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ULTRAFAST SPECTROSCOPY AND LASERS

THE CITY COLLEGE
OF THE CITY UNIVERSITY OF NEW YORK

REPORT to MAGNEGAS Corp on Magnegas Flame Spectra

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Abstract:

Experiments were performed for Magnegas Corporation using emissions to measure the spectra from flames of Magnegas gases to determine the emission lines and temperature of the Magnegas

Two types of flame were studied, MG flame from Crude oil combined with Oxygen, and MG flame from Antifreeze combined with Oxygen. Emission lines from both types of flames are observed. Intensity for MG from Antifreeze was much higher than from crude oil. The temperature of both flames was computed using Wein's law for the peak of each flame's spectrum. MG flame was evaluated at 10,500F in temperature,. The distribution is non- black body like. Non H emission lines were visible which indicates unknown elements in MG; suggestions are given.

Signature Robert R Alfano 03/23/2012
Robert Alfano Date

Introduction:

Magnegas has been known to have very fast metal cutting capabilities. It's been tested against other competing gases currently used in the market to cut metal, like using Acytelene. Magnegas promises to be a gas with various applications in energy, powering automobiles, and other applications.

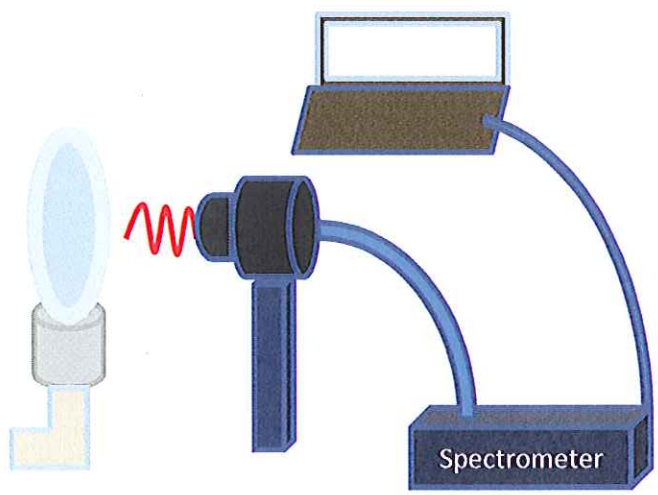
The focus of this work was to measure the emission spectra from flames from 2 types of Magnegas – one from crude oil and the other from antifreeze.

Materials and Methods

A 10mm focusing Lens was mounted perpendicular to the flame from Magnegas at 5mm from the flame source. (see Figure 1a). The lens was connected to a High-resolution Fiber Optic spectrometer "Ocean Optics HR2000" through a fiber optic cable. (Figure 1b is the lay out of the set up). The spectrometer provides an optical resolution to 0.035 nm (FWHM). Measurements were taken at different heights starting from the base of the flame and going up. The nozzle is shown in Fig 2. Alignment was done with a laser pen aimed at the center axis of the flame in the Z direction.

Also, measurement was done on the flame by taking a circular slice and going from the center to the outer part/perimeter of the flame in the horizontal Y direction.

a



b

Figure 1. a)Set up of lens in front of MG flame. b) Experimental set up.

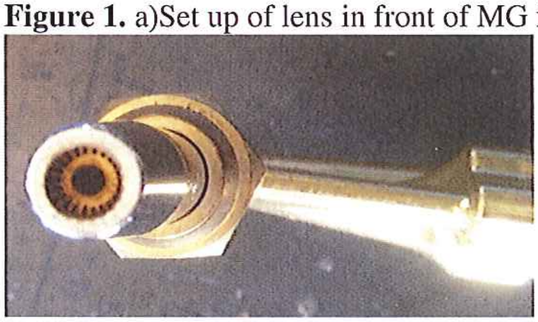


Figure 2. The Harris nozzle tip #2NXP used to produce the torch.

Magnegas from Crude oil was at kept at 15 Psi pressure, the one from Antifreeze was at 20 Psi pressure, and Oxygen at 40 Psi pressure.

First experiment consisted of combining Magnegas from crude oil and Oxygen together. The second was combining Magnegas from antifreeze to Oxygen. The mixing of Magnegas and Oxygen occurred at the tip of the Harris nozzle.

For the measurement of Magnegas flame while cutting, a scanning method was used. Recording of data was taken at time t=0 when cutting of metal began, and continuously afterwards data was collected at intervals of 50ms until cutting was complete at approximately 3-5 seconds depending of the size of the metal cut. Each scan of 50ms produced a graph of the electromagnetic spectrum from the flame at that particular time. Later all the graphs where compared for temperature and emission lines.

Results

Spectra measurements

1 - Graphs of Magnegas from Crude oil flame without and with cutting metal, emission lines, temperature, and Blackbody fit.

a)Flame only

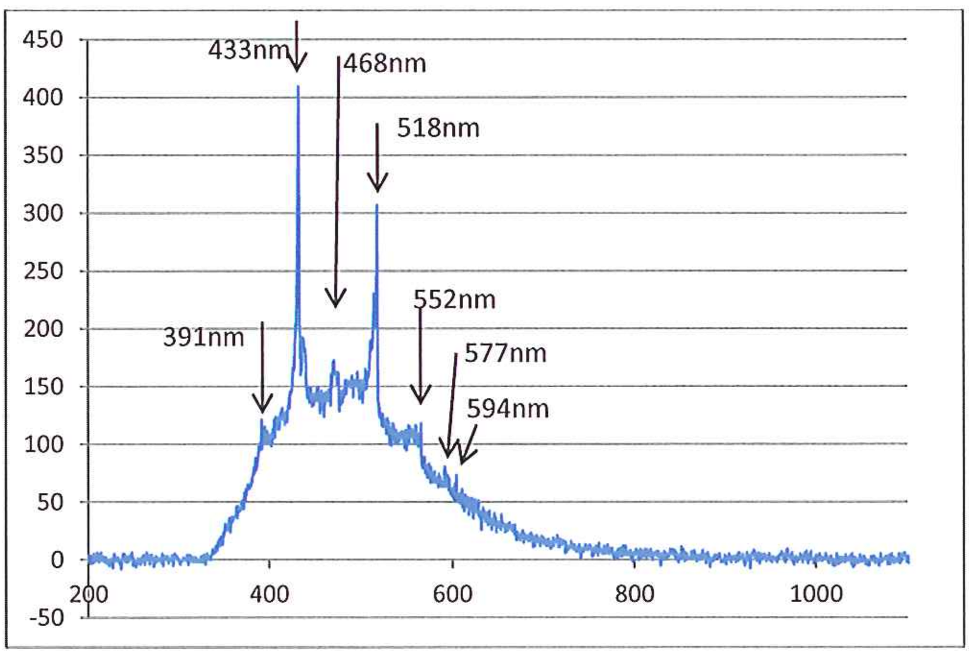


Figure 3. Magnegas from crude oil. Flame only, 3mm from the base. Emission lines are indicated with arrows (assigned as per ref. 1).

