$\bar{p}$ Note #416

EVALUATION OF TITANIUM SUBLIMATION PUMPS

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Titanium Sublimation Pumps (TSP's) are to be used to attain the ultra high vacuum necessary to operate the accumulator. Tests were conducted to gain a "hands on" understanding of their operation, and evaulate the controllers and power supplies needed for their operation.

The test chamber consisted of a 270 litre/sec ion pump, two ion gauges, a variable leak valve and a 8" TSP chamber. (see Fig. 1)

The vacuum in the chamber was maintained at 10^{-7} TORR, during tests, by opening the variable leak valve, using dry N_2 as an inlet gas. This was done in order to achieve a pressure where changes in chamber pressure, due to pumping of TSP, could be observed. Pressure and filament current data were chart recorded. Filaments were activated for periods of 90 seconds at 15 minute intervals. Ion gauges were calibrated.

Constant Voltage Tests

A commercial control unit (Varian #922-0043), was used in conjunction with a Varian TSP cartridge, (916-0017). Two filaments were cycled just over 500 times before drops in pumping capability were observed. (see Fig. 2a and Fig. 2b) Surge and operating filament current valves decreased proportionally throughout cycling. Surge current dropped after about 7 seconds to an operating current value. for each cycle. (Fig. 3)

Modification of TSP Cartridge for Constant Emission

In order to evaluate the constant emission system, which uses filament electron emission as a means of measuring titanium sublimation rate, modification of the cartridge was necessary to have a means of "collecting" the electrons emitted from the hot filament. This was accomplished by the replacement of the center filament with a 1/2" s.s. tube, collector of length approximately proportional to that of the filaments. (see Fig. 4)

Initial cycling of the modified cartridge showed that sublimed titanium would cause shorting between the filaments and the collector. To prevent this a ceramic shield was placed at the base of the collector. This protected the area surrounding the base from becoming coated with titanium; thus preventing shorting.

Additional cycling showed that poor electrical conductivity existed at the external connections of the cartridge. To remedy this the normally loose fitting s.s. sleeves were silver soldered to the 6 gauge braided wire.

Tests of Modified Cartridge Using Various Emission Currents

Tests were performed using various emission current values ranging from 4 ma to 20 ma. A Fermi constant electron emission controller was used in conjunction with the modified Varian cartridge (#916-0017). Emission values and corresponding filament currents are as follows.

Emission Current	Operating Filament Current
4 ma	36.6 Amps (RMS)
5	37.1
8	37.6
10	38.1
12	38.5
15	38.8

Values below 4 ma were not tested because of obvious losses in pumping capability. All filaments melted at 20 ma emisison. An intermediate value of 10 ma was chosen as the optimum emission value, being the maximum sublimation rate for a minimum amount of current. Sublimation rate was based on rate of pressure rise in the vacuum chamber after sublimation was completed and all active titanium saturated. (see Table 1)

Filament Life

An additional four filaments were cycled at 10 ma emission at a pressure of 10^{-7} TORR and 10^{-10}TORR. All cycled over 1000 times showing little loss in pumping capability. After ≈500 cycles, operating filament current began to rise as surge current continued to fall. This inverse relation continued to ≈850 cycles. At this point the filament current seemed to become constant. The difference between surge and operating filament currents (I_s-I_o) decreased continually throughout cycling. This difference could possibly be used to determine filament life, as (I_s-I_o) approaches zero. (see Fig. 5 and Fig. 6)

Degas Testing

New filaments were observed through a port hole in the chamber while power was being applied. Degassing was achieved at 25 amps RMS with filaments connected in parallel. From first applying power, 90 seconds elapsed before a soft orange illumation of filament was observed. Outgassing continued for 30 minutes.

