THE SPECTRUM OF A HIGH FREQUENCY

GAS SOURCE AT LOW PRESSURE

THESIS

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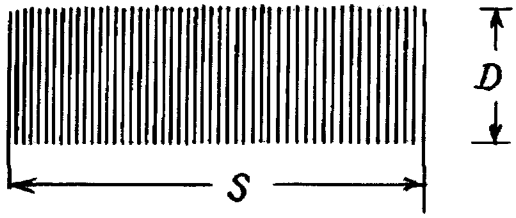
The high frequency radio oscillator had first to be built. This consisted of a Hartley circuit using an "R.C.A." U.X. 852 "short wave" tube which has a plate dissipation of 75 watts. The oscillator worked well with a grid leak resistance of 48,000 ohms and a grid leak condenser of 0.25 $\mu\mu$.f.

The filament was lit by an 11 volt 50 ~ circuit with a rheostat to control its current to 3.25 amperes. The plate voltage was 2000 volts 50 ~ with a rheostat in the 110 volt primary side of the transformer to limit the plate voltage to 2000 volts and the plate current to about 120 milliamps when the set was oscillating.

Dr.P.S.Epstein drew my attention to the following standardization of radio-frequency chokes through Mr.A.P.Alford. The five radio-frequency chokes that were used were standardised to the required choking wave length from the following table taken from a graph in the paper by Lenz in the *Ann. der Physik*: Vol.43, 1914, p.749 on the choking wave length of close wound cylindrical coils. The dielectric may affect these wave lengths somewhat but these coils should all choke more or less together which is an important point in preventing dissipation of the high frequency energy.



S = length of cylindrical coil.

D = diameter of cylindrical coil.

L = length of wire wound on coil.

λ = wave length of fundamental choked

$\frac{S}{D}$	$\frac{\lambda}{L}$	$\frac{S}{D}$	$\frac{\lambda}{L}$
0.50	2.9_5	3.0	1.6
0.67	2.6_5	4.5	1.4
1.0	2.3_5	6.0	1.2
1.5	2.0	8.0	1.0
2.0	1.8_5		

The radio frequency choke coils for the plate and grid leads were wound of No. 34 S.W.G. silk covered wire but for the filament leads No. 22 S.W.G wire was used because these coils had to carry a current of 3.5 amps. By varying the positions of the plate, filament and grid leads on the inductance coil and the setting of the 35 $\mu\mu f$. condenser it was possible to obtain a maximum energy supply to the discharge tube because these adjustments changed the wave length to that of the radio frequency chokes.

Precautions had to be taken to prevent body contact with the 2000 volt circuit and also to first open the plate current circuit-- in the primary of its transformer-- before opening the filament switch so as to protect the tube from the inductive current surge from the transformer.

The discharge tube source of light consisted of a soft glass tube 2.5 cms. diameter and 87 cms. long and this was connected through a mercury trap to a Langmuir two stage mercury pump and fore pump. The glass cut off light of wave lengths less than 3100 Å.

The high frequency field from the oscillator was applied at two sheets of thin copper foil wound round the discharge tube and separated by about 5 cms. at their inner edges. This alternating field causes the electrons and ions to oscillate synchronously back and forth in the tube and the consequent collisions with molecules cause the giving out of light. A Ford car ignition coil could be connected to terminals at the ends of this tube.

When the set was oscillating, motion of the hand near the coil altered the plate current, and a screw-driver held by its insulated handle drew sparks at its tip from either the plate or the grid lead. When a Neon tube, or the wave meter, was brought near the coil it was brilliantly lit. All leads of the high frequency oscillating circuits had to be kept as short as possible and as far away as practicable from each other. A slight instability in the light was sometimes noticed but this was probably due to the use of alternating current for the filament and the plate, because if the Ford coil was started while the oscillator was on it stopped the light and this did not appear again until some seconds after the Ford coil had been open circuited.

The high frequency alternating field gives light at gas pressure of, say, 10^{-3} to 10^{-4} m.m., and these are lower than 10^{-2} to 10^{-3} m.m. at which pressure a Ford car ignition coil ceases to give a discharge, because the moving electrons and ions can be reversed in motion by the higher frequency, even at this lower pressure where their mean free path is longer, before they reach the ends of the tube.

After the tube has been run for some time with mercury vapor it is necessary to run a Ford coil discharge for about an hour with liquid air on the trap to remove the mercury from the terminal plates and tube. Then to completely suppress the spectral lines of mercury the bottom of the trap must be immersed in the liquid air and not merely put in the vapor of the liquid air.