Emission lines (spikes) at:		Known emission lines (ref.1):	
391nm		391nm	CH & CN
433nm		433nm	CH
468nm		468nm	CH
518nm		518nm	C2
556nm		556nm	C2
577nm	- Unidentified		
594nm	- Unidentified		

Sensitivity is low below 400nm, no emission lines were observed.

b) Flame while cutting metal

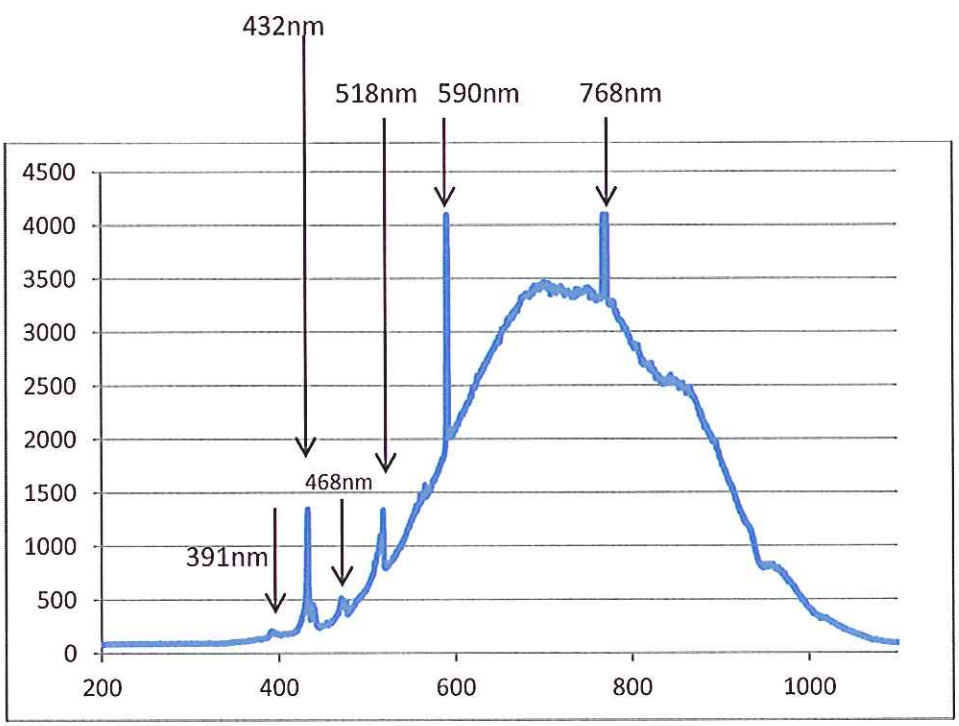


Figure 4. Flame of Magnegas from crude oil at 3mm above the surface of metal while cutting it.(approximately 2mm from base of flame)

Emission lines (spikes):		Known Emission lines (Ref.1):	
391nm		391nm	CH & CN
432nm		432nm	CH
468nm		468nm	CH
518nm		518nm	C2
590nm	- Unidentified		
768nm	- Unidentified		

c) Fitting with Blackbody curve Flame only

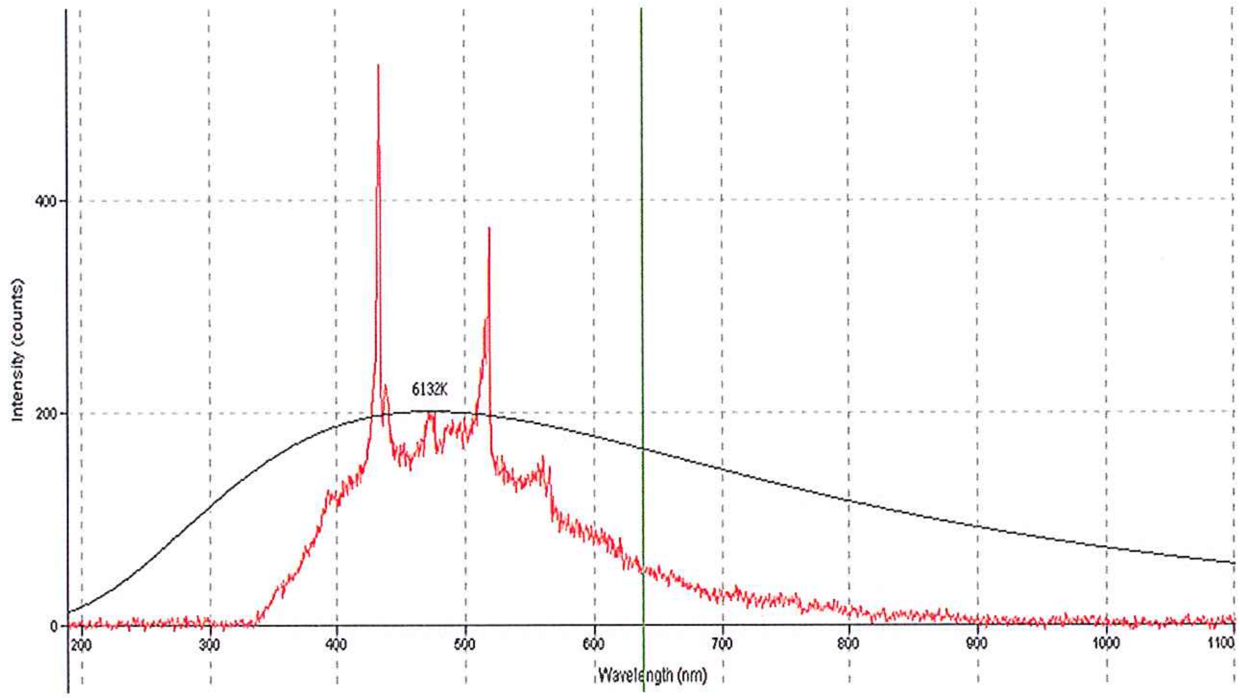


Figure 5. Temperature of Magnegas from crude oil. Flame only, 3mm from base and fit with Blackbody. Temperature at peak, **T= 6,132K.**

d) Fitting with Blackbody curve Flame while cutting metal

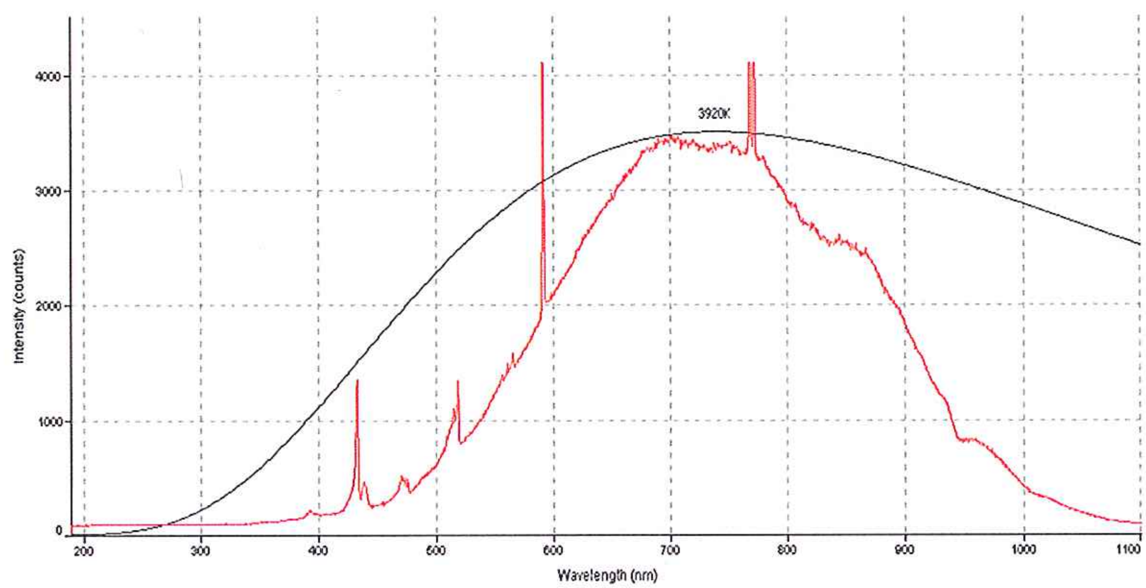


Figure 6. Temperature Flame of Magnegas from crude oil at 3mm above the surface of metal while cutting it,(approximately 2mm from base of flame)And fit with Blackbody. Temperature at peak, **T=3,920K**

e) Other comparisons:

