MEMO REPORT P-186

General Physics Research Department
RESEARCH LABORATORY

April 9, 1959

THE STABILIZATION OF TANTALUM CARBIDE FILAMENTS
AT HIGH TEMPERATURES

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Abstract

Tantalum carbide has a higher melting point and a higher luminous efficiency than tungsten. However, at 2000 - 2500°K the carbide decomposes to carbon and a sub-carbide which has a melting point about equal to that of W but a poorer luminous efficiency than that of W. Attempts in the past to retard the decomposition by use of hydrocarbon-containing atmospheres have met with limited success. In this work cyanogen- and cyanogen bromide-containing atmospheres are compared with hydrocarbons and found to have certain advantages.

NOTICE

Introduction

Tantalum carbide, TaC, has two properties that make it extremely attractive for study as a potential incandescent filament material. These are a melting point (4150°K) that is 500° higher than that of tungsten and a ratio of visible to total emissivity (ϵ_v/ϵ_t) that is more favorable than that of tungsten. On the other hand, it has some serious shortcomings that make its general use in incandescent lamps infeasible at the present time. For example, it is much more brittle than tungsten (tensile strength of W at 25°C is about 100 - 200 x greater than that of TaC) and it begins to lose carbon rapidly above about 2000 - 2500°K. to form a sub-carbide, Ta_2C, which has a m.p. about equal to that of W but a poorer (ϵ_v/ϵ_t). The latter problem, the decomposition of TaC, has been the focus of most of the effort on TaC for about the last 30 years.[1-4]

The method generally adopted to minimize decomposition of a TaC filament is to provide an atmosphere of carbon vapor around the incandescent filament in an attempt to establish an equilibrium sufficiently displaced toward TaC to retain its favorable properties. The most frequently used source of carbon has been a hydrocarbon gas in admixture with hydrogen. Pyrolysis of the hydrocarbon in the vicinity of the incandescent filament results in a carbon vapor containing atmosphere around the filament. The hydrogen prevents the hydrocarbon from decomposing at too low temperatures and thus minimizes the volume of decomposition products. Unfortunately, the relatively high thermal conductivity of H_2 results in extensive heat loss and decreased efficiency. The non-hydrocarbons, CO, CS_2 and CCl_4 have also been used as sources of carbon vapor but without significant improvement.[1] In the case of the oxygen containing gas, CO, very stable tantalum oxides are formed and lead to rapid deterioration of the filament.

The use of hydrocarbons to depress the decomposition of TaC, while resulting in a significant improvement, was still insufficient for satisfactory use over extended periods of time. The reason for this is illustrated in Fig. 1 which is an exaggerated and simplified sketch showing the physical processes occurring in the

vicinity of a straight incandescent filament. Here, we assume that there is a cylindrical volume element around the hot filament within which some large arbitrary fraction of the hydrocarbon is decomposed to carbon and hydrogen. Then, carbon can diffuse to the filament where it can participate in the equilibrium, $TaC \rightleftharpoons Ta_2C + C$, or it can diffuse out of the cylindrical sheath and eventually deposit on the wall. In the latter case the carbon is lost and a continuation of this process results in a reduction of the density of carbon vapor within the sheath and a consequent shift in the equilibrium toward Ta_2C. Supporting this thesis is the observation of severe bulb blackening and eventual conversion of the filament to Ta_2C and burn-out when TaC filaments are operated in sealed lamps containing hydrocarbon-hydrogen mixtures. It is clear that, on the basis of the model in Fig. 1, the larger the cylindrical volume, the greater the surface area through which diffusion to the wall may take place and the greater the rate at which carbon is lost. It would appear, therefore, that any method which would reduce the volume but maintain the density of carbon vapor would lead to increased filament life. Indeed, the use of hydrogen in admixture with hydrocarbons serves just this purpose. A further advance in the same direction can be made by using carbon containing compounds in which the carbon is more tightly bound than it is in a hydrocarbon. Such a compound would require a higher temperature for any given fraction of decomposition and the resultant decomposition products would be confined to a smaller volume around the filament provided that the temperature gradient remained the same.

A comparison of bond energies indicates that the C-N bond is one of the strongest bonds to carbon. The simplest stable compound containing only C and N is cyanogen, C_2N_2. In order to minimize its decomposition around a hot filament the use of cyanogen-nitrogen mixtures would be required. This provides two additional advantages over the use of H_2 with hydrocarbons. Since N_2 has a much lower thermal conductivity than H_2, the use of N_2 would result in a much steeper temperature gradient which would further restrict the volume of decomposition products and it would also serve to reduce conductive heat losses.

Thermodynamic Calculations

For comparison purposes, the % decompositions of 1 mm C_2N_2 in 1 atm. N_2 and 1 mm C_2H_2 in 1 atm. H_2 were calculated as a function of temperature. The % decomposition was calculated by use of the expression

$$K_p = P\left(\frac{x}{1-x}\right) \tag{1}$$

where K_p is the equilibrium constant in pressure units, P is the pressure of N_2 or H_2 in atm. and x is the fraction of decomposition of C_2N_2 or C_2H_2 in the reactions

$$C_2N_2 \rightleftharpoons C_2 + N_2 \tag{2}$$

$$C_2H_2 \rightleftharpoons C_2 + H_2 \tag{3}$$

Although carbon vapor consists of atoms and various polyatomic molecules, the distribution of which depends upon the temperature, the simplifying assumption that all of the carbon appears as C_2 does not seriously affect a comparison of the decompositions (2) and (3). K_p was calculated as a function of temperature by standard methods from values of ΔH_{298}, ΔF_{298} and $C_p(T)$. The sources of these values are given as reference numbers in the following table.

	ΔH_{298}	ΔF_{298}	$C_p(T)$
C_2N_2	(5)	(5)	(7)
C_2H_2	(5)	(5)	(7)
C_2	(6)	(6)	(6)
N_2	-	-	(7)
H_2	-	-	(7)

The results of these computations are plotted in Fig. 2 and clearly illustrate the greater stability of C_2N_2.

