The Orimulsion® Experience at Arawak

A.P.C.A.C.

PRESENTATION

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Introduction

Arawak Cement Company Limted is a single line dry process cement plant wholly owned by the TCL Group of Companies and is located at Checker Hall St. Lucy in the northern section of Barbados some 25 kilometeres from the capital city of Bridgetown. The plant consists of a 90 t/h Loesche vertical roller mill for raw material grinding, a 1000 mtpd SKET kiln of 4.0 m diameter and 60 m long with a VA-ZAB five (5) stage preheater made up of two cyclone stages and three shaft stages using an electrostatic precipitator for cleaning of the kiln exhaust gases and a gravel bed filter for cleaning of the cooler vent gases. The finish grinding operation is a 52t/h two chamber ball mill supplied by Voest Alpine.

The plant was originally commissioned in 1984 by Voest Alpine and ran until 1991 when the high cost of the main fuel (Bunker C/ No.6 Fuel Oil) severely affected its profitability and forced the closure of the kiln line. It functioned as a grinding station until 1997 when, after a large reactivation project the kiln was relit using Orimulsion® as a main fuel. Orimulsion® was not at that time and still is not in wide use in the cement industry, two plants had carried out test burns with Orimulsion® but did not go into full-scale use. As part of its commitment to reactivate the kiln Arawak identified Orimulsion® as a potentially suitable fuel, primarily due to the significant costs savings compared to No. 6 Fuel Oil, to return Arawak to profitability as a clinker producing plant. There were a number of questions about the suitability of a bitumen water emulsion to cement operations including:

- Flame shape control

- Burning zone heat transfer
- Clinker quality
- Effects on refractory life
- Environmental issues
- Fuel handling and storage

Arawak in light of the circumstances of its closure in 1991 went into the full-scale commercial use of Orimulsion® and these technical uncertainties would have been seen simply as challenges to overcome to ensure the continued operation of the pyro-processing operations. Since switching to Orimulsion the plant has managed to experience profitability and it has the distinction of being the only cement plant in the world burning Orimulsion as its main fuel.

Orimulsion®-The Fuel

Orimulsion® is a liquid fuel consisting of approximately 70% bitumen and 30% water emulsion stabilized by a commercially available surfactant package (<0.2%) consisting of a non ionic surfactant and an organic amine. In 1997 when Arawak commenced firing of Orimulsion® through the main burner, the fuel was Orimulsion®100. Due to environmental considerations Bitor ceased the production of Orimulsion®100 and in 1998 it was modified to the Orimulsion®400 formulation.

Fig. 1 Typical analysis of Orimulsion® 400 (Orimulsion®)

Properties	Typical	levelWATER
CONTENT % w/w	29.00	
DENSITY (15°C), g/ml in air	1.0090	
MEDIAN DROPLET SIZE, µm	14.50	
DROPLETS > 150 µm (Sieve)	0.25	

Properties	Typical level
APPARENT VISCOSITY, mPas	
30°C, $20s^{-1}$	260
70°C, $100s^{-1}$	210
GCV, $MJkg^{-1}$	30.20
NCV, $MJkg^{-1}$	27.800
SULPHUR, % w/w	2.85
SODIUM, ppm	12
VANADIUM, ppm	320
NICKEL, ppm	75
ASH, % w/w	0.07
pH	> 9.20

Fig 2 Typical Elemental Analysis of Bitumen (expressed as wt% emulsion)

Carbon	**60**
Hydrogen	**7.3**
Sulphur	**2.7**
Nitrogen	**0.5**
Oxygen	**0.2**

Fig. 3 Comparison of Orimulsion and Bunker “C”

	Orimulsion®	**Bunker “C”•High**
heat value:	**7143 kcal/kg**	**10391 kcal/kg**
•Low heat value:	**6593 kcal/kg**	**9675 kcal/kg**
•Water content:	**30 %**	**1%**
•Sulfur content:	**2.85%**	**2.2%**
•Flash Point:	**>90 °C**	**66 °C**

Kiln Burner

The Kiln Burner is a Unitherm ZL 8000 burner with radial and axial oil channels and is designed for double forward flow operation. The tip of the burner lance is fitted with a changeable nozzle plate ranging in size from 2.0 mm to 6.2 mm at full production. A single fan supplies the primary air to the axial and radial primary air channels. As the original design was for dual fuel capability using Bunker “C” and natural gas, there are also axial and radial primary air channels diametrically closer to the nozzle tip that can assist in additional flame shaping and improved combustion.