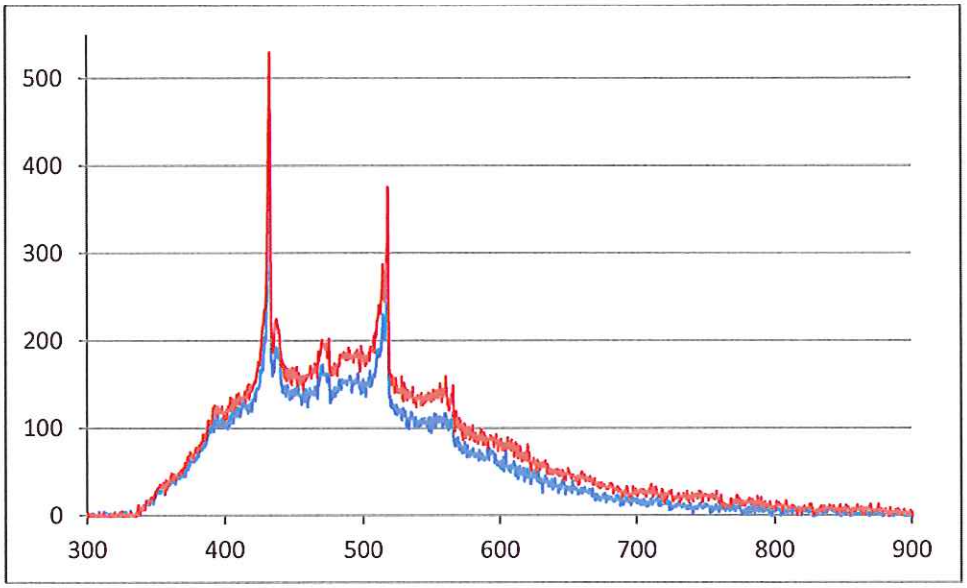


Figure 7. MG from Crude oil Shows higher intensity of flame-only and higher emission lines (in red) when we go from center of the flame to 2mm from the center.

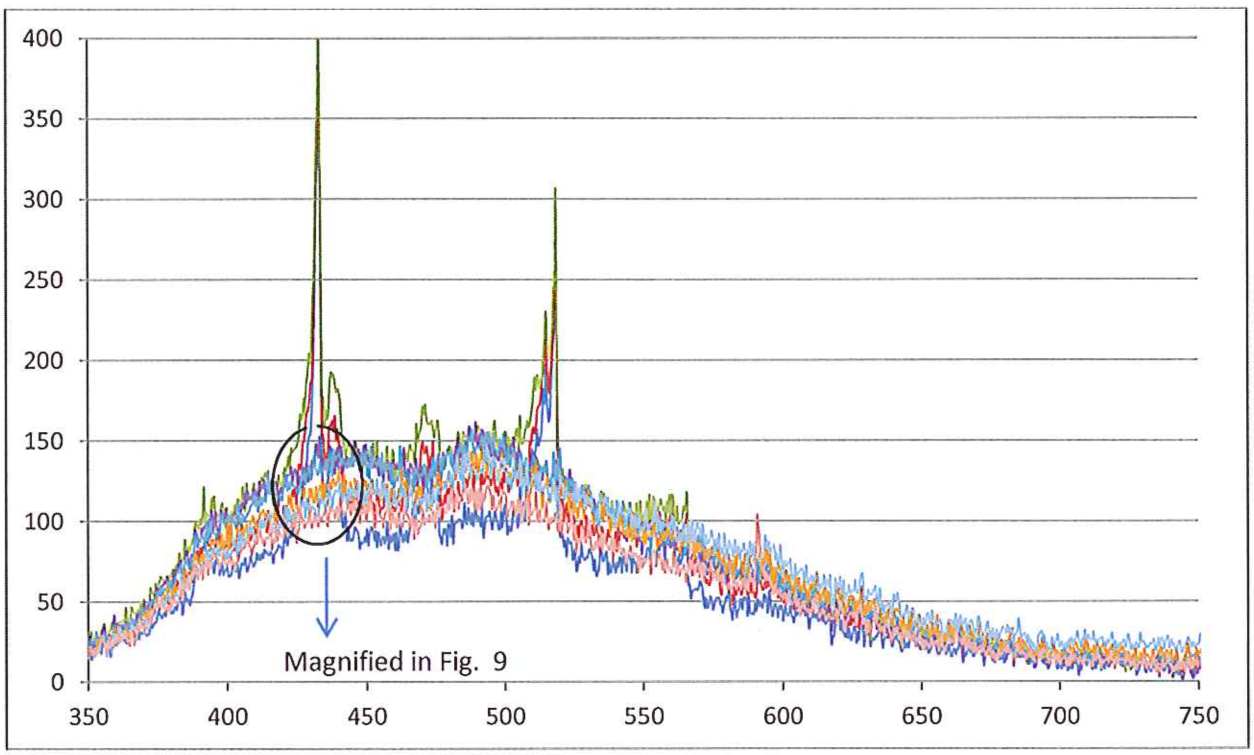


Figure 8. Shows the intensity increasing as we go from Base of flame, to 2mm from base, and then peaks at 3mm from base(in Green), then intensity starts droping at 5mm from base and continues droping as we keep moving away from the base of flame up to 12mm (in Blue).

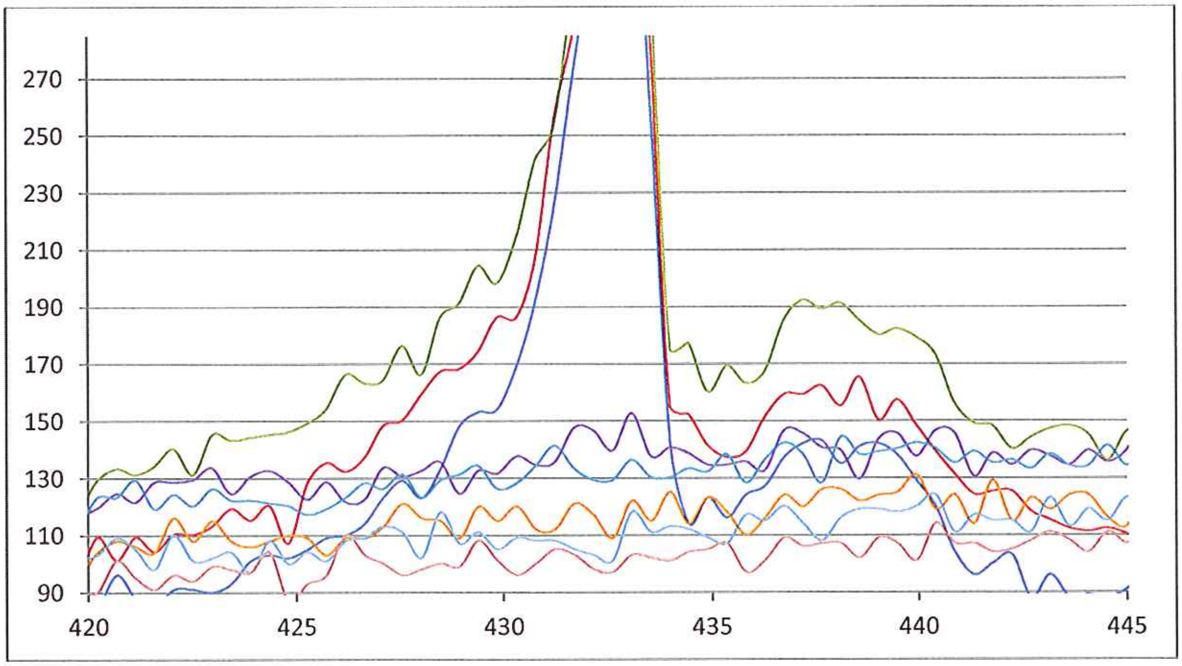


Figure 9. Details of flame intensity peaking from 0-3mm(green) from base of flame, then droping to lowest from 5-12mm.(blue, orange, purple) as we move away from the base of flame