From experiments carried out by Mr.A.P.Alford it appears that a more intense light source might be obtained by using a much narrower glass tube, say, only 1 cm. in diameter or less and by inductively coupling the light circuit to the inductance of the oscillating circuit so as to increase the voltage across the light tube "terminals".

Prof.R.W.Wood of Johns Hopkins University refers to the taking of spectra caused by light from a high frequency electrodeless discharge in a gas tube at a low pressure.

See Wood and Loomis:

	Nature:	Vol. 120, Oct.8, 1927, p.510

See also:

Kirchner:	Ann. der Physik:	Vol. 77, Aug. 1925, p.287.
J.R.Clarke:	Nature:	Vol. 120, Nov.19,1927, p.727
Gill and Donaldson:	Phil.Mag.:	Vol. 2, July 1926, p.129

The following papers describe the High Frequency Low Pressure Lamp:

Foulke:	J.A.I.E.E.:	Vol. 46, Feb. 1927, p.139
J.and W.Taylor:	Nature:	Vol. 121, Feb. 4,1928, p.171

These papers deal with the problem more or less indirectly:

Wood:	Phil.Mag.	Vol. 42, Aug. 1921, p.729
Wood and Voss:	Nature:	Vol.121, Mar.17,1928, p.48
Ponte:	Nature:	Vol.121,Feb. 18,1928, p.243
J.R.Clarke:	Nature:	Vol.121, Feb.25,1928, p.282
S.P.McCallum:	Nature:	Vol.121, Mar.10,1928, p.353
Sinclair Smith:	Nature:	Vol.121, Jan. 2,1928,p. 91
Emelius& Carmichael:	Nature:	Vol.121, Jan. 7,1928, p. 14

Two spectrographs were used, one having a glass prism for preliminary surveys and the second one having a quartz prism which gives greater dispersion and resolution for the more detailed survey. Each of these was calibrated by identifying the known spectrum of mercury.

The usual double "V" slide was used across the slits for the comparison of spectra and by making the edges of these spectra slightly overlap a more sensitive method was available to detect whether any faint line occurs in only one of two spectra being compared because any overlapping will show up as an increased intensity, but if there is a space between the edges of spectra it is easier to identify lines when putting one plate on the other. It would be best to make one edge of the central spectrum overlap and the other edge to clear the inner edges of the two outer "half spectra."

The results obtained from the mercury spectrum showed that at low pressures the intensity of singlets is relatively stronger than for higher pressures.

An appendix will be filed to this report in three weeks giving the spectra of mercury at (1) high frequency at a pressure in the range 10^{-2} to 10^{-3} m.m.

and (2) Ford coil discharge at a pressure in range 10^{-2} to 10^{-3} m.m.

A large number of plates were exposed but only the best and most representative data are tabulated.

The writer is indebted to Dr.R.A.Millikan for his interest and for suggesting this problem and also to Dr.S.S.Mackeown for continued assistance in the building of the oscillator. Dr.R.D.Bennett and Mr.A.P.Alford also helped with the oscillator. Dr.I.S.Bowen calibrated the spectrographs and identified many of the spectral lines.

Line Spectrum of Mercury

Excited by a 7.0 Meters High Frequency Oscillator at a Pressure in the Range 10^{-3} to 10^{-4} m.m.

Wave Length Å		Intensities #11	#14	#15	Glass prism #10	Series Designation
6930		½	½	–	½	
6716		2	2	1	½	$7^1S - 8^1P$
6234		3	3	2	2	$7^1S - 9^1P$
6123		3	3	2	3	
6073		2	2	2	2	
* 5791		12	12	12	5	$6^1P - 6^1D$
5770		12	12	12	5	$6^1P - 6^3D$
5679		3	2	2	1	
5461	broad	15	20	20	7	$6^3P_2 - 7^3S$
5393	"	–	–	–	1	
5366	"	–	–	–	1	
4922		–	–	–	6	
4916		12	12	15	–	$6^1P - 8^1S$
4867		–	–	–	½	
4797		½	1	½	½	
* 4358		12	17	15	8	$6^3P_1 - 7^3S$
4348		12	12	10	5	$6^1P - 7^1D$
4339		4	6	4	3	
4108		5	8	10	–	$6^1P - 9^1S$
* 4078		12	20	12	5	$6^3P_1 - 7^1S$
4047	broad	15	30	20	6	$6^3P_0 - 7^3S$

Line Spectrum of Mercury

Excited by a 7.0 Meters High Frequency Oscillator at a Pressure in the Range 10^{-3} to 10^{-4} m.m.