Similar calculations were made for various pressures and the results were used to construct decomposition contours for $C_2N_2 - N_2$. Some of these are shown in Fig. 3. This set of curves illustrates

the effect on the volume of decomposed C_2N_2 of variations in N_2 pressure. For any fixed N_2 pressure, each curve represents the temperature at the surface of a volume within which at least the indicated percentage of C_2N_2 is decomposed. It is interesting to observe that all of the curves turn sharply at P_{N_2} 0.15 - 0.30 atm. At pressures below this range, small changes in N_2 pressure result in large shifts in the temperature zone within which any given fraction of C_2N_2 is decomposed. At pressures above this range, pressure variations cause very little change in this temperature zone. It is clear that large increases in P_{N_2} above about 1/3 atm. can only result in small decreases in the volume of decomposition products surrounding the filament. However, increased N_2 pressure will decrease the rate of diffusion of carbon from this volume to the wall although this will occur at the expense of increased heat losses by thermal conduction.

Emissivity Measurements

Dudley Marple[8] measured the emissivity of a slightly porous TaC disc, obtained from a Sylvania RF lamp, in various atmospheres and under several temperature conditions. Some representative results are plotted in Figs. 4, 5 and 6. The temperature of measurement is shown to the right of each curve. These curves, together with some qualitative observations, support the following general statements:

1. A mixture of 1.3 mm C_2N_2 and 30 cm N_2 gave the same emissivity for TaC as a mixture of 8 mm CH_4, 8 cm H_2 and 40 cm Ar at all temperatures up to 3100°C. (Figs. 4 and 6).

2. Heating in vacuum for an hour above 2200°C. or for < 1 min. above 2700°C. reduced the emissivity of the disc in the visible and increased it in the infrared.

3. Heating in Ar produced a similar qualitative effect as heating in vacuum but required higher temperatures and longer times. (Figs. 5 and 6).

4. After heating in vacuum for 1 min at 2700°C to modify the emissivity, then cooling to 2150°C and admitting 2 mm C_2N_2, the emissivity returned to that of TaC in C_2N_2 - N_2 or CH_4 - H_2 - Ar in < 1 min.

Filament Preparation

Ta filaments are usually carburized by heating them electrically for about 1 hr to about 2500°C in an atmosphere of 4-8 parts of H_2 to 1 part of CH_4 or 8-16 parts of H_2 to 1 part of C_2H_2 by volume.[2] The absolute amount of the hydrocarbon used is that which contains 1.5 times the amount of carbon necessary to completely form TaC from the available Ta. The reaction is considered complete when the hot resistance of the filament remains constant for about 15 min. Filaments thus prepared are bright yellow in color and resemble brass.

In this work, it was found to be more convenient to carburize filaments in pure benzene vapor. This produced satisfactory filaments and obviated the necessity of preparing gas mixtures.

A rough measurement of the tensile strength of a TaC filament prepared in benzene was made by suspending weights from the end of the filament. The measured value was 1.5 kg/mm^2. The reported value[2] is 2 kg/mm^2.

Burn-out Temperature Measurements

A number of 5 mil diameter, 1.5 cm long Ta filaments mounted in inverted U form between tungsten leads, 1.0 cm apart were carburized and used to measure burn-out temperature in various gaseous atmospheres and in vacuum. Two operators made these measurements. One observed the filament with a Pyro Micro Optical Pyrometer and the other operated a Variac to increase the voltage across the filament as rapidly as the first could follow the temperature change with the pyrometer. All filaments were heated to burn-out in $< \frac{1}{2}$ min. The last temperature reading by the pyrometer operator was necessarily somewhat lower than the actual temperature at burn-out but this error can reasonably be assumed to be about the same for all runs. The highest burn-out temperatures obtained for various fixed conditions are given in Table I. The temperature values are corrected for emissivity at 6650A,[8] the emissivity values in turn having been corrected for bulb transmission by visually comparing the bulbs, after burn-out, with neutral density filters. This latter correction was subsequently found to be in error in such a direction as to give too low true

temperatures. The 6650A transmission of the bulbs was lower than that estimated by comparison with neutral density filters particularly when filaments were burned out in C_2N_2 atmospheres since brown bulb coatings were compared with gray filters in these cases.

Table I

	Pressure, mm					Power at burn-out, watts	Highest temp. reading, °C
CH_4	H_2	C_2N_2	N_2	C_6H_6	Ar		
0	0	0	0	0	0	25	3250
2	20	0	0	0	0	250	3310
0	0	0	0	0.9	0	27	3345
0	0	0.9	0	0	0	27	3400
0	0	1	9	0	0	36	3460
0	0	1	28	0	0	42	3550
0	0	1	99	0	0	54	3600
0	0	1	200	0	0	55	3650
0	0	1	299	0	0	68	3690
0	0	1	397	0	0	60	3610
0	0	1	301	0	0	82 (D.C.)	3590*
0	0	1	300	0	300	61	3570

*Result of only one run in which filament was heated with D.C.

The values in the table may be compared with the melting points of Ta_2C ($3400^{\circ}C$) and TaC ($3880^{\circ}C$). It is noteworthy that filaments burned out in vacuum or in hydrocarbon atmospheres became silvery-gray in color over their entire lengths while those burned out in C_2N_2 atmospheres retained the brassy color characteristic of TaC except for about 0.5 mm lengths at the burned out ends which were silvery-gray. It is interesting to note that the results on C_2N_2 - N_2

mixtures listed in Table I confirm the prediction, based on thermo-dynamic calculations, that N_2 pressures above about 1/3 atm have very little additional effect on the volume of carbon vapor around the filament and therefore on the burn-out temperature.

The result obtained with C_2N_2 - N_2 - Ar will be considered along with other experimental observations and discussed later in this report.

X-Ray Diffraction Analysis

Several TaC filaments, both freshly prepared and burned out in various atmospheres were analyzed by x-ray diffraction with a G.E. XRD-4 X-ray Diffraction Apparatus operated at 40 kv and 20 ma. An eight hour exposure was made in all cases.

The diffraction pattern of freshly prepared TaC agreed with that recorded in the literature.[9] No lines other than those recorded for TaC appeared. The lines that did appear were continuous.

Filaments burned out in CH_4 - H_2 or in vacuum gave diffraction patterns characteristic of a mixture of α- and β- Ta_2C.[10] No lines other than those recorded for Ta_2C appeared. The lines were dis-continuous indicating an orientation of the crystals along the axis of the filament.