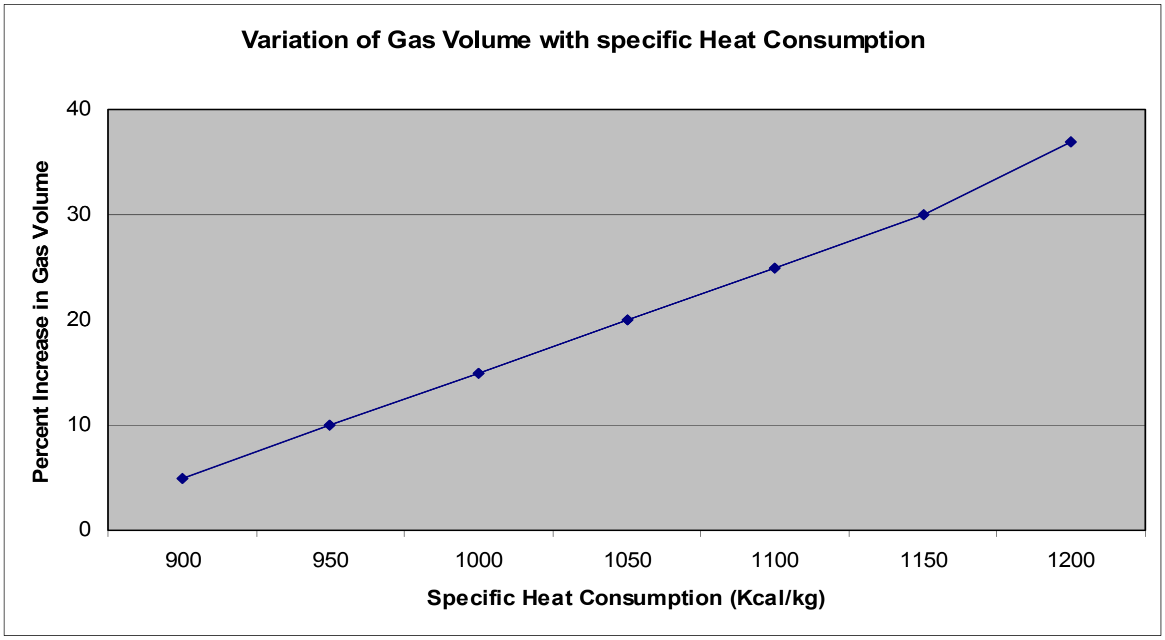
Fig 4: Arawak's Kiln Burner

Fig 5: Kiln Burner Tip (Nozzle plate not shown)

The Orimulsion Flame

The Orimulsion flame temperature is approximately 1965 ºC, which is lower than the 2050 ºC that can be expected when using Bunker "C". The lower flame temperature is to be expected, considering the significant percentage of water in the fuel, which went burnt, will absorb appreciable quantities of heat due to its high heat capacity relative to the other combustion products. The lower flame temperature reduces the radiant heat transfer to the kiln load in the burning zone and results in a higher exit gas temperature (See Fig. 8). The reduction in radiant heat transfer results in a greater heat requirement and therefore a higher specific heat consumption (See Fig 6 [2]) when compared to Bunker "C". The higher heat consumption results in a 8-13 % increase in gas volume. This gas volume increase would cause an increase in preheater tower pressure drop (See Fig.8) and also result in fan limitations for any fan not resized for Orimulsion® operation.

Fig 6: Graph showing Variation of Gas Volume with Specific Heat Consumption



Ignition of the Orimulsion® Flame

When re-lighting the kiln from a "cold" condition the Orimulsion® has proven very difficult to light. It is therefore necessary to prepare the burning zone by using a gas pilot flame for a minimum duration of three to four hours. The profile Orimulsion flame tends to be long and bushy and is difficult to control into a compact flame (See Figure 7).