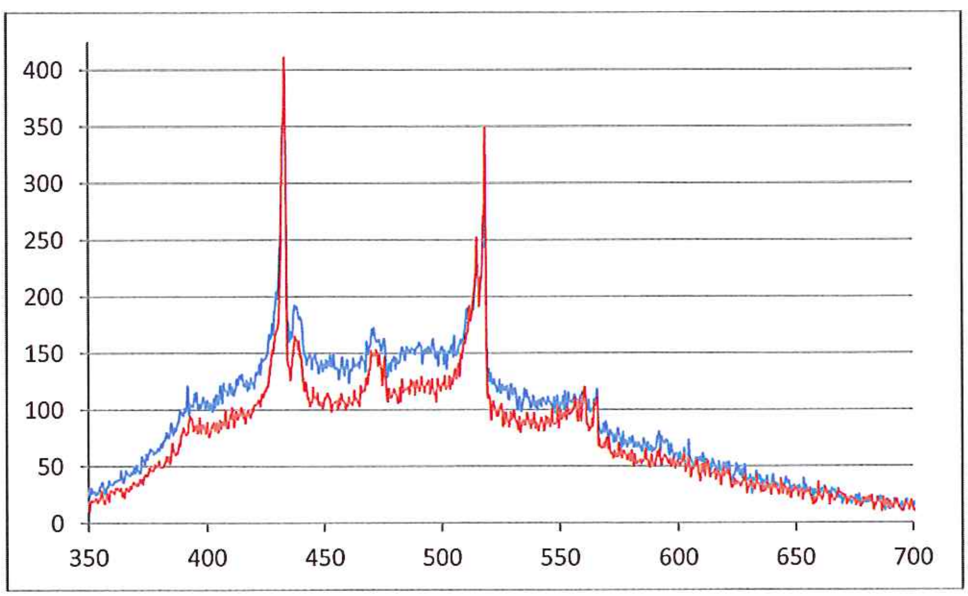


Figure 10. Shows MG from Crude oil at 3mm from base have incresed emission lines (red) when oxygen flow has increased in pipe. That corresponded with a overal slight decrease in intensity compared to no additional oxygen (Blue)

2 - Graphs of Magnegas from Antifreeze flame without and with cutting metal, emission lines, Temperature, and Blackbody fit.

a) Flame Only

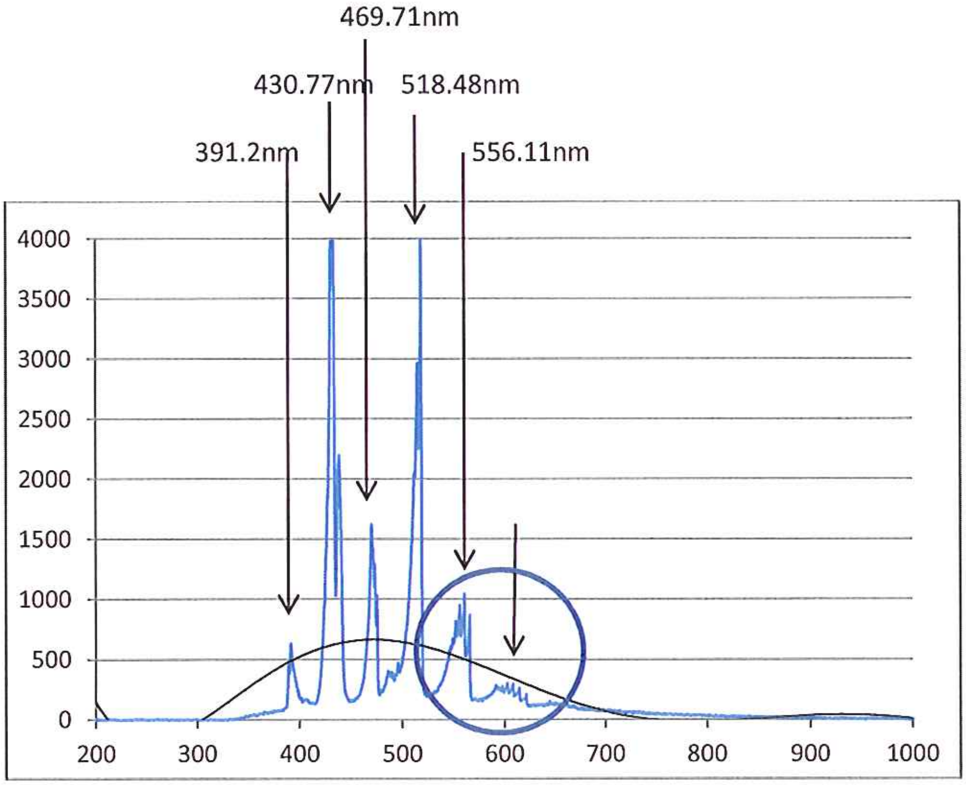


Figure 11. Magnegas from Antifreeze. Flame only. 3mm from the base.

Emission lines (spikes):	**Known emission lines (Ref.1):**
391.2nm	CN & CH
430.77nm	CH (long spike) & C2(shorter spike)
469.71nm	C2
518.48nm	C2
556.11nm	C2
600nm	C2

The circed area in the spectra should be further analyzed to detrmine what elements and mechanisms forms these broad spectra lines.

b)Flame while cutting metal

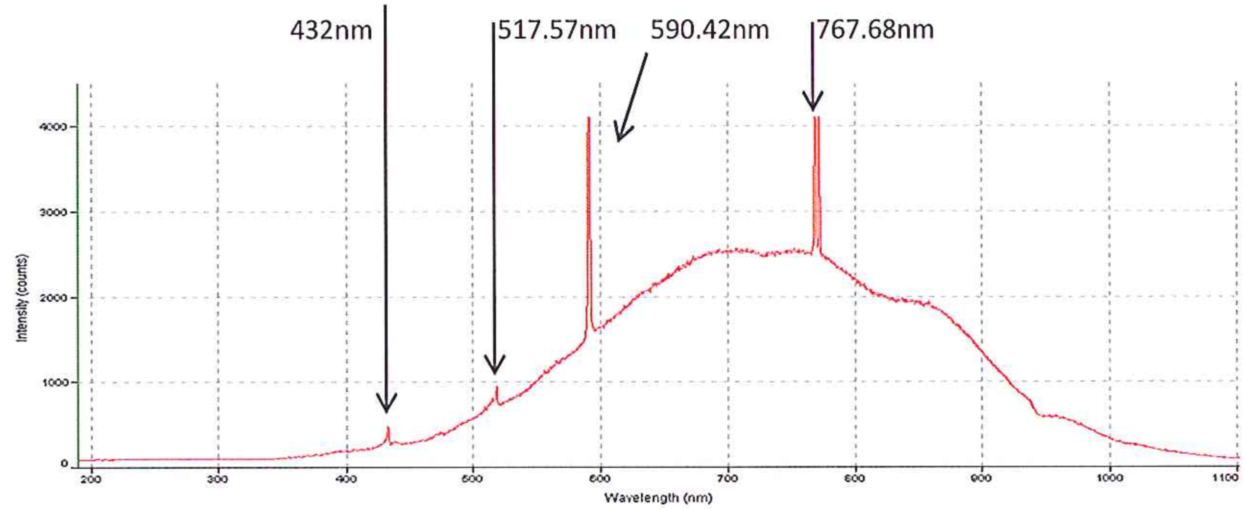


Figure 12. Flame of Magnegas from Antifreeze at 3mm above the surface of metal while cutting it.(approximately 2mm from base of flame)