Filaments burned out in C_2N_2 - N_2 gave discontinuous diffraction patterns which were otherwise identical with those obtained with freshly prepared TaC. There was no evidence of any Ta_2C, Ta_2N, Ta or C formation even when the burned out ends were included in the exposure. This indicates that the silver-gray color of the burned out ends is probably due to a surface decomposition only.

Ta filaments carburized in C_2N_2 - N_2 also gave a TaC pattern consisting of discontinuous lines.

X-ray diffraction patterns of several filaments which had been life tested in various atmospheres were photographed. TaC life tested in CH_4 - H_2 had been entirely converted to Ta_2C. Life tests in C_2N_2 - N_2 occasionally resulted in premature failure due to a structural defect in the filament. Such filaments gave TaC patterns after failure. In most cases, however, the filaments life tested

in C_2N_2 - N_2 sagged just prior to burn-out and were silver-gray
after the life test was over. These had diffraction patterns
characteristic of Ta_2C. The diffraction pattern of Ta_2C is almost
indistinguishable from that of Ta_2N. [11] However, the lines in the
patterns of the life tested filaments all matched the pattern of
Ta_2C whereas all but one line matched the pattern of Ta_2N.

Life Tests

A limited number of life tests were made with coiled TaC fila-
ments at $3400^\circ K$ true temperature in various atmospheres. The fila-
ments were prepared from 5 mil diameter Ta wire, 6 cm long, 30 mil
coil diameter, 15 mils between turns mounted between leads which
were 1 cm apart. The entire filament mount was sealed into a
spherical Pyrex bulb of about 280 cc volume. Similar W filament
lamps were life tested for comparison purposes. Table II lists the
results obtained. Only the longest life obtained for any given set
of conditions is included in the table.

It is clear from the results in the table that there is a
maximum in life at a pressure of C_2N_2 of about 1 mm. The reason for
the decrease in life at C_2N_2 pressures above 1 mm may be that the
increased carbon vapor density around the filament leads to a solid
solution or a eutectic mixture of C in TaC which has a lower melting
point than TaC itself. A eutectic of C in TaC is known to exist. [12]
It has been suggested by D. W. Magee of the Lamp Development Depart-
ment, Nela Park, that the optimum C_2N_2 pressure may be temperature
dependent.

TaC filaments in optimum C_2N_2 - N_2 mixtures have lives at $3400^\circ K$
comparable to W filaments in N_2. However, at this temperature, the
luminous efficiency of TaC is about 10% greater than that of W. In
addition, both W in N_2 and TaC in C_2N_2 - N_2 are considerably better
than TaC in CH_4 - H_2. For the CH_4 - H_2 mixture, the use of at least
8 mm of CH_4 with 4 to 8 times the pressure of H_2 was found to give
the most satisfactory results. [2,8]

The most striking effects are the results of Ar addition to
CH_4 - H_2 and C_2N_2 - N_2. In the former case, a very sharp increase
in life is observed whereas in the latter case, filaments decarburize
and burn out before the operating temperature of $3400^\circ K$ can be

Table II
Life Tests at 3400°K

TaC filaments

C$_2$N$_2$	N$_2$	CH$_4$	H$_2$	Ar	Initial Voltage, volts	Initial Current, amps	Life, min
0	541				26.7	3.35	103
1.0	540				26.0	3.65	161
1.1	540				25.8	3.62	133
1.9	510				27.9	3.53	65
3.2	540				25.2	3.80	56
4.7	540				26.3	4.10	33
1.0	300			250	~33 } final	4.65 } final	0 } Burned
1.1	290			290	~32 }	4.70 }	0 } out at ~3250°K
		10	40		45.0	7.30	40
		10	40	490	30.0	5.00	230
		20	80	440	27.5	4.95	121

The "Pressure, mm" heading spans the C$_2$N$_2$, N$_2$, CH$_4$, H$_2$, Ar columns.

W filaments

C$_2$N$_2$	N$_2$	CH$_4$	H$_2$	Ar	Initial Voltage, volts	Initial Current, amps	Life, min
	500				18.5	3.60	108
	550				19.0	3.85	120
	600				18.2	3.75	150

attained. In fact, burn-out occurs at about the same temperature
at which a TaC filament burns out in vacuum. There was no evidence
of any electrical breakdown in the gas. In addition, while the
usual burn-out or life test in C_2N_2 is accompanied by deposition of
a brown coating on the bulb wall (discussed at greater length later
in this paper) which is soluble in concentrated H_2SO_4, burn-out in
C_2N_2 - N_2 - Ar resulted in considerable blackening of the bulb.
The black material was insoluble in concentrated H_2SO_4 and was presumed
to be carbon. A further indication of this effect is evident in
Table I where the addition of Ar results in 120° reduction in the
burn-out temperature. All of the results seem to indicate that the
use of approximately equimolar Ar-N_2 mixtures in some manner prevents
the C_2N_2 from reaching the filament. Furthermore, this must be a
function of the mixture ratio since Ar - N_2 mixtures in 85:15 ratio
have been used successfully in TaC lamps[2] and pure Ar is evidently
used in the Sylvania RF lamp.

Paracyanogen Formation-Chemical Analysis

When C_2N_2 is heated to about 300°C, a dark, brown, solid polymer,
$(CN)_x$, forms which decomposes to C_2N_2 again at about 850°C. [13] The
properties and structure of this polymer, known as paracyanogen, have
been reported by Bircumshaw et al.[14] The most likely structure appears
to be a ribbon polymer of the form
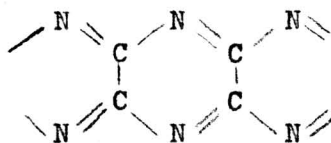
although properties of the polymer differ slightly depending upon
the mode of preparation. This could result from modifications of the
structure or differences in chain length.