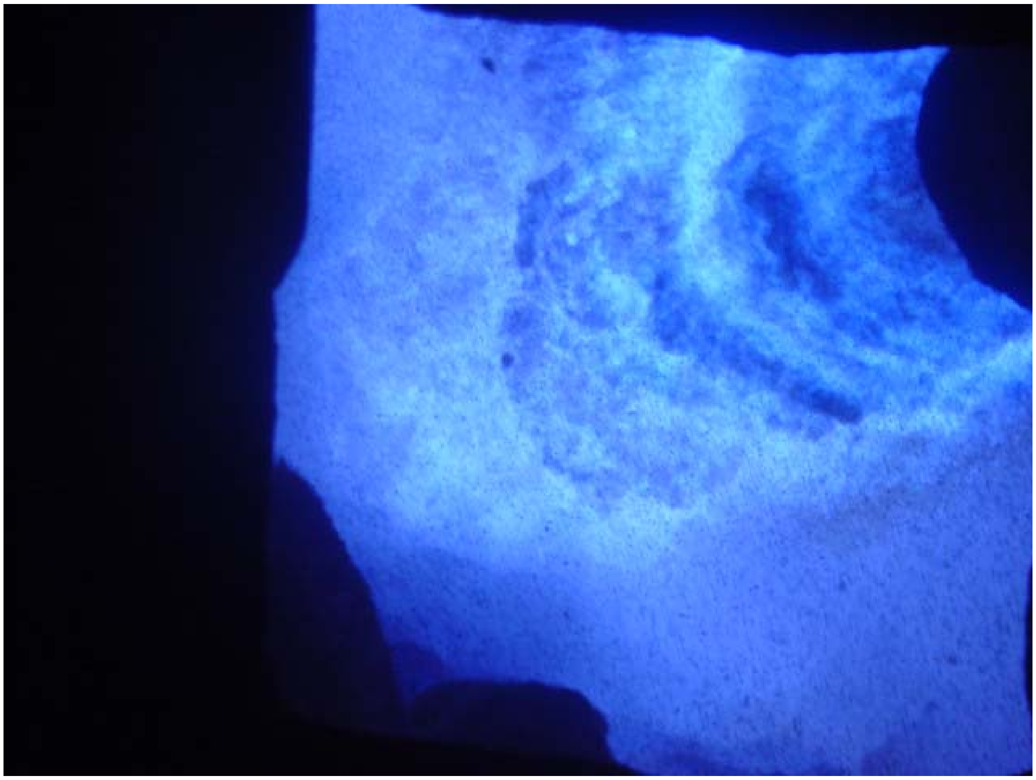


Fig.7.Orimulsion Flame: Fuel flow of 6000 litres and nozzle plate diameter 6.2 mm.

Fig. 8 Comparison of Pressure Drop and Preheater Outlet Temperature

	Orimulsion®	Bunker "C"
Pressure Drop (mbar)	45 – 55	35 – 45
Preheater Outlet Temperature (º C)	450- 510	380 - 430

Raw Materials

The table below shows a typical analysis of our raw materials.

Table 1.: Typical analysis of Raw Materials at Arawak.

	LIMESTONE	HIGH Si SHALE	LOW Si SHALE
% Composition			
SiO_2	2.68	75.3	63.4
Al_2O_3	0.95	9.7	16.3
Fe_2O_3	0.41	3.4	5.4
CaO	52.72	1.19	1.5
MgO	0.65	0.96	1.7
SO_3	0.02	0.18	0.25
Na_2O	0.02	1.06	1.81
K_2O	0.12	1.3	1.85
Moisture	3-12 %	8-11%	

Due to the high sulphur content of Orimulsion®, in order to achieve an alkali sulphate ratio that would allow for maximum production, we would have to use a significant quantity of low silica shale, which contains a greater alkali contribution. At the same it must be noted that the low silica shale also contains the higher sulphate content. This necessitates tight control of the raw mix to ensure that the components are proportioned to prevent the formation of encrustations in the kiln inlet which would lead to preheater plugging. In order of significance, the moduli that are used to control raw mix proportioning are: L.S.F (L.S.T. II), S.R., Total Alkali and A.R.

Arawak's experience has been that most blockages which occur at the kiln inlet have been due to excess sulphates based on the sulphur input from Orimulsion and the raw materials. This has been further compounded by the high chloride levels in the raw materials which preferentially sequester the available alkali thereby exacerbating the alkali sulphate ratio even further.