Estimation of Quantity Gas Pumped by TSP

Ion gauges were degassed and calibrated in order to calculated pumping speeds. Chamber pressure was kept at 10^{-7} TORR at P_2. (see Fig. 1) TSP was cycled at 30 minute intervals with an ON time of 90 seconds. The interval between sublimations was increased to 30 minutes in order to insure total saturation of titanium between cycles. At 10^{-7} TORR, it took approximately 20 minutes to saturate all of the titanium.

Using Fischer-Mommsen's method pumping speeds were calculated at times of peak sublimation and total saturation. (No active titanium-ion pump only!) The difference between the two, at various cycle times, gave an average pumping speed of 300 litre/sec at 10^{-7} TORR for the TSP, given this particular chamber geometry and pump opening. (see Table 2)

The TSP actively pumped approximately 1 molecule per cycle at a pressure of 2.2×10^{-7} TORR. The amount of gas pumped per filament over a 1000 cycle period was calculated to be 15.8 TORR litre.

Saturation Times at Various Emission Values

Emission Current	Operating Current	Base Pressure Before Sublimation	Ultimate Pressure After Sublimation	Rate of Rise to Base Pressure
15 ma	- 38.8 Amps RMS	5.2×10^{-7} (TORR)	2.2×10^{-7} (TORR)	8.7(min)
12 ma	- 38.5	5.2×10^{-7}	2.2×10^{-7}	10.4
10 ma	- 38.1	5.2×10^{-7}	2.2×10^{-7}	10.9
8 ma	- 37.6	5.2×10^{-7}	2.2×10^{-7}	8.0
5 ma	- 37.1	5.2×10^{-7}	2.3×10^{-7}	5.0
7 ma	- 36.6	5.2×10^{-7}	2.3×10^{-7}	5.1

TABLE 1

Effective Pumping Speeds (Litre/Sec)

# Cycles	Measured $S_{IOP+TSP}$	Measured S_{ION}	Difference Se_{TSP}
300	540 ℓ/s	231 ℓ/s	309 ℓ/s
350	511 ℓ/s	226 ℓ/s	285 ℓ/s
500	569 ℓ/s	270 ℓ/s	299 ℓ/s
550	540 ℓ/s	257 ℓ/s	283 ℓ/s
600	541 ℓ/s	250 ℓ/s	291 ℓ/s
650	576 ℓ/s	243 ℓ/s	333 ℓ/s
850	540 ℓ/s	238 ℓ/s	302 ℓ/s
900	540 ℓ/s	237 ℓ/s	303 ℓ/s
Average			300 ℓ/s

TABLE 2

FERMILAB

ENGINEERING NOTE

SECTION	PROJECT	SERIAL-CATEGORY	PAGE
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SUBJECT

NAME

Fischer-Mommsen.

Test dome w/ TSP & Ion Pump.