Brown deposits were almost always observed on bulb walls when
TaC filaments were burned out or life tested in C_2N_2 - containing
atmospheres. This is in contrast to black deposits which were formed
when TaC filaments were burned out or life tested in vacuum or in
hydrocarbon-containing mixtures. In agreement with the reported

properties of paracyanogen,[14] the brown deposits were insoluble in water and soluble in conc. H_2SO_4 with which they formed red-brown solutions leaving a very small amount of black solid residue. The solid could be re-precipitated by addition of water to the H_2SO_4 solution. Black deposits, on the other hand, were always insoluble in conc. H_2SO_4. The H_2SO_4 solutions of the brown deposits exhibited a yellow fluorescence upon 3650A excitation. Although a sky-blue fluorescence has been reported[14] for H_2SO_4 solutions of $(CN)_x$, there are apparently some differences which depend upon the mode of pre-paration. Similar observations were made on bulb coatings supplied to the Analytical Chemistry Unit.[15] In addition, they made analyses of the gases remaining in TaC filament lamps which had been operated in C_2N_2 - N_2 and found that the C_2N_2 had been severely depleted. Small amounts of HCN and C_4N_2 (dicyanoacetylene) were detected. In another test,[16] fragments of glass coated with the brown material were sealed in a quartz tube, attached to a mass spectrometer and heated stepwise from 200-900°C, while concurrently analyzing the gases evolved. Below $\sim$ 800°C, H_2O, CO_2 and CO were most abundant. Above $\sim$800°C, HCN was the most abundant gas evolved and traces of C_2N_2 were detected. It appears that C_2N_2 formed by decomposition of $(CN)_x$ reacts with H_2O desorbed from the glass to form HCN.

It has been found that C_2N_2 polymerizes by addition of CN free radicals to C_2N_2.[17] As a consequence of the large temperature gradients in the lamps described in this work, it is clear that there must be a 300-850°C temperature zone in which the formation of $(CN)_x$ is favored. Migration to cooler zones would ultimately result in the deposition of $(CN)_x$ on the wall. Furthermore, the 300-850°C zone is closer to the wall and has a larger surface area for diffusion than does the zone in which C_2N_2 is decomposed to carbon and nitrogen. The rate of deposition of $(CN)_x$ therefore would be expected to be much greater than the rate of deposition of carbon. It is also of interest that a pressure decrease equivalent to the loss of 11% of the C_2N_2 was observed when a TaC filament was operated at 3400°K for 52 min in 4.6 mm C_2N_2 + 497 mm N_2. Decomposition of C_2N_2 should result in no pressure change but polymerization of C_2N_2 is expected to result in a pressure decrease. The accumulated results indicate that the brown wall coatings are chiefly $(CN)_x$ and possibly contain small amounts of carbon.

It is clear, from the results listed in Table II, that the life of a TaC filament lamp is critically dependent upon the density of carbon near the filament or the density of C_2N_2 in the lamp. Obviously, as C_2N_2 is lost by deposition as $(CN)_x$, the density of carbon near the filament falls below the optimum value and the filament decarburizes and burns out more rapidly than it would if C_2N_2 density could be maintained. Therefore, in order to realize fully the advantages of C_2N_2 in TaC filament lamps some method must be found to minimize its depletion by polymerization. This may be accomplished by designing a flow system so that fresh C_2N_2 enters the lamp at a rate sufficient to replace that which is lost by polymerization. A more practical procedure would involve the use of a quartz bulb with the bulb wall at a temperature > 850°C to prevent $(CN)_x$ from depositing there. Finally, since $(CN)_x$ is formed by addition of CN radicals to C_2N_2,[17] polymerization may be minimized by the use of cyanogen derivatives in which one end of the molecule is blocked.

Cyanogen Halides

The cyanogen halides are convenient compounds with which to test the validity of the above suggestion. In particular, cyanogen bromide, BrCN, is a readily available solid having a melting point of 52°C and a room temperature vapor pressure of about 100 mm. It may be expected that the decomposition of BrCN to Br and CN will ultimately result in the formation of $(CN)_x$. However, this process will be accompanied, to an extent dependent upon relative rates of recombination, by the re-formation of BrCN. Thus, the over-all rate of $(CN)_x$ formation will be less than it would be in C_2N_2 alone.

A single life test was made of a TaC filament lamp at 3400°K in an atmosphere of 2 mm BrCN and 540 mm N_2. It should be noted that the pressure of BrCN was twice the experimentally determined optimum pressure for C_2N_2. This BrCN pressure was selected in order to keep the carbon vapor density around the filament the same as it was when the optimum C_2N_2 pressure was used. The initial current and voltage of the lamp described were 3.55 amps and 23.0 volts. Lamp life was 218 min. This may be compared with the values in Table II. Of additional interest was the formation of a transparent, light brown film on the bulb wall. This was apparently a form of

$(CN)_x$ in that it dissolved in conc. H_2SO_4 to give a brown solution which fluoresced light blue under 3650A excitation and the solid could be re-precipitated by addition of H_2O to the solution. The amount of polymer formed was much smaller than that produced in C_2N_2 atmospheres. Furthermore, the current and filament temperature of this lamp remained more nearly constant throughout life than had been observed for any of the C_2N_2 of CH_4 containing lamps.

Two other life tests were made with TaC filaments in 2 mm BrCN + 600 mm N_2. The first lamp was run about 100° above the melting point of W several times for a total of about 10 min running time. The lamp was then operated at 3475^oK, 24 volts, 3.7 amps and had a life of 75 min. The filament was still golden in color after burn-out. The bulb wall was only slightly discolored. The second lamp was operated at about 3000^oK, 16 volts, 3.1 amps and had a life of 58 hrs. The filament was still golden and had not sagged during life but appeared to have fractured at a point about 1/3 the distance between leads. There was a small amount of transparent brown coating on the bulb wall. The closest comparison available with a W filament lamp is with the 100 watt, T-8 projection lamp.[18] The comparison is shown below.

	TaC filament, 2 mm BrCN+600 mm N_2	W filament, T-8 projection lamp
Volts	16	115
Amps	3.1	0.87
Filament temp, ^oK	2990	2970
Life, hrs.	58	50 (average)
Lumens/watt neglecting conductive and convective losses	33	27

On the basis of the preliminary work reported above, BrCN appears to have certain advantages over C_2N_2. Of course, a mixture of C_2N_2 and Br_2 would be expected to yield an equilibrium mixture of BrCN, C_2N_2 and Br_2 after being heated for some time so that such a mixture may be as effective as BrCN itself.