The VA ZAB shaft design was used at Arawak for the purpose of handling the high chloride content in the raw material. The normal level of chloride in the raw mix is 0.02% and in the kiln feed 0.14% (See Fig.9).The chloride level in the kiln feed is between 10 to 20 times what would be expected as the maximum operable chloride level for a normal suspension preheater. In fact as indicated in Duda[5] "by passing of kiln gases is necessary at a chloride content of more than 0.015% in the raw mix". The presence of high chloride raw materials resulted in the selection of the VA ZAB preheater which is less sensitive to condensation of the volatile components in the raw mix due to the wide spaces in the lower shaft stages. Nevertheless the sulphate and chloride levels indicated in kiln inlet sample in the table below would result in excessive encrustations occurring in Arawak's Kiln Inlet.

Table 2: Typical analysis of Premix, Raw Mix, Kiln Feed and Kiln Inlet samples at Arawak.

	PREMIX	RAW MIX	KILN FEED	KILN INLET
% Composition				
SiO2	15.3	13.37	14.54	15.92
Al2O3	3.7	3.45	3.75	3.99
Fe2O3	1.56	1.94	2.02	2.95
CaO	42.7	43.48	42.46	46.01
MgO	ND	0.81	0.95	1.11
SO3	0.07	0.28	0.18	2.55
Na2O	0.22	0.22	0.25	0.42
K2O	0.36	0.42	0.47	2.91
CL	0.02	0.02	0.14	2.37
Moisture	3-12 %	<1%		

Operational Challenges

Arawak's principal operational challenge since firing Orimulsion® as the main fuel has been the high incidence of Preheater blockages. These blockages have occurred in two areas in the Preheater Tower; The Second Stage Cyclone and the Kiln Inlet.

The blockages that have occurred in the Second Stage Cyclone, have been quite severe in some cases resulting in as much as seven (7) days plant downtime. Investigations have shown that over temperature was a significant contributor to the problems experienced, and since May 2002 when a fuel to feed ratio interlock was installed, the incidence of major blockages in the Second Stage Cyclone has been reduced to zero.

A number of strategies have been used to counteract Kiln Inlet build ups.

1) Increase Alkali Level
2) Use of Air Cannons (Blasters)Installation of Cardox SystemBurner Positioning (Elevation and Insertion Distance)Flame ConfigurationsUpgrade of Refractory LiningThe ability to maintain high production rates with

Orimulsion is extremely dependent on the alkali sulphate ratio in the raw meal. If the alkali level is below 0.6% there is a deficiency in alkali to counteract the internal sulphur volatility cycle which takes place between the burning zone and the kiln feed end /entrance to the Preheater Tower, there is then a definite propensity for build ups to occur in the kiln inlet. These build ups contribute to an increase in pressure drop across the tower and lead to a reduction in the kiln production rate. Arawak has been able to increase it alkali level largely through selective mining of the shale ore reserves. This is not a sustainable situation with the finite reserves available and some other strategies have been used on a trial basis that have shown additional improvement. These strategies will be highlighted later in the paper.

The build ups can also be caused by operating conditions and temperature profiles which result in the condensation point for the volatiles being located in the inlet. Arawak has experimented with a number of flame configurations to counteract this condition. All indications thus far have shown positive improvements but the results are not fully conclusive.

. Blasters were installed to help remove the encrustations as they formed. The adequate performance of the blasters depends largely on the build up rate at the kiln inlet. Experiences have shown thus far that the rate of build up at the kiln inlet is directly dependent on the positioning of the kiln burner. There have been cases were a ¾" vertical movement on the burner resulted in the kiln moving from an 85% production rate to a 100% production rate within three hours.

Cardox ports have also been installed to allow us to use CO_2 cartridges to assist with online build up removal when the rate of build up is in excess of what the blasters can cope with or if the build up are in other areas of the tower that do not contain blasting points.

The refractory in the kiln inlet was changed to the coating rejecting castable, silicon carbide. This has shown limited success as the kiln still experiences slows due to high preheater pressures

The Orimulsion experience has shown that to get good performance from the pyro-processing unit attention to detail is extremely critical. Arawak has had to embark on frequent Air ingress minimization campaigns especially in the raw mill and electrostatic precipitator circuits and continuously examine its mode of cooler operation.