Emission lines (spikes):	Known Emission lines (Ref.1):
432.15nm	CH
517.57nm	C2
590.42nm	Unidentified
767.68nm	Unidentified

c) Fitting with Blackbody curve   Flame only

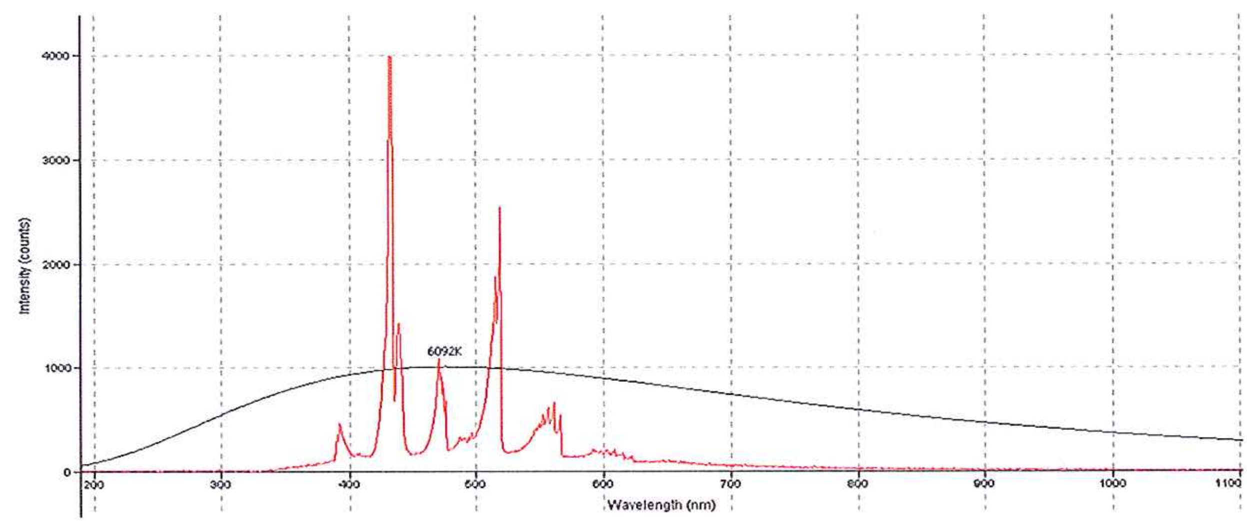


Figure 13. Temperature of Magnegas from antifreeze. Flame only, 3mm from base and fit with Blackbody. **T= 6,092K**

d) Fitting with Blackbody curve   Flame while cutting metal

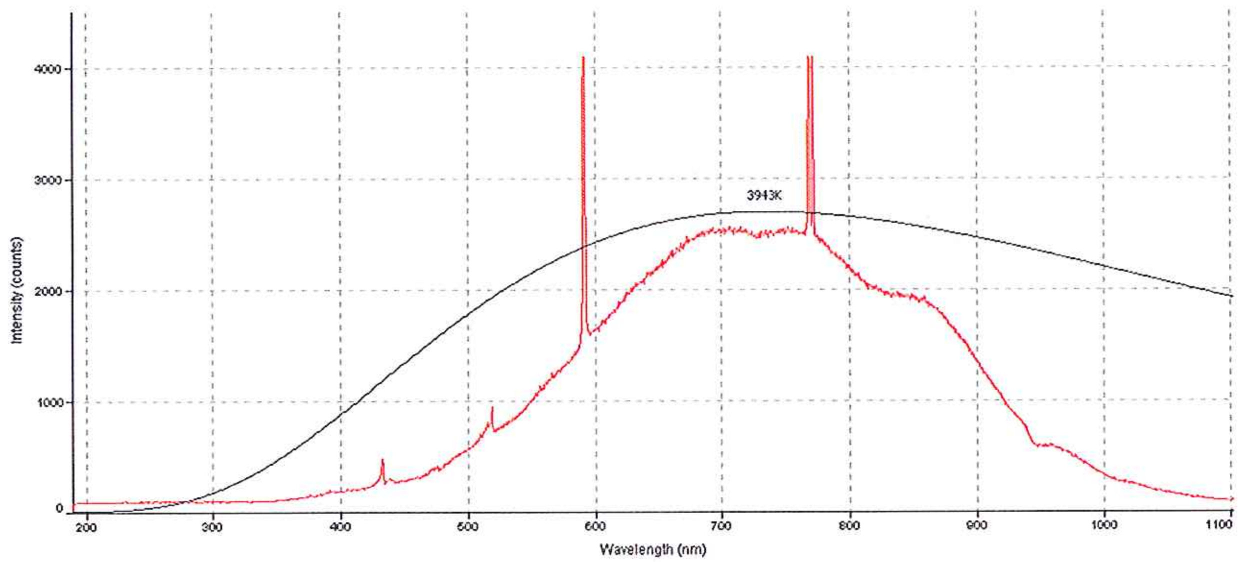


Figure 14. Temperature Flame of Magnegas from antifreeze at 3mm above the surface of metal while cutting it.(approximately 2mm from base of flame)
And fit with Blackbody. **T=3,943K**

e) Other comparisons:

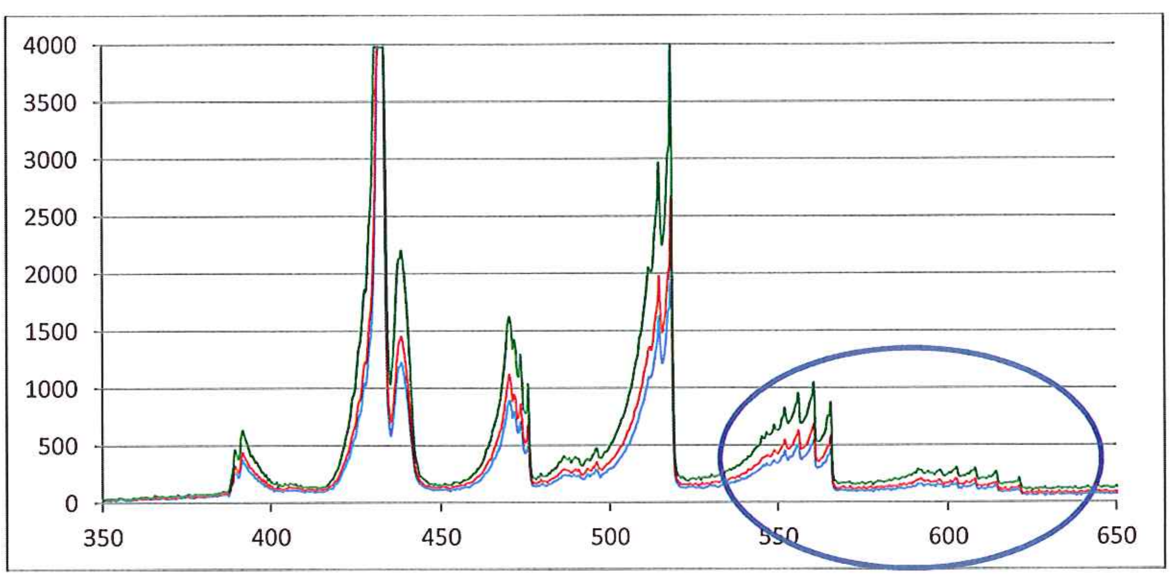


Figure 15. MG from Antifreeze shows higher emission lines and intensity as we move from the center of the flame(Blue) to 1mm away from center(red) to 2mm away from center(green). Circled area should be further investigated.