General Conclusions and Recommendations for Future Work

The results indicate that the use of C_2N_2 - N_2 or BrCN - N_2 for stabilization of hot TaC filaments is more satisfactory than the use of hydrocarbon-hydrogen mixtures for the following reasons:

1. Smaller conductive heat losses.
2. Less bulb wall discoloration.
3. Maintenance of TaC emissivity for longer periods of time.
4. Longer life.
5. Capability of higher temperature operation.

Only 1 and 2 apply with certainty when comparison is made with CH_4 - H_2 - Ar mixtures. However, the anomalous effect observed when Ar replaced about 1/2 of the N_2 in C_2N_2 - N_2 mixtures should be studied in greater detail. When this effect is understood there is the possibility of further improvement of operation, perhaps by use of a C_2N_2 - N_2 - Ar mixture of some other composition ratio. In addition, the use of Ar with BrCN - N_2 should be investigated. In general, extensive life testing programs are required to obtain more reliable comparisons among the various gas mixtures.

Some of the results reported here have been confirmed by F. Pikus of the Large Lamp Department, Nela Park.[19] On the basis of the work at the Research Laboratory, application has been made for a patent covering the use of nitrogen mixtures of C_2N_2, cyanogen halides and cyanogen + halogens for the stabilization of hot TaC filaments.

The problem of the brittleness of TaC still remains and is probably the major restriction to the general use of TaC for incandescent lighting purposes. The author knows of no effort by metallurgists to solve this problem. It is felt that the high luminous efficiency and high melting point of TaC justify a continuing program of study with particular emphasis on the metallurgical aspects.

Acknowledgments

The author is pleased to acknowledge the contribution of Raymond E. Grande who did most of the experimental work reported here.

Many enlightening discussions with Dr. D.T.F. Marple during the course of this work were invaluable to the interpretation of the results.

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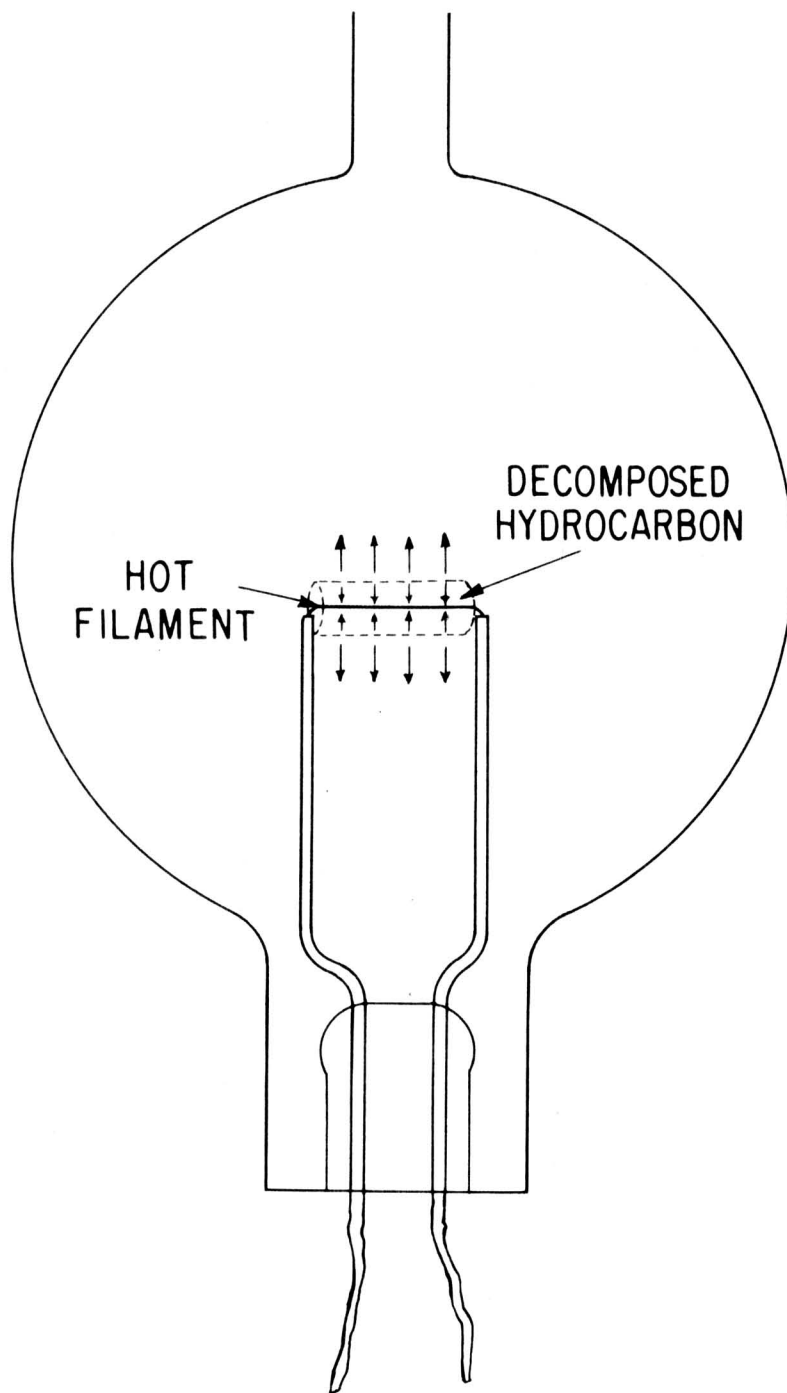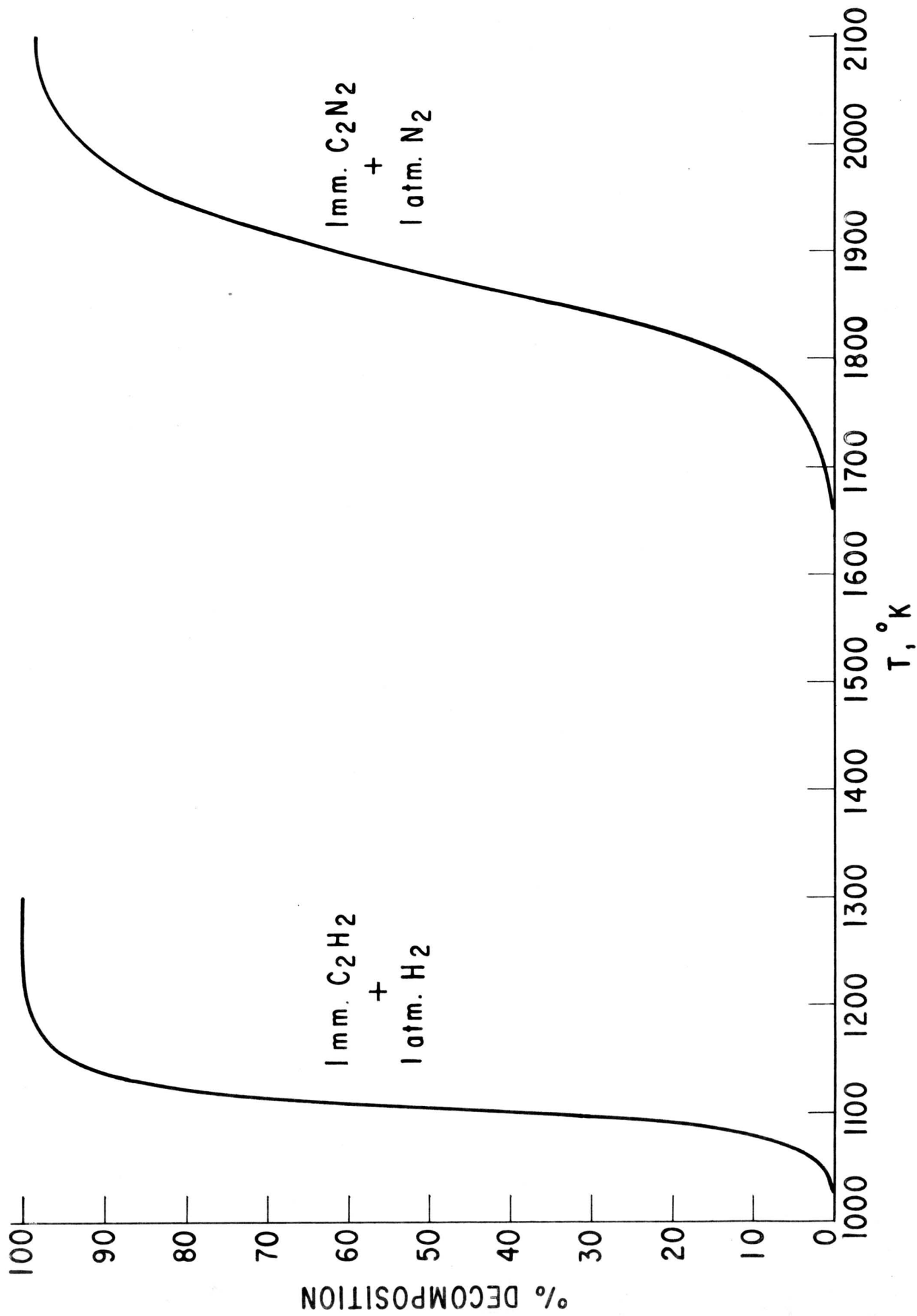   436-50, Jan. 8, 1959.