Wave Length Å	Intensities			Glass prism	Series Designation
3984	-	-	-	7	
3906	9	14	12	-	$6^1P - 8^1D$
3860	-	-	-	3	
3802	3	$\frac{1}{2}$	4		$6^1P - 10^1S$
3735	-	-	-	6	
* 3704	5	4	5	Glass prism	$6^1P - 9^1D$
3663	12	6	15	cuts off	$6^3P_2 - 6^3D_1$
3655	12	6	15	further	$6^3P_2 - 6^3D_2$
3650 fuzzy	15	12	25	lines.	$6^3P_2 - 6^3D_3$
3593	1	1	2		$6^1P - 10^1D$
* 3341	5	12	8		$6^3P_2 - 8^3S$
3132	3	4	6		$6^3P_1 - 6^3D_1$
3126	1	1	5		$6^3P_1 - 6^3D_2$

* Nitrogen bands have approximately the same wave lengths as these.

Band Spectrum of Nitrogen

Excited at a Pressure in the Range 10^{-2} to 10^{-3} m.m.

Wave Length	Character of Line		Intensities	
			Ford Coil	H.F.7 Meters
Å			#12	#12
6752	wide	fuzzy	½	½
6682	"	"	½	½
6604	"	"	4	½
6524	"	"	3	½
6448	"	"	2	½
6375	"	"	1	½
6048	"	"	1	-
5994	"	"	1	-
5943	"	"	1	-
5891	"	"	½	-
5839	"	"	½	-
5737	"	"	½	-
4814	band		½	-
4723	"		½	-
4675	"		½	½
4574	"		3	1
* 4489	"		3	1
4416	"		2	1
4276	"		4	3
4207	"		4	3
4142	"		3	1
4079	"		1	½

Band Spectrum of Nitrogen

Excited at a Pressure in the Range 10^{-2} to 10^{-3}m.m.

Wave Length	Character of Line	Intensities	
		Ford Coil	H.F.7 Meters
Å		#12	#12
4064	band	6	4
3995	"	8	4
3940	"	4	3
3919	"	3	2
3894	"	1	$\frac{1}{2}$
3790	"	15	12
3771	"	15	12
* 3704	"	8	5
3671	"	5	3
3642	"	—	$\frac{1}{2}$
3641	"	$\frac{1}{2}$	$\frac{1}{2}$
3577	"	20	20
3536	"	15	12
3500	"	8	4
3371	"	20	15
3339	"	2	$\frac{1}{2}$
3309	"	1	$\frac{1}{2}$
3285	"	2	$\frac{1}{2}$
3268	"	$\frac{1}{2}$	$\frac{1}{2}$
3159	"	6	2
3136	"	1	$\frac{1}{2}$

* Mercury lines have approximately the same wave lengths as these.

Band Spectrum of Nitrogen

Excited by a 7.0 Meters High Frequency Oscillator at a Pressure in the Range 10^{-3} to 10^{-4} m.m.

Wave Length	Character of Line		Intensities Glass Prism	
Å			#13	#10
6850	wide	fuzzy	½	-
6752	"	"	2	3
6682	"	"	4	6
6604	"	"	6	7
6524	"	"	8	7
6448	"	"	6	7
6375	"	"	6	7
6306	"	"	5	6
* 6233	"	"	4	4
6171	"	"	2	3
6108	"	"	-	3
6048	"	"	4	6
5994	"	"	4	6
5943	"	"	4	6
5891	"	"	4	6
5839	"	"	4	6
5790	"	"	10	6
5737	"	"	4	5
5393	band		-	½
5366	"		-	½
4814	"		4	2
4723	"		4	3
4666	"		5	3

Band Spectrum of Nitrogen

Excited by a 7.0 Meters High Frequency Oscillator

at a Pressure in the Range 10^{-3} to 10^{-4} m.m.

Wave Length Å	Character of Line	Intensities #13	Intensities Glass Prism #10
4648	band	-	4
4634	"	6	-
4574	"	8	4
4489	"	8	5
4416	"	6	$\frac{1}{2}$
* 4356	"	20	4
* 4344	"	12	4
* 4267	"	12	5
4142	"	12	$\frac{1}{2}$
* 4057	"	12	4
3995	"	-	7
3940	"	20	7
* 3919	"	12	-
3894	"	6	4
3857	"	-	3
3805	"	-	4
3771	"	-	20
3755	"	-	2
3671	"	12	Further lines
3589	"	4	cut off
3577	"	12	by the
3500	"	8	Glass
3468	"	1	Prism

Band Spectrum of Nitrogen

Excited by a 7.0 Meters High Frequency Oscillator at a Pressure in the Range 10^{-3} to 10^{-4} m.m.