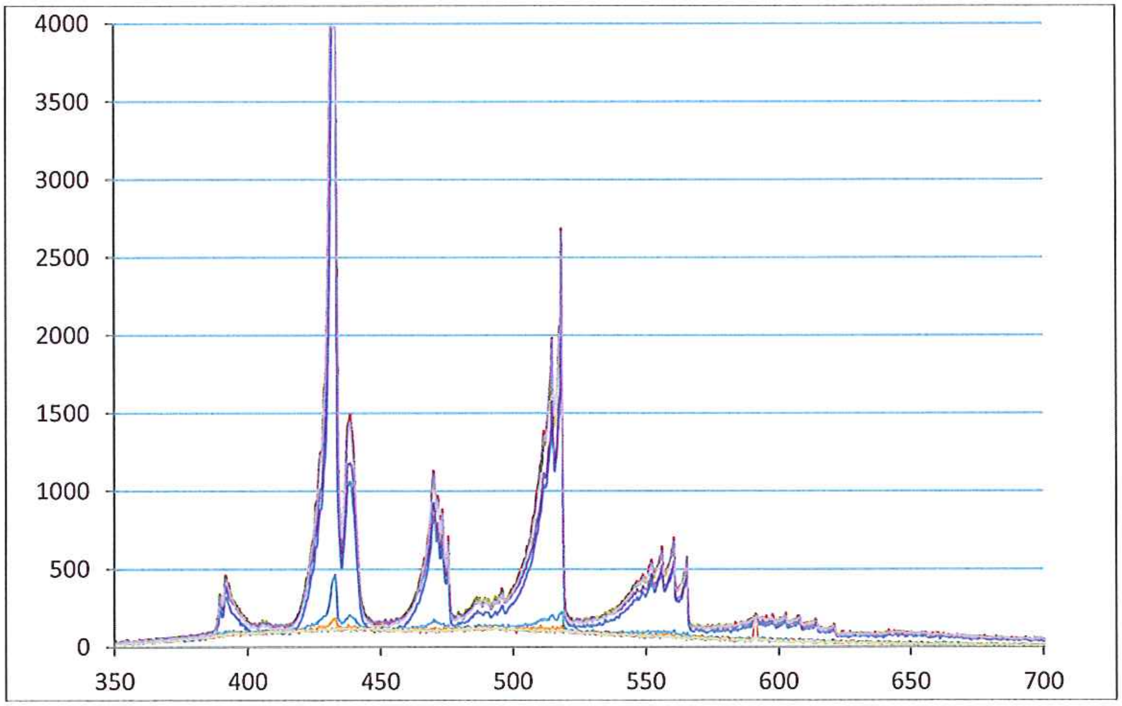


Figure 16. Shows Intensity of MG flame from Antifreeze increasing from base, to 1mm, then peaking at 2mm, then dropping slightly at 3&4mm, to dropping sharply at 5&6mm, then almost becoming flat at 8,10,&12mm.

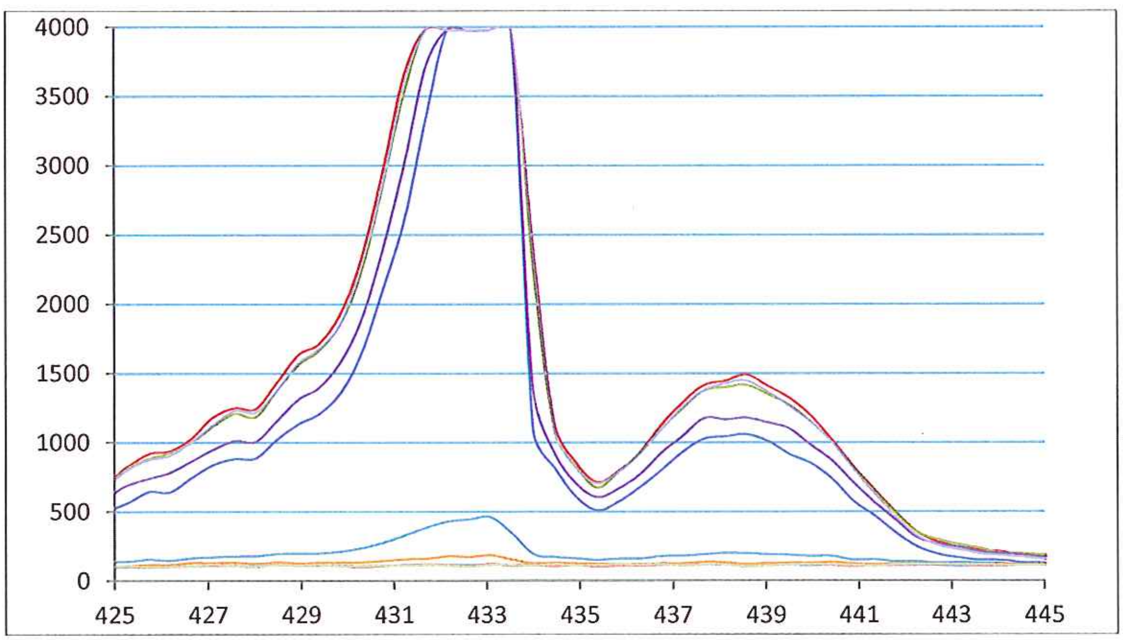


Figure 17. Detailed increase to peaking at 2mm from base then dropping in intensity as we move away from the base of the flame.

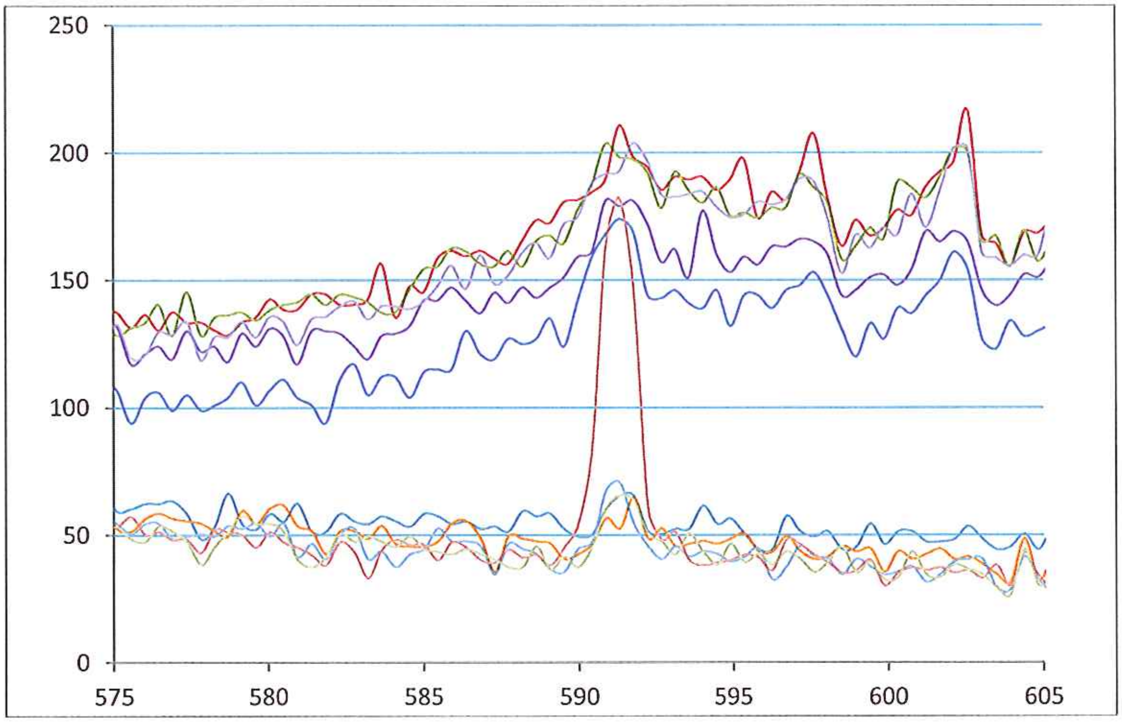


Figure 18. MG from antifreeze shows an emission line(591nm) at 12mm away from base of flame. It's peak is higher than all others around 591nm.