FIGURE 1

DECOMPOSED
HYDROCARBON

HOT
FILAMENT

FIGURE 2

FIG. 3. DECOMPOSITION CONTOURS FOR C_2N_2

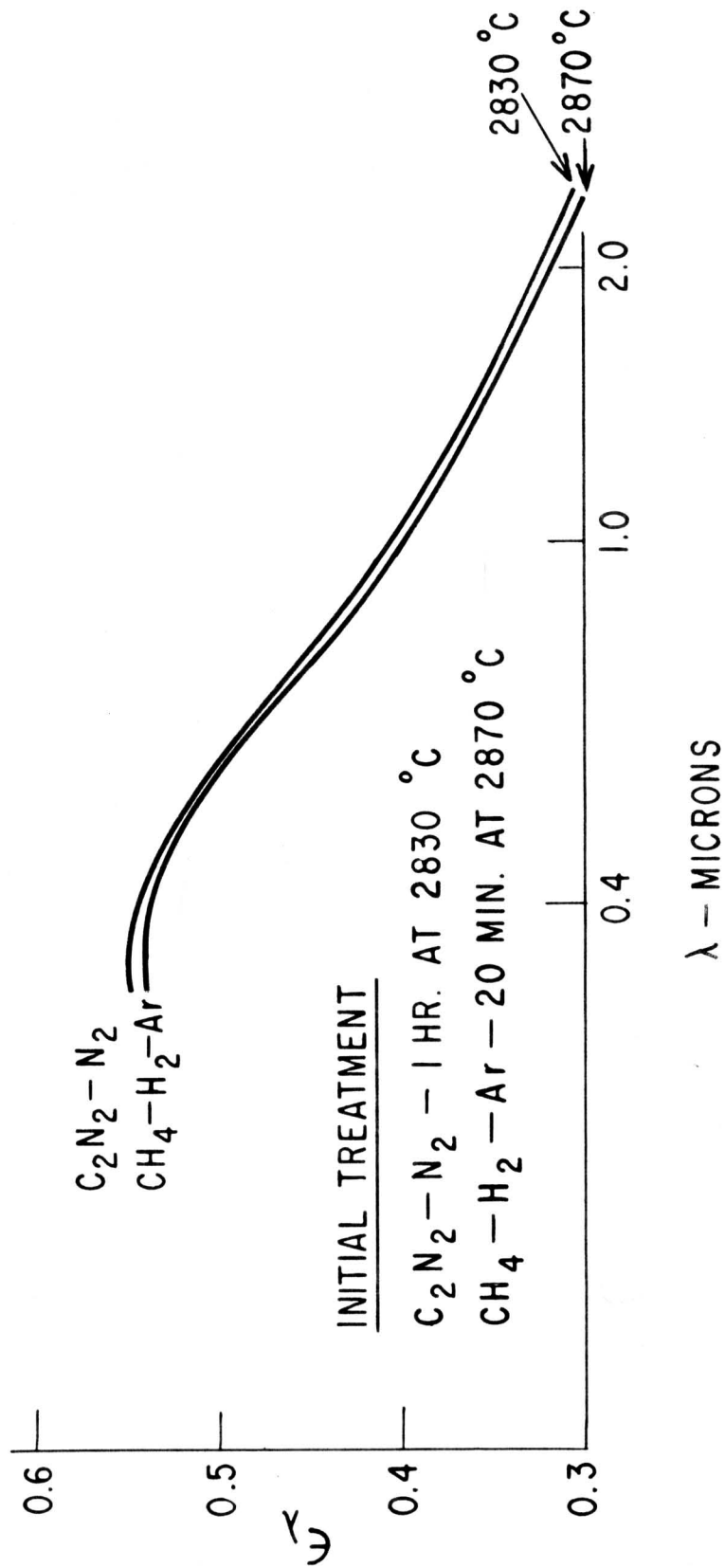$(P_{C_2N_2} = 1 \text{ mm})$
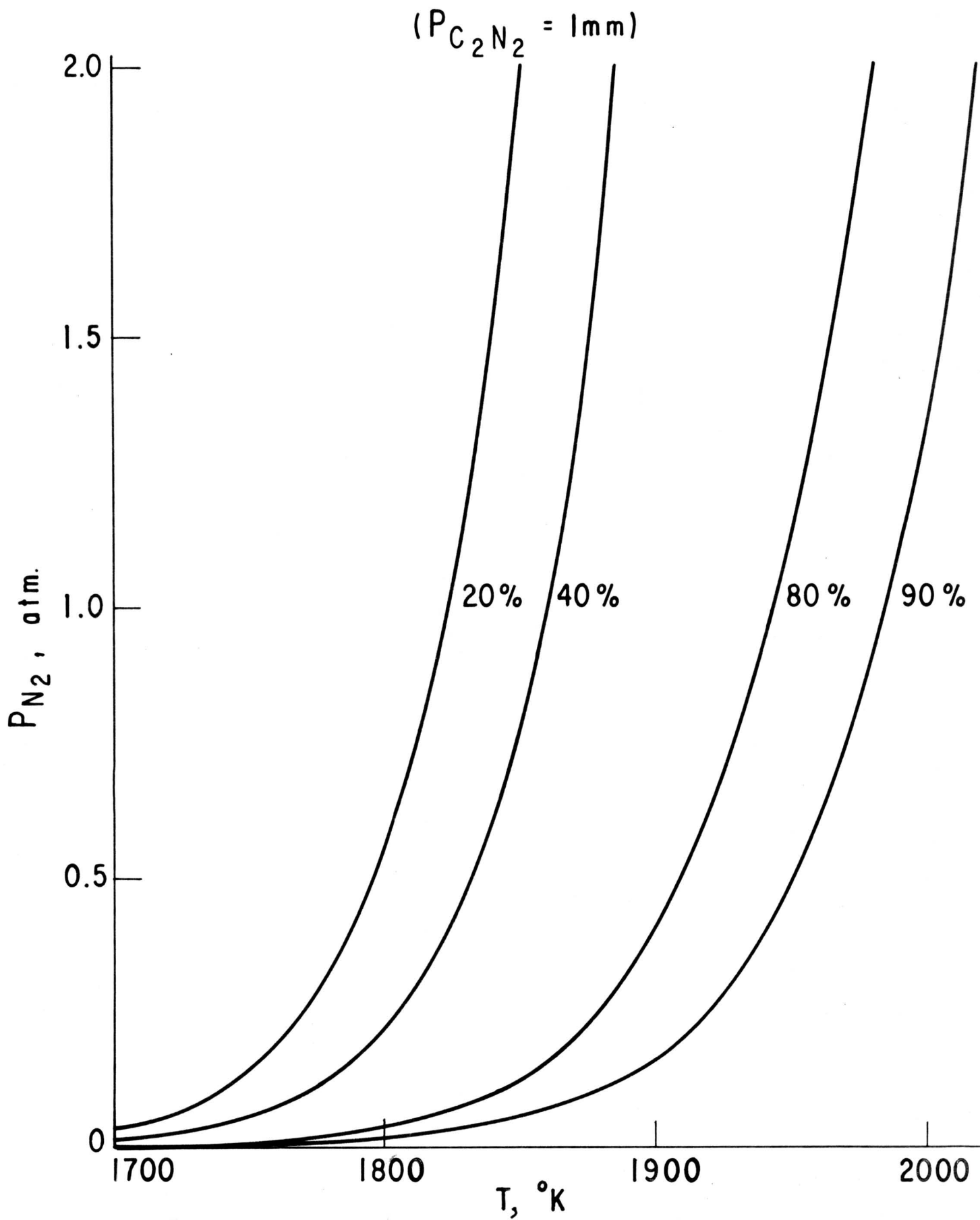
FIGURE 4