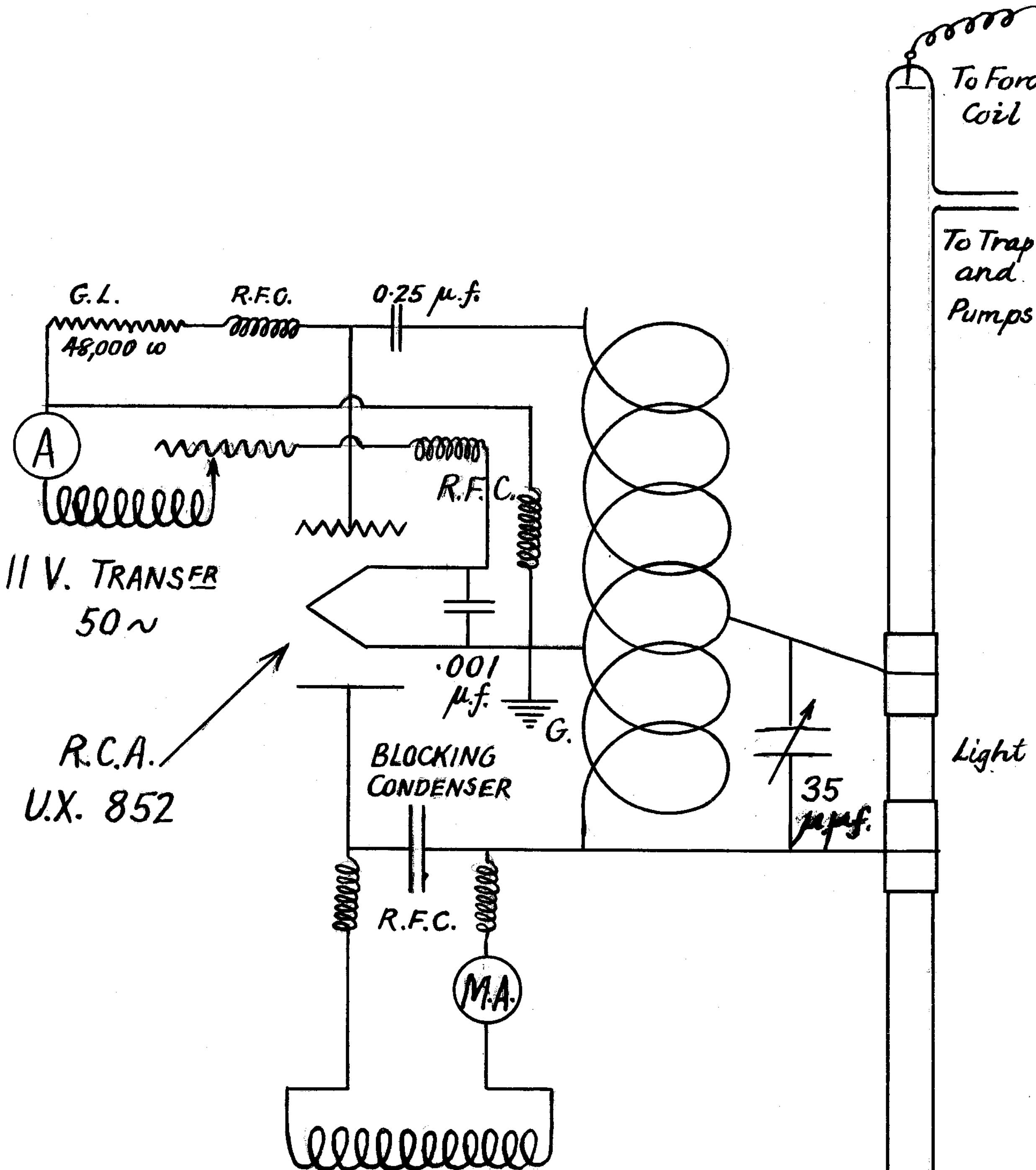
Wave Length	Character of Line	Intensities	Glass Prism
Å		#13	#10
3371	band	20	Further
3339	"	6	lines
3309	"	6	out off
3285	"	6	by the
3268	"	6	Glass Prism

There were eight faint unidentified broad bands of wave lengths from 3243 to 3175 Å.

3168	band	$\frac{1}{2}$
3159	"	8
3117	"	$\frac{1}{2}$

* Mercury lines have approximately the same wave lengths as these. (see last 2 pages)

DIAGRAM OF CIRCUIT



2,200 V. TRANSFORMER
50 ~
Switch and Control Resistance in the Primary

Mr.J.M.Pearson suggests that the following circuit would eliminate the need of "chokes".