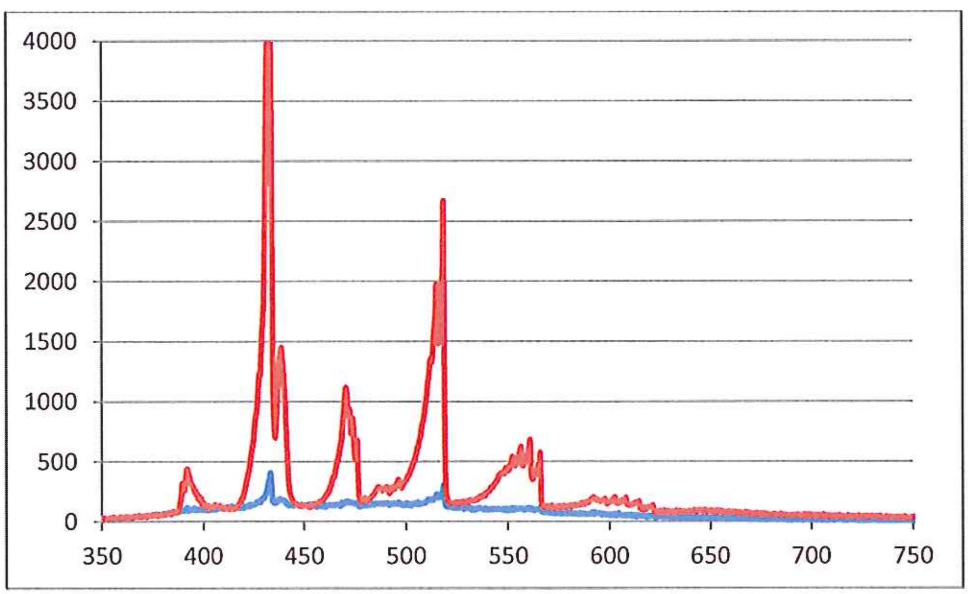


Figure 19. Comparison of MG flame from Crude oil(Blue) to Antifreeze in (Red). We can clearly see that the flame intensity from Antifreeze is 15-20 folds more intense than MG flame from crude oil.

Discussion

Emission lines were observed in the flames from both Magnegas from Crude oil and Magnegas from Antifreeze. The peak wavelength of MG from Crude oil flame only is λ_{max}=473nm and the peak wavelength while cutting metal is λ_{max}=739nm, that's a 266 nm difference. The difference for MG from Antifreeze was 259 nm; λ_{max}=476 nm for flame only and λ_{max}=735nm for flame while cutting metal.

The reason for the difference is due to interaction of the flame with metal when the flame is positioned very close to the metal (2-4mm) in order to cut it. This resulted in a spectrum of flame/metal in the red range. When no metal was present, the flame displayed a blue color.

Intensity peaked as we went up away from the base of the flame for the first 2-4 mm, then started decreasing as we kept getting away from the base. Maximum effect of the flame lays directly above the base, and gets weaker as we move away from it (Figs 8 and Fig. 16).

Going in the horizontal direction (Fig. 7 MG from crude oil and Fig. 15 MG from antifreeze), intensity increased in both gases at 2mm away from the center of the flame.

Intensity from MG antifreeze was 15-20 times higher than that of crude oil. The reason is unknown, but one factor for higher intensity could be that MG Antifreeze was kept at 20Psi while MG Crude oil was at 15Psi. It's 33.3% increase in pressure. The 33.3% pressure increase could not alone justify the over 1500% increase in intensity.

Pressing the handle of the Harris torch for additional flow of oxygene (Fig.10), shows an increase in the emission lines only, but results in a decrease of the overall intensity of the flame.

Summary of the measured emission lines is shown in table below:

Emission lines of: (in nano meters)	MG crude oil flame only	MG crude oil cutting metal	MG Antifreeze flame only	MG Antifr
		376		
CH	390		390	
CH	430	430	430	432
C2	467	467	469	
	510			
C2			518	517
C2	550			
C2		560	560	
	580			
		590		590
C2	595			
			603	
		680		
		768		767
		827		

The spectra from Magenegas can be identified as a mix of CH and C_2 emission lines (ref.1).

a) Lines at 390 nm and 430 nm belong to $B^2\Sigma^-$–$X^2\Pi$ and $A^2\Delta$-$X^2\Pi$ transitions of the excited CH molecule

b) Lines at 470 nm, 518 nm and 556 nm and 600 nm belong to so called "Swan series" of C_2 molecule (components of A^3P_g-X^3P_u transition)

"The sub-spikes" (fine structure visible at zoom) are rotational or vibrational components.

The above lines are common for hydrocarbonate flames, e.g. butane flame. Relative intensities depend strongly on temperature, content of different hydrocarbonates and mix with oxygen.

There should be more lines attributed mainly to OH, they are in the 200 nm – 300 nm range. The reason they are not seen probably is due to low sensitivity of the Ocean Optics spectrometer in the UV range.

For example below (Fig. 21) is a graph of butane flame spectrum (from Ref. 2). It looks similar to the one obtained with Magnegas from Antifreeze. There was no similar known spectrum that we could find that resembles MG from Crude oil. Butane torch flame and notations from the above reference (Ref.2):

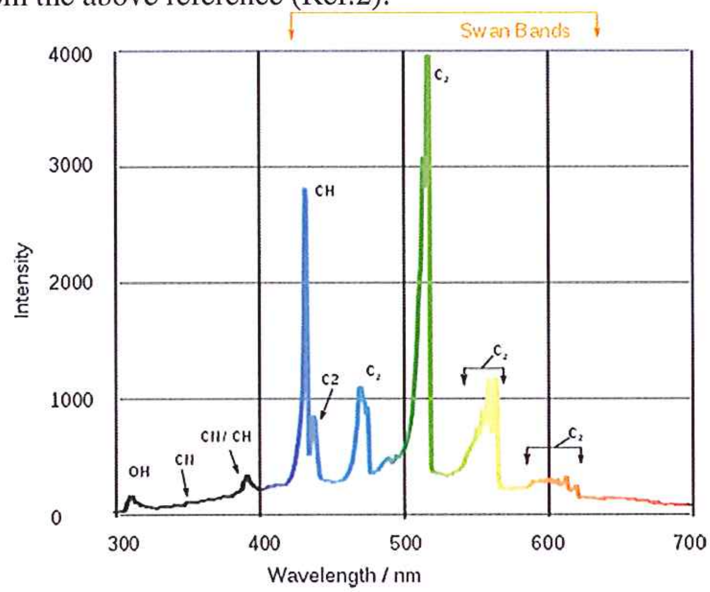


Figure 21. Butane flame spectrum from Ref.2.

The temperature was calculated using Wien's law: T= (2.9x10^6)/ λmax

Figure1: peak at 473nm was used. T=6,132K (10,578F, 5,859C).

Figure2: peak at 739nm was used. T=3,920K (6,597F, 3,647C).

Figure 3: peak at 476nm from polynomial of the order 6 was used. T=6092K (10,506F, 5,816C).

Figure 4: peak at 735nm was used. T=3,943K (6,638F, 3,670C).

<u>**Wien's law**</u>:

$$\lambda_{\max} = \frac{hc}{x}\frac{1}{kT} = \frac{2.89776829\ldots \times 10^{6}\ \mathrm{nm}\cdot K}{T}.$$

Conclusion

The peak wavelength from the MG flame has a non-Blackbody distribution form. Magnegas flame from Crude oil and Antifreeze displays a high temperature in the 6,100K range (10,500F). The Blackbody fit could have some inaccuracies because of strong influence of the chemiluminescence glow in the visible range of spectrum. The experimental spectra are a mix of the two phenomena.

More studies could be done to determine the elements present in MG. We propose experiments to compare the spectra from flames of Magnegas made from different sources: water, D_2O, and antifreeze with the spectra from Acetylene and H2 gas flames in search of H_3. We plan to add carbon particles into a flame to obtain better measurements of temperature fit to Black Body.