Clinker Quality

The clinker produced using Orimulsion® fuel has been of acceptable quality for the manufacture of ASTM Type I cement. The alkali content is usually in range of 0.75 - 0.9 percent provided there is no alkali deficiency in the raw mix.

Refractory Life

There has been significant improvement in the refractory life in the kiln. The performance of each zone will be discussed below:

Burning Zone:

Initially, the best life recorded in the burning zone was 6- 8 months. Many of the failures showed alkali sulphate salt infiltration[6]. This was not significantly different from what was achieved with Bunker "C" but was well below the industry standard. The use of a standard 200 mm magnesia chrome brick was maintained, together with improved control of the raw mix and burner positioning, and resulted in a burning zone refractory life of sixteen (16) months for the last campaign. It must also be noted that even at that stage more than half of the burning zone refractory showed 80% retained brick height (See Fig.9) at the end of that campaign and the lowest retained height was

60%.  Fig 9 Standard Mag. Chrome Brick

Cooling Zone

Arawak's previous best performance in the cooling zone was 4- 6 months. The brick quality used in the discharge was changed to a higher-grade alumina refractory and the brick length was increased from 200mm to 300 mm. The kiln shell and discharge design were changed in 2001. Shortly thereafter Arawak experienced frequent failures in this area and only after all the discharge segments were removed and refitted in 2003 did the refractory life improve to the 12 months that was achieved on the last campaign. It is therefore probable that they were other factors affecting the refractory life in this area other than the use of Orimulsion®.


Fig 10 High Alumina Brick

Emissions Performance

NO_x

The NO_x emissions with Orimulsion® are lower than the normal emissions with No. 6 Fuel Oil due in part to the lower Orimulsion® flame temperature. Normal NO_x emissions using Orimulsion are 300 - 500 mg/Nm^3 whereas the NO_x emissions on Bunker "C" would be in the 500 - 700 mg/Nm^3 range

SO_x

The SO_x emissions with Orimulsion® are similar to the normal emissions with No. 6 Fuel Oil. Normal C emissions using Orimulsion are 0 - 30 mg/Nm^3 whereas the SO_x emissions on Bunker "C" would be in the 0 - 40 mg/Nm^3 range.

Particulates

Arawak's electrostatic precipitator was designed for 100 mg/Nm^3 particulate emissions load. There has been a slight deterioration of the emissions when compared to Bunker "C" due to the significant corrosion that has occurred within the electrostatic precipitator.

Electrostatic Precipitator.

The other main plant item which has been significantly affected since the switch to Orimulsion® has been the electrostatic precipitator. This has caused an increase in the air ingress to the electrostatic precipitator and would adversely affect the precipitator's performance and the production capability of the pyro-processing and raw grinding systems. The Raw Mill ducting has also experienced some accelerated corrosion when compared to Bunker "C". It is believed that the presence of the water vapour and So_x in the gas stream are the main contributors to this level of corrosion.

Fuel Handling and Storage

Orimulsion® fuel must be stored and handled in a precise manner. All stock must be consumed on a first in first out basis with the maximum recommended storage time being four months. Control valves should not be used to control the flow as they may induce shearing. A better alternative for valve control is ball valves and these must be either fully opened or fully closed. Pumps with a low shear rate must be used to prevent the possibility of shearing the Orimulsion® and causing deteriorated Orimulsion®.

A slops tank must be included in all storage systems to hold any Orimulsion® which may return from the burner during burner lights since it must not be allowed to mix with the unused Orimulsion® in the storage tanks otherwise it could induce deterioration of the Orimulsion® in storage. During the conversion to Orimulsion® considerable attention must be paid to the design of the storage system to ensure that residual tank volumes will not result in deterioration of the product.

Key Performance Indicators

The clinker production rates have increased steadily since 1997 (see Fig 4) and in 2003 the plant was able to reach its nominal capacity for the first time in its operating history.