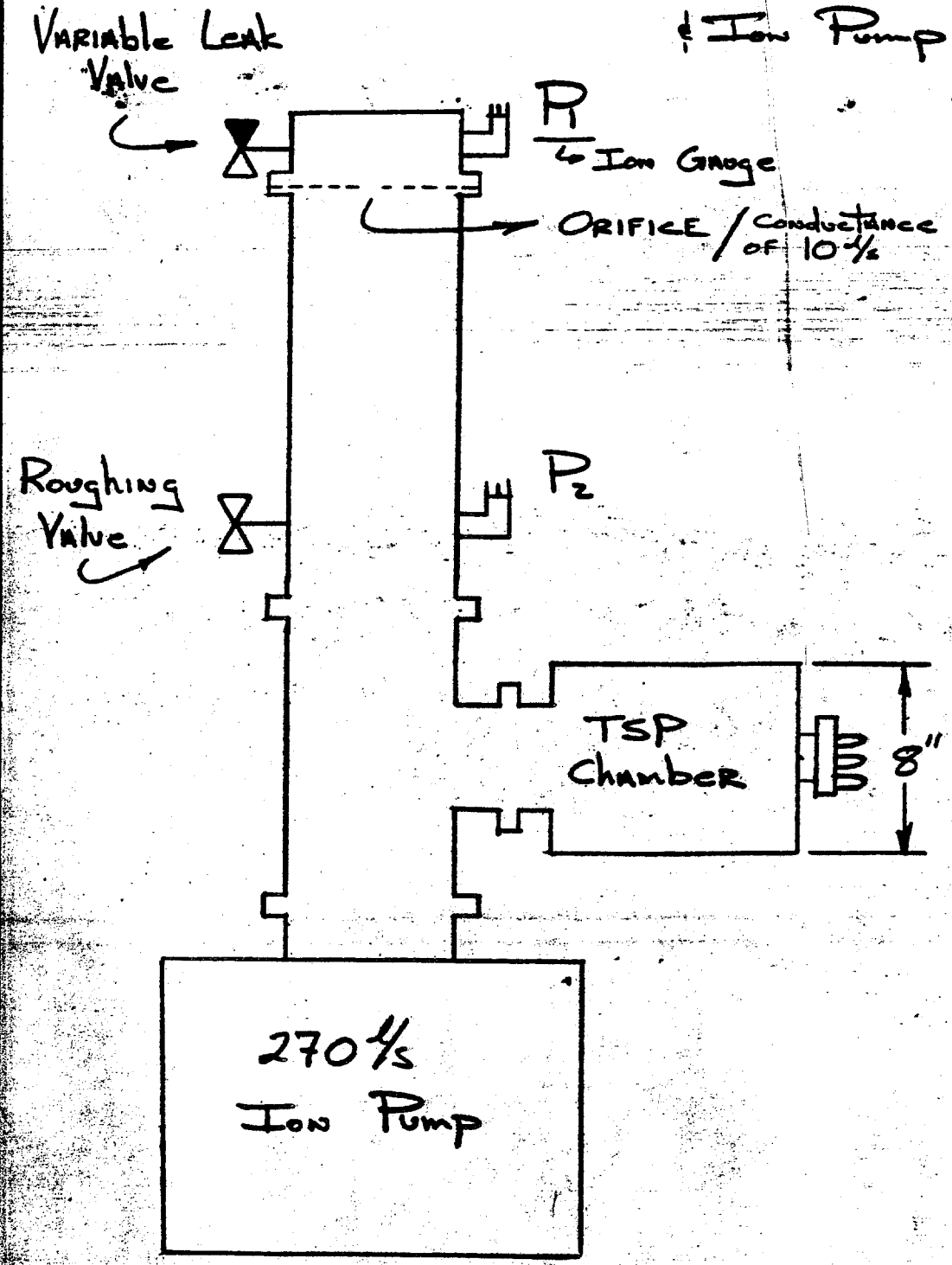


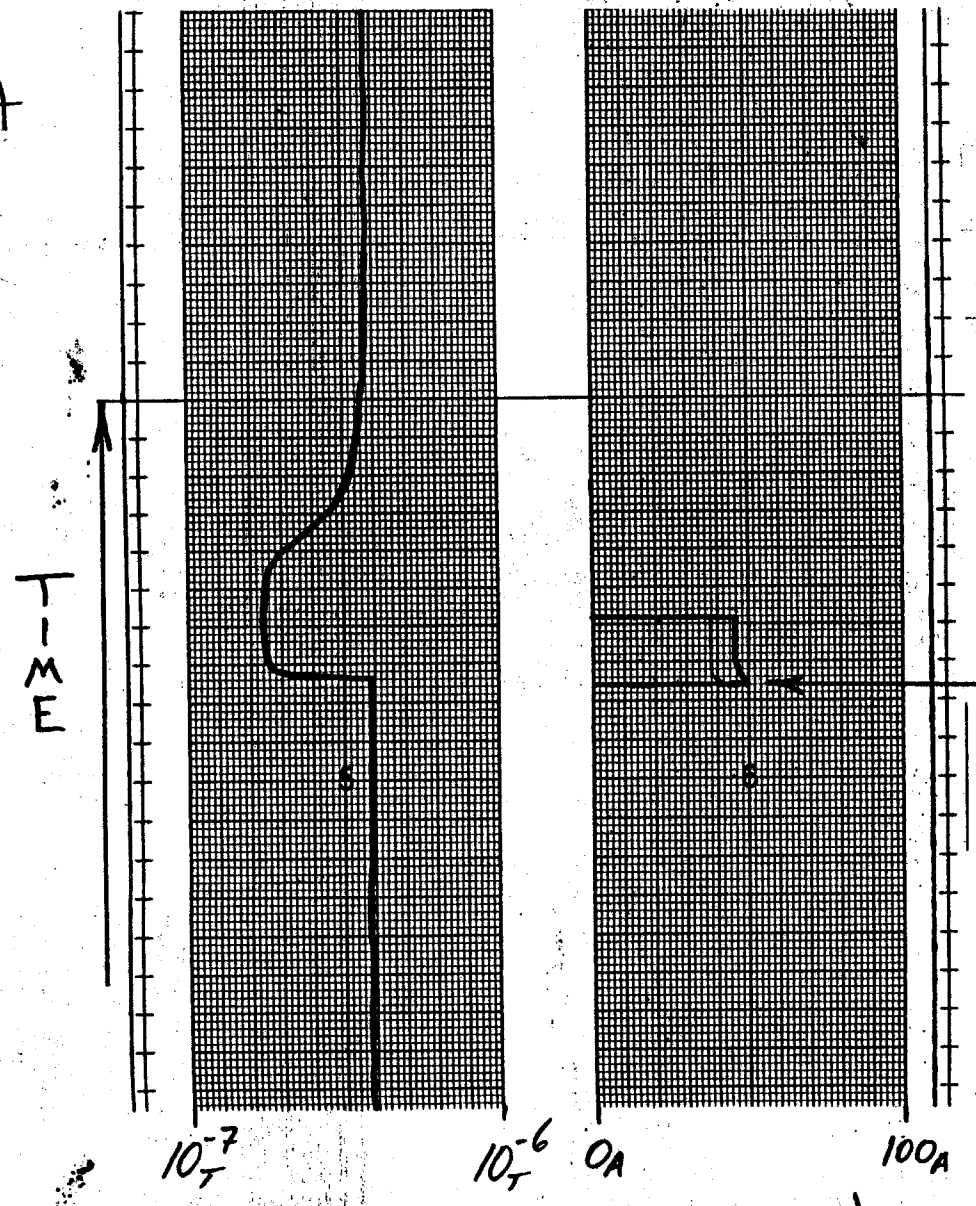
Fig. 1

Constant Voltage Evaluation After 5 Sublimation Cycles

Operating Current
↳ $[I_o] = 45A$ (RMS)

Pressure @ P_2
↳ $0^{?}$ TORR

Chart Speed
↳ 5 mm/MIN.