Appendix

Known emission lines Ref. 3

Carbon emission	Oxygen emission	H3 emission
Lines: (Angstrom)	Lines: (Angstrom)	Lines (nm):
3918.98 570	3911.96 450	425
	3919.29 160	450
3920.69 800	3947.29 185	460
4074.52 250	3947.48 160	560
4075.85 350	3947.59 140	580
4267.00 800	3954.37 220	605
4267.26 1000	3954.61 100	710
4771.75 200	3973.26 450	
4932.05 200	3982.20 220	
5052.17 200	4069.90 160	
5132.94 350	4072.16 285	
5133.28 350	4075.87 450	
5143.49 350	4083.91 80	
5145.16 570	4087.14 50	
5151.09 400	4089.27 150	
5380.34 300	4097.24 110	
5648.07 250	4105.00 220	
5662.47 350	4119.22 285	
5889.77 570	4132.81 160	
5891.59 350	4146.06 50	

6001.13 200	4153.30 220	
6006.03 250	4185.46 285	
6007.18 110	4189.79 450	
6010.68 150	4233.27 80	
6013.22 300	4253.74 50	
6014.84 250	4253.98 50	
6578.05 800	4275.47 50	
6582.88 570	4303.78 50	
6587.61 200	4317.14 285	
6783.90 250	4336.86 160	
7113.18 250	4345.56 220	
7115.19 250	4349.43 285	
7115.63 250	4366.90 220	
7116.99 200	4368.25 100	
7119.90 350	4395.95 220	
	4414.91 450	
	4416.98 285	
	4448.21 160	
	4452.38 160	
	4465.45 50	
	4466.28 50	
	4467.83 50	
	4469.41 50	
	4590.97 360	
	4596.17 285	
	4609.39 80	
	4638.85 160	

	4641.81 360	
	4649.14 450	
	4650.84 160	
	4661.64 360	
	4676.23 285	
	4699.21 220	
	4705.36 285	
	4924.60 160	
	4943.06 220	
	5329.10 135	
	5329.68 160	
	5330.74 190	
	5435.18 90	
	5435.78 110	
	5436.86 135	
	5577.34 120	
	5958.39 160	
	5958.58 190	
	5995.28 80	
	6046.23 160	
	6046.44 190	
	6046.49 110	
	6106.27 100	
	6155.98 400	
	6156.77 450	
	6158.18 490	
	6256.83 80	

	6261.55 100	
	6366.34 100	
	6374.32 100	
	6453.60 320	
	6454.44 360	
	6455.98 400	
	6604.91 80	
	6653.83 100	
	7001.92 360	
	7002.23 450	
	7156.70 210	

Known emission lines Ref. 4

• Identification	Wavelength (Å)	log N_{cr} (cm^{-3})	Identification	Wavelength (Å)	log N_{cr} (cm^{-3})
[C III	1909	9.0	[Fe VII]	5721.1	7.6
[O II]	3726.1	3.5	[N II]	5754.6	7.5
[O II]	3728.8	2.8	[Fe VII]	6086.9	7.6
[Fe VII]	3760.3	7.6	[O I]	6300.3	6.3
[Ne III]	3868.8	7.0	[S III]	6312.1	7.2
[Ne III]	3967.5	7.0	[Fe X]	6374.6	9.7
[S II]	4068.6	6.4	[N II]	6583.4	4.9
[O III]	4363.2	7.5	[S II]	6716.4	3.2
[Ar IV]	4711.3	4.4	[S II]	6730.8	3.6
[Ar IV]	4740.0	5.6	[Ar III]	7135.4	6.7
[O III]	5006.9	5.8	[O II]	7319.9	6.8
[Fe VIII]	5159.0	6.5	[O II]	7330.2	6.8
[Fe VI]	5176.4	7.6	[N I]	5197.9	3.3

Known emission lines Ref. 5

TABLE 3.11
Critical densities for collisional de-excitation

Ion	Level	$N_c(\text{cm}^{-3})$	Ion	Level	$N_c(\text{cm}^{-3})$
C II	$^2P_{3/2}$	8.5×10^1	O III	$^1D_2$	7.0×10^5
			O III	$^3P_2$	3.8×10^3
C III	$^3P_2$	5.4×10^5	O III	$^3P_1$	1.7×10^3
N II	$^1D_2$	8.6×10^4	Ne II	$^2P_{1/2}$	6.6×10^5
N II	$^3P_2$	3.1×10^2			
N II	$^3P_1$	1.8×10^2	Ne III	$^1D_2$	7.9×10^6
			Ne III	$^3P_0$	2.0×10^4
N III	$^2P_{3/2}$	3.2×10^3	Ne III	$^3P_1$	1.8×10^5
N IV	$^3P_2$	1.4×10^6	Ne V	$^1D_2$	1.6×10^7
			Ne V	$^3P_2$	3.8×10^5
O II	$^2D_{3/2}$	1.6×10^4	Ne V	$^3P_1$	1.8×10^5
O II	$^2D_{5/2}$	3.1×10^3			

NOTE: All values are calculated for $T = 10,000°$ K.

Known emission lines Ref. 6

O2	7594 - 7621
O2	6867 - 6884
H	6563
O2	6276 - 6287
Na	5896 & 5890
Fe	5270
Mg	5184 & 5173
Fe	4958
H	4861
Fe	4668
Fe	4384
H	4340
Fe & Ca	4308
Ca	4227
H	4102
Ca	3968

Ca	3934	

HR2000 Specifications

Dimensions:	148.6 mm x 104.8 mm x 45.1 mm
Weight:	570 grams
Power Consumption:	95 mA @ 5 VDC
Detector:	Sony ILX511 linear CCD array
Detector Range:	200-1100 nm
Pixel size:	14 µm x 200 µm
Optical bench:	f/4, 101 mm focal length
Gratings:	Choose from 13 different gratings
Pixel elements:	2048
Entrance Aperture:	5, 10, 25, 50, 100 or 200 µm wide slits or fiber (no slit)
Order-sorting filters:	Installed longpass and bandpas filters
Stray Light:	<0.05% at 600 nm; <0.10% at 435 nm
Dynamic Range:	2 x 10^8 (system); 2000:1 for a single scan
Fiber Optic Connector:	SMA 905 to single-strand optical fiber 0.22 NA)
Data Transfer Rate:	Full scans into memory every 13 milliseconds
Integration Time:	3 milliseconds to 65 seconds
Operating Systems:	Windows 98/ME/2000/XP, Mac OS X and Linux when using the USB interface on desktop or notebook PCs. Any 32-bit Windows operating system when using the serial port on desktop or notebook PCs.

TEST REPORT of INTERNAL VAPOR ANALYSIS done by Oneida Research Services, Inc.

PRESSURE torr 126
NITROGEN %v 16.9
OXYGEN ppmv ND
ARGON ppmv ND
CO2 ppmv ND
MOISTURE %v 1.11
HYDROGEN %v 57.8
METHANE %v 12.4
AMMONIA ppmv ND
HELIUM ppmv ND
FLUOROCARBONS
ppmv ND

KRYPTON ppmv ND
UNKNOWN* %v 11.8

References:

1-. G. Zizac, "Flame-emission spectroscopy:Fundamentals and applications"
http://www.tempe.mi.cnr.it/zizak/tutorial/cairol06-flame-emission.pdf

2- http://en.wikipedia.org/wiki/File:Spectrum_of_blue_flame.svg

3- http://astro.u-strasbg.fr/~koppen/discharge/index.html

4- **http://www.astr.ua.edu/keel/galaxies/emission.html**

5-http://ncra.tifr.res.in/~ngk/TEACHING/ISM2011/Lectures/ISM-L9.pdf

6-http://www.harmsy.freeuk.com/fraunhofer.html