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TERMODINÂMICA DE SISTEMAS LTDA


To**: Eng. Mark Zulauf**

**Company: Vega Bahia Tratamento de Resíduos SA.**

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**Fax.:**3.522/05 **From:** Sérgio Marcondes **Date**:04/08/05 **Page**: 01/ 11


**Ref.:** Technical assistance to start-up and operation of the enclosed flares supplied by BTS, to Vega Bahia, rendered days 16 and 17 December, 2.004.

Dear sirs,

Following the phone contacts kept with you and in attention to your request regarding the start-up of the enclosed flares system supplied by us, we have sent the engineer Sérgio Marcondes to your installations on the days above mentioned, aiming joint verification of the operation of the enclosed flares system and start-up of them, which report we send attached to this document.

In case of any question, we promptly stay at your disposal for the explanations that may come necessary.

Regards,

Sérgio Marcondes

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**Ref.: TECHNICAL ASSISTANCE REPORT.**

**DATE OF ASSISTANCE: 16 and 17 December of 2004**

**Site : Vega Bahia Tratamento de Resíduos SA Installations**
**Estrada Cia Aeroporto Km 6,5 – Salvador – BA.**

**PEOPLE AND COMPANIES ENVOLVED / PERIOD:**

**Vega - Eng. Mark Zulauf, Sebastião.**

**BPM : Eng. Sérgio Marcondes**

**EQUIPMENT INSTALLED: ENCLOSED FLARES FL-100/200/300**

**BASICS CHARACTERISTICS OF THE EQUIPMENT**

The three ENCLOSED FLARES supplied are identical and were dimensioned to burn gases from the landfill, in each one, through 06 (six) burners manufactured in stainless steel AISI 316, provided of elements to retain the flame at one burning level, automatically controlled through pressure / flow in the upstream of distribution Manifold.

For each unit, the progressive increasing of gases flow is controlled in the flow valve control in the installation, considering a maximum gases flow in the flare of 6.000 $m^3/h$ (around 5.360 $Nm^3/h$ ) at $50^oC$ of temperature .

The average composition of the gas considered was 55% (fifty five percent) of methane, with heat power of around 5.100 $kcal/Nm^3$ .

The system has condition to receive gases with up to 30% (thirty percent) of methane, i.e., a heat power minimum of around 3.000 $kcal/Nm^3$, in which a thermic capacity lower than this will be necessary utilization of an auxiliary gas of support for stabilization of the flame and obtain the required temperature of $850^oC$ for the complete gases combustion / thermoxidation.

The pipe to transport the gases to be burned is linked to the pipe of gases distribution inside each flare, with diameter of 16“ (sixteen) inches, manufactured in carbon steel schedule 40.

The six burners are equally distributed in relation to the enclosed chamber center, manufactured in stainless steel AISI 316, each one provided of sealing fluid against flame retrogression, disposed in its basis, in the internal floor of the chamber of combustion air distribution, in which is induced chamber depression, also manufactured with stainless steel AISI 316.

The enclosing, self supported, was dispatched in one piece, with thermic capacity up to

30.000.000 kcal/h, **having an external diameter of 3.400 mm and total height of 15.000mm.** The body was manufactured in steel plate of carbon steel, in two rings, having the first one ½" of thickness and the above with 3/8" of thickness. In its superior edge it has a reinforcing ring, finishing, and isolation protection against rain and acceleration exit of gases in stainless steel AISI 304.

In the inferior part of the flare, there are air/gas distributors installed, ignition pilot, admission of air of purge and air of combustion / dilution.

The combustion/dilution air control and consequently the flare operation temperature is pre fixed in the electric panel of command and control, in which the temperature foreseen to operate in the project is 850$^oC$, (minimum advised of 700$^oC$ and maximum of 1.100$^oC$) that once determined, is kept by the registration of window type set automatically for the air flow control and temperature desired for the operation of the thermic combustion/oxidation chamber.

The flares internal body was wrapped with ceramics fibers, 96 kg/$m^3$ of density, and