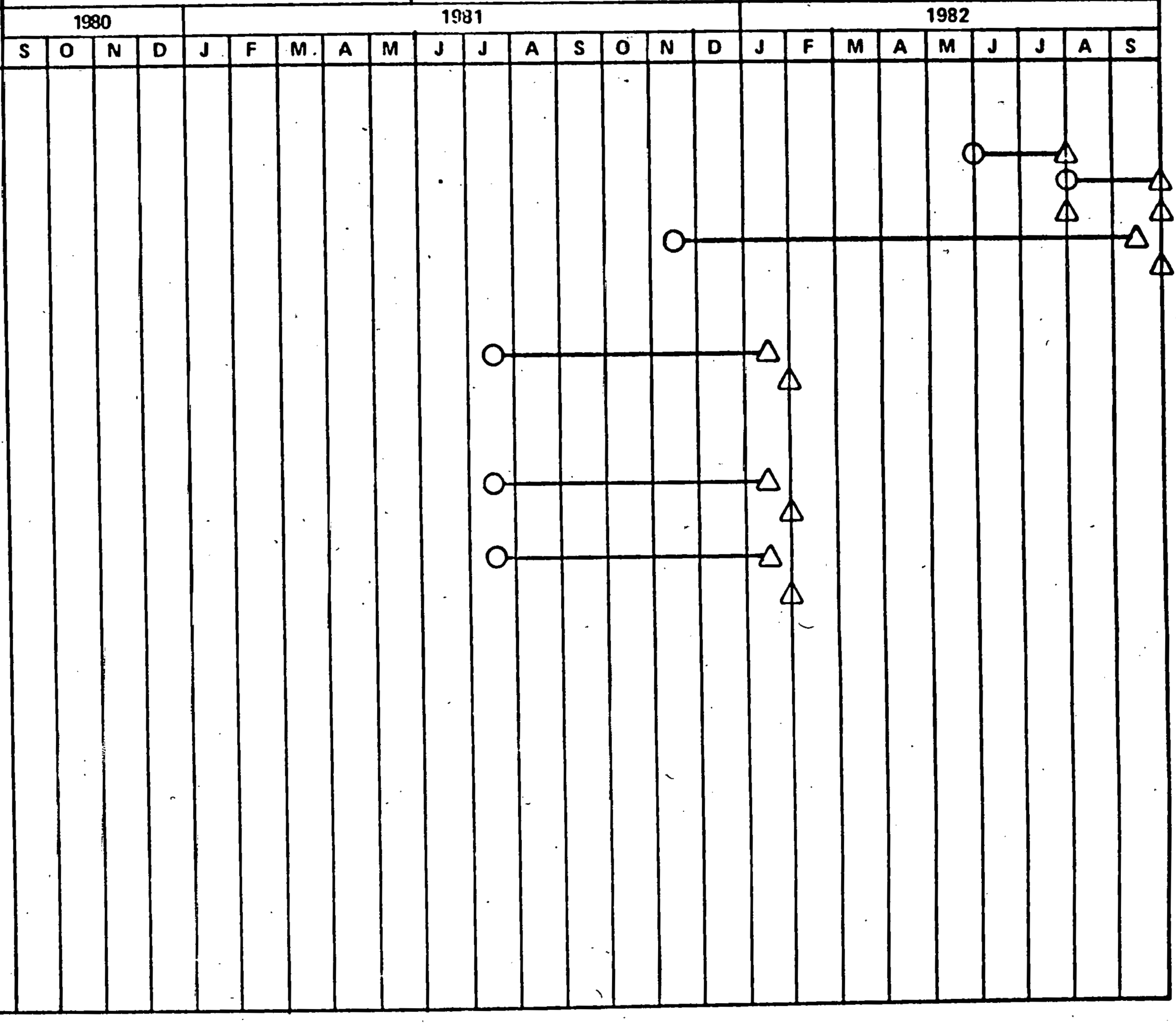
STATUS REPORT DATE
28 SEPTEMBER 1979

DESCRIPTION

E. DELIVERABLE AMPLIFIERS
CW AMPLIFIER CIRCUIT (Cont.)
15 Retest II, First Tube
16 Retest II, Second Tube
17 Ship
18 Build Deliverable Driver
19 Ship Driver

F. PURCHASE DELIVERABLE
1.0 Magnet
2.0 Ship

G. WATERLOAD, POWER SAMPLER AND ARC DETECTOR
1.0 Build Deliverable Waterload
1.1 Ship
2.0 Build Deliverable Power Sampler and Arc Detector
2.1 Ship



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