Filament ON Time
Approximately 90 sec

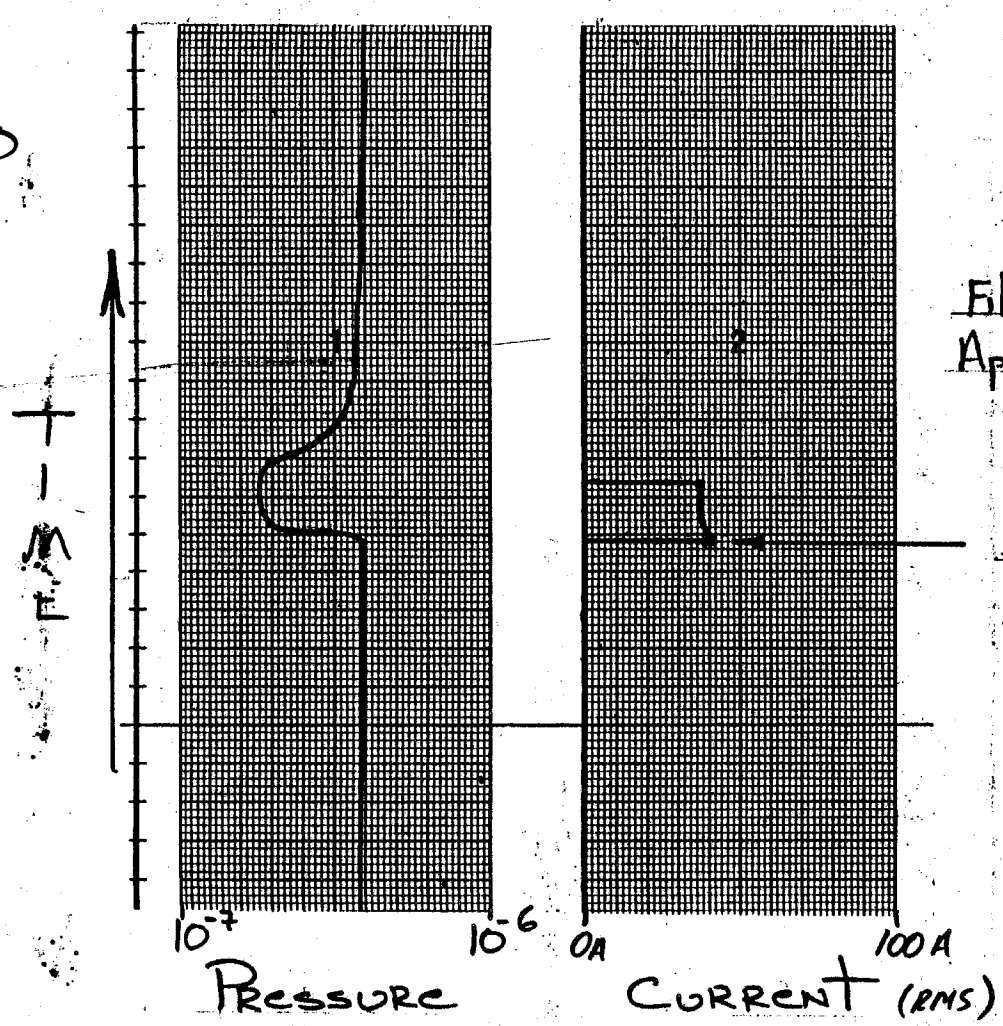
Surge Current
↳ $[I_s] = 49A$ (RMS)

Constant Voltage Evaluation
After 500 Sublimation Cycles

Operating Current
↳ [I] = 36.5 A (RMS)

Pressure @ P_2
↳ 10^{-7} TORR

Chart Speed
↳ 5 mm/MIN.



Filament ON Time
Approximately 90 sec.

Surge Current
↳ [I_s] = 41.5 A (RMS)

Fig. 2b

Constant Voltage
Filament Currents
vs
Cycles
$P_2 = 5.0 \times 10^{-7}$ Torr
Filament Current Amps RMS
50
45
40
35
0
50
100
150
200
250
300
350
400
450
500
Cycles
Surge Current
Operating Current