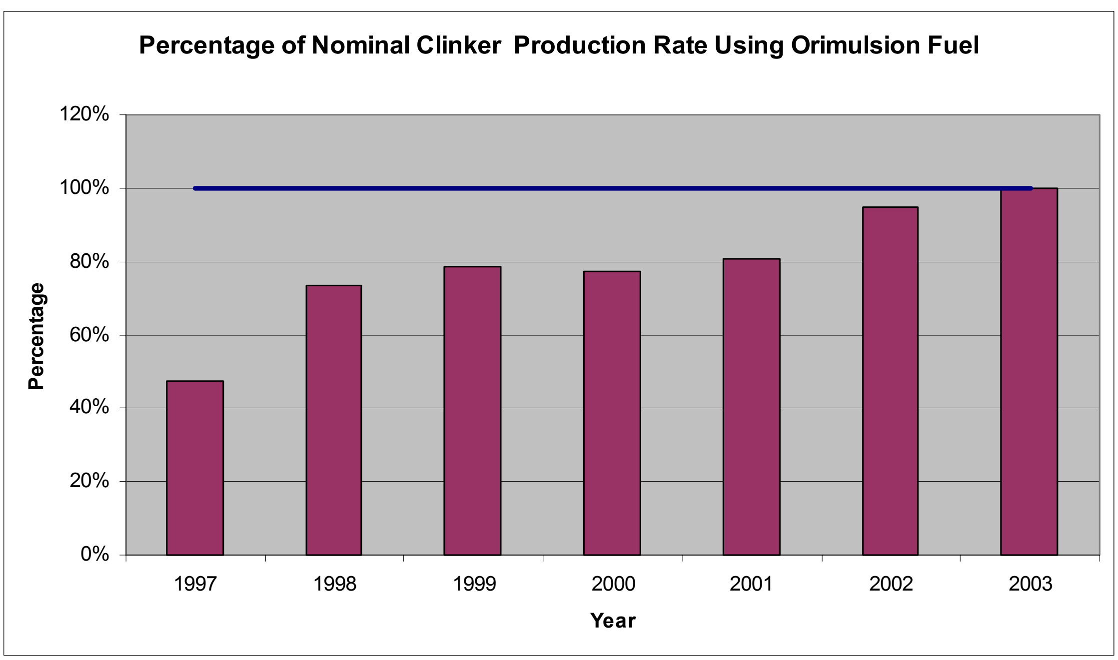
The Best Demonstrated Practice (BDP) on Orimulsion®for a few key production performance indicators is shown below

Kiln Production Rate: 1060 tonnes per day

Heat Consumption: 960 kcal/kg

Preheater Outlet Pressure: 41-43 mbar

Fig 11 Graph showing Percentage of Nominal Clinker Production by year since using Orimulsion®



Looking Forward

Riser Firing in the 5th Stage of our Preheater tower

A system has been installed and tested to burn fuel in the 5th stage of the Preheater tower. This will allow Arawak to experiment with various fuel mix combinations including waste oils, oil slops and Orimulsion®. This should result in more highly calcined material entering the kiln and a more stable burning zone operation.

Alkali addition

Arawak has started using alkali addition as a means of boosting raw meal that is deficient in alkali content. This addition is necessary to counteract the internal sulphur cycle, which was mentioned earlier in the paper. The high sulphur content of Orimulsion® is a significant contributor to this cycle. The alkali is added in powder form to the kiln feed bin to reduce the time lag between the alkali addition and realizing an improvement in the pressure drop within the Preheater Tower. A noteworthy benefit of alkali addition is that it will allow the use of previously non-ideal shale sources within our reserves and therefore will allow more of the mine to be recovered for cement production since selective ore recovery methods would not be necessary to get acceptable raw mix alkali content.

Conclusions

The key factor in the performance of the pyro-processing system when burning Orimulsion®, is the kiln burner. The overall burner configuration in terms of the flame shaping axial and radial air is very important in allowing some measure of control of the long and bushy Orimulsion® flame.

Due to the sulphur content in Orimulsion® the stoichiometric balance between all alkali and sulphate inputs is critical to achieving high production rates and avoiding any unplanned downtime due to plugging in the preheater tower. Invariably it will always be a minimum requirement to install online build up removal systems like blasters or Cardox ports to assist in cases where there is an alkali deficiency leading to an excess of sulphate.

Refractory life consistent with industry standards, is possible with Orimulsion® in all zones of the kiln. Arawak's best experience in the burning zone thus far has been sixteen (16) months.

Particular care and attention must be paid to the storage and handling of Orimulsion®.

In summary it is clear that the Arawak's experience has shown Orimulsion® has proven to be a suitable fuel for the manufacture of acceptable clinker quality.

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