FIGURE 5

FIGURE 6

INITIAL TREATMENT

$C_2N_2-N_2$ — 5 MIN. AT 2850 °C
CH_4-H_2-Ar — 5 MIN. AT 2860 °C
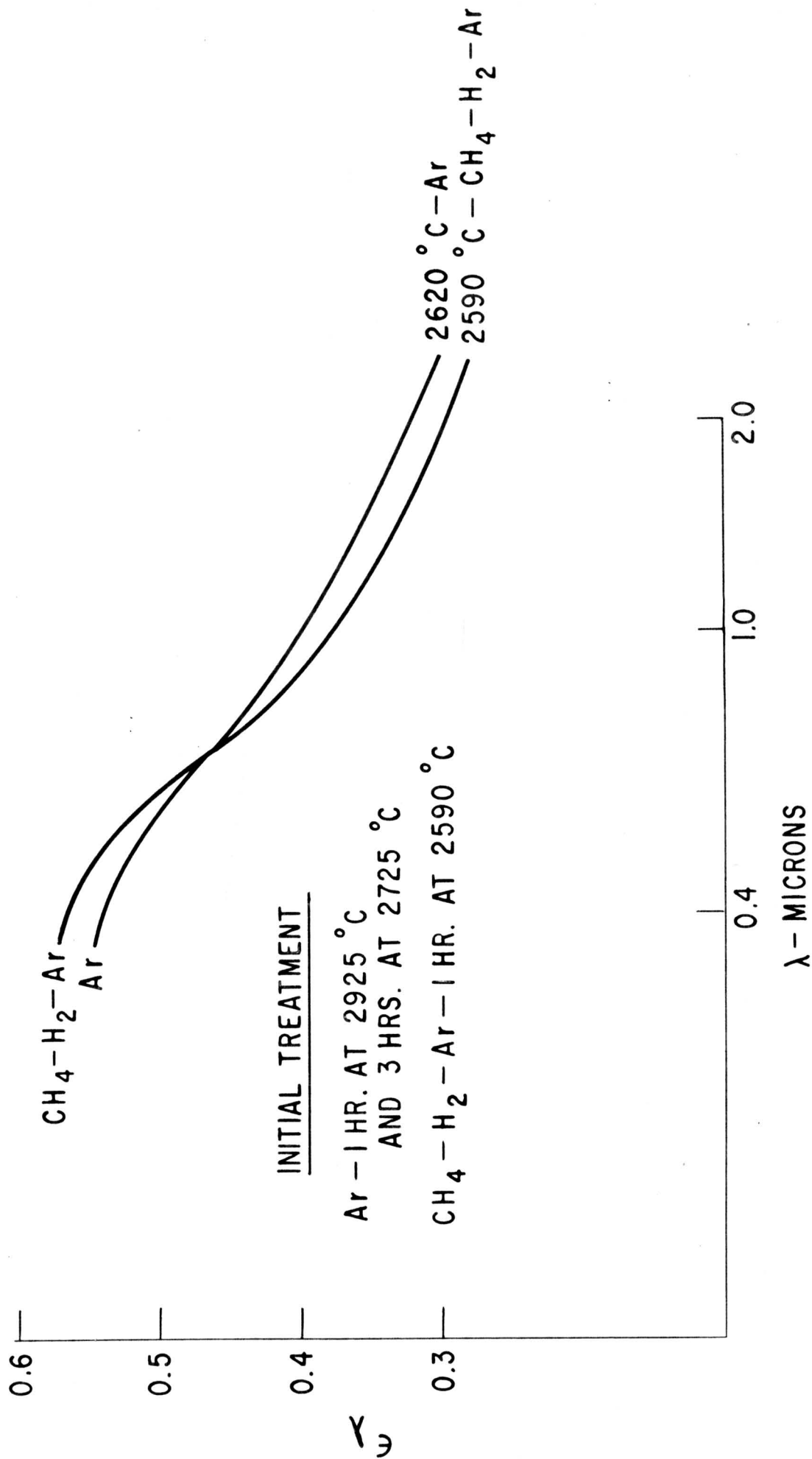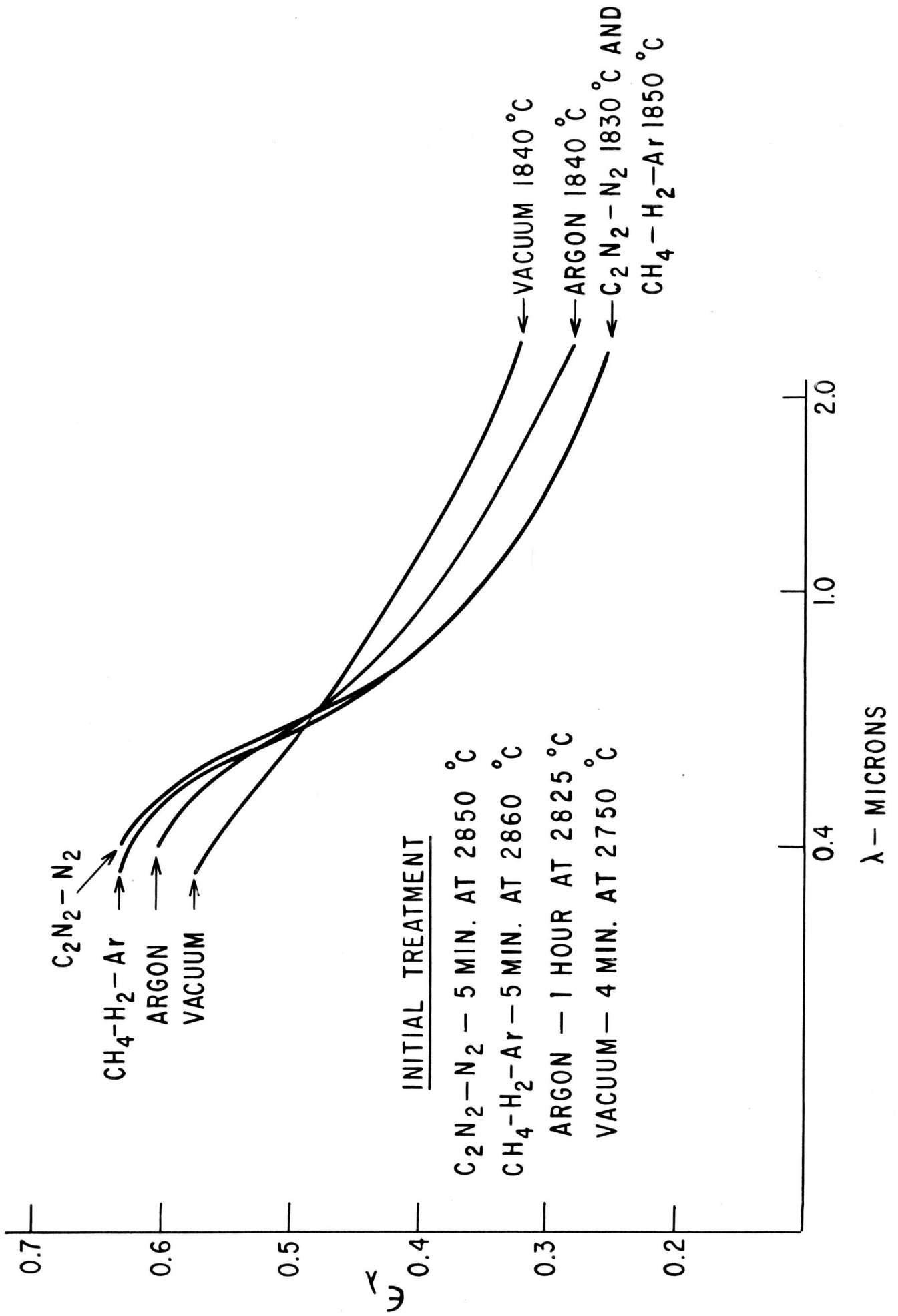ARGON — 1 HOUR AT 2825 °C
VACUUM — 4 MIN. AT 2750 °C

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