E-2

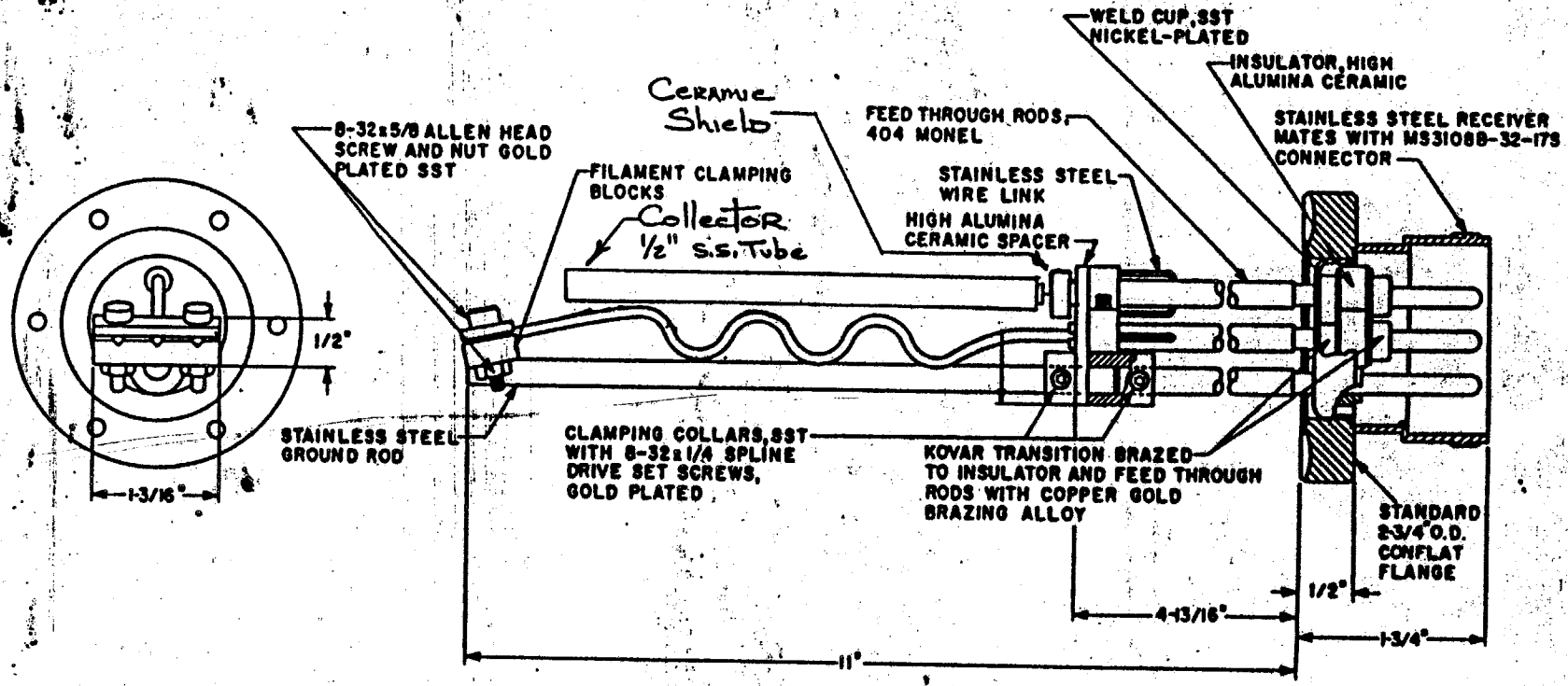
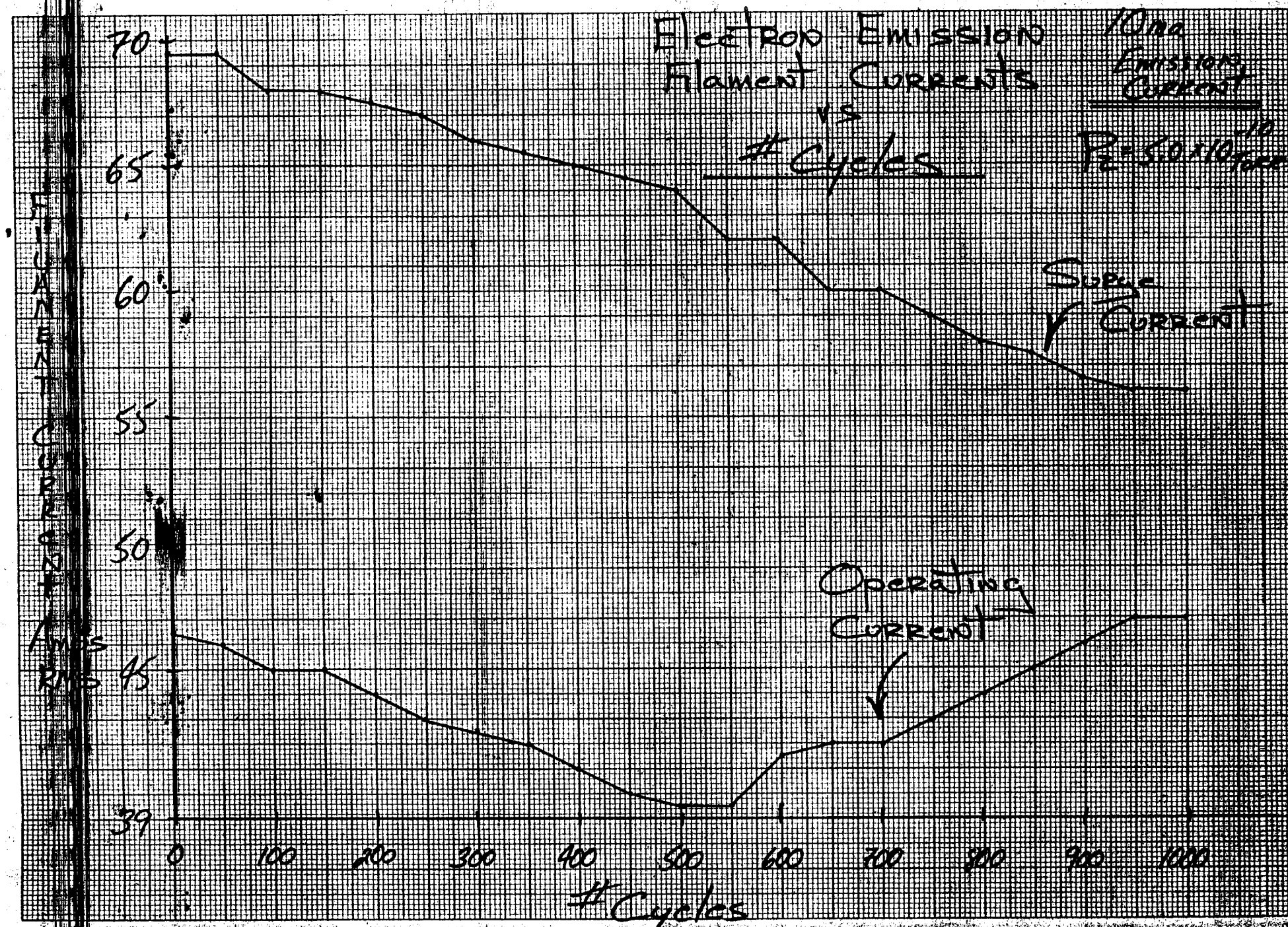
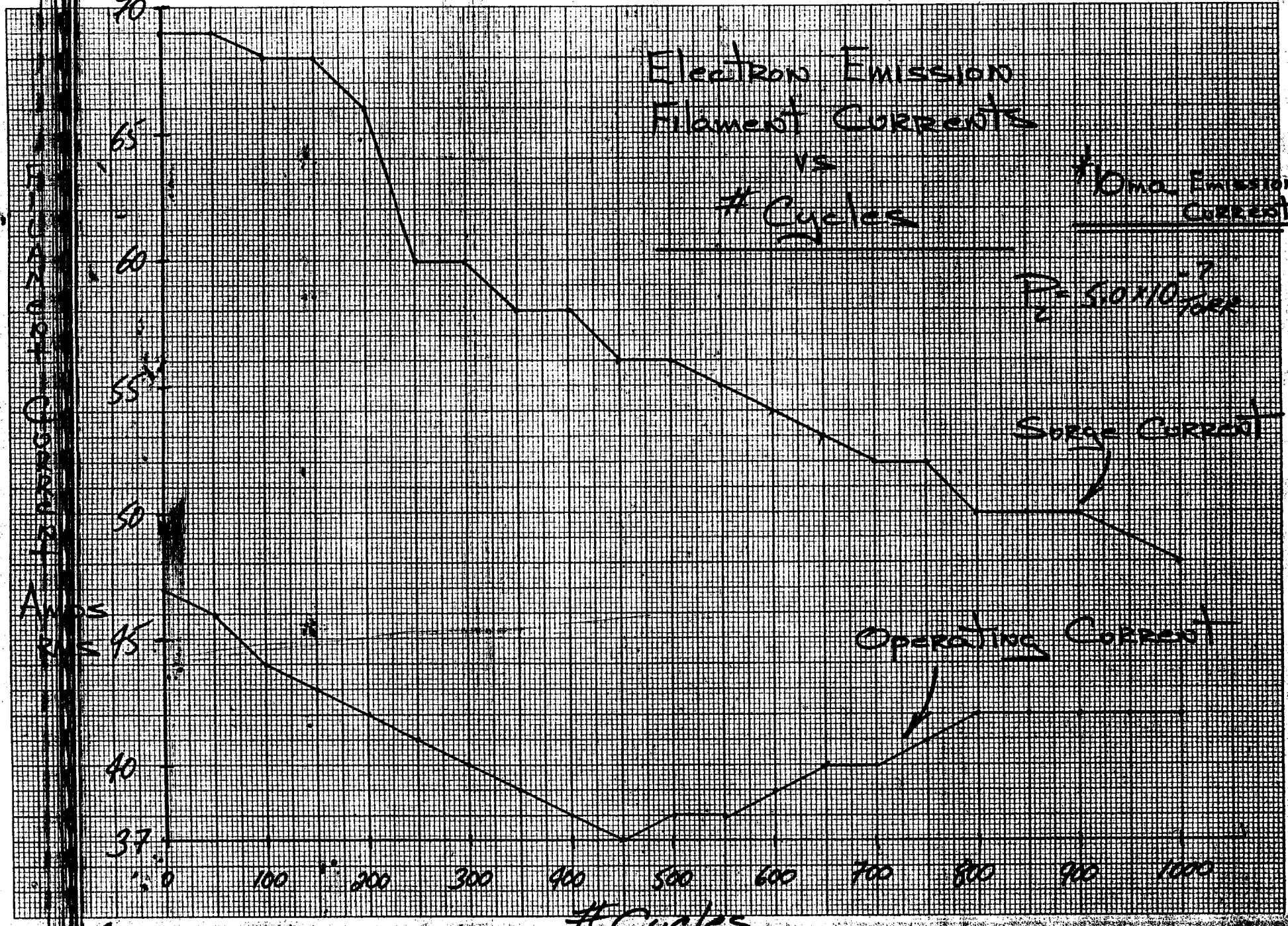


Figure 4. Outline Drawing of Titanium Sublimation Cartridge
with Collector Modification for
Constant Electron Emission System



Electron Emission
Filament Currents
vs
Cycles
10ma
Emission
Current
$P_2 = 5.0 \times 10^{-10}$ Torr
Surge
Current
Operating
Current
Filament Current
Amps
RMS
70
65
60
55
50
45
39
0
100
200
300
400
500
600
700
800
900
1000
Cycles


Electron Emission
Filament Currents
vs
Cycles
Nominal Emission Current
$P_2 = 5.0 \times 10^{-7}$ Torr
Surge Current
Operating Current
Filament Current in Amps RMS
70
65
60
55
50
45
40
37
0
100
200
300
400
500
600
700
800
900
1000
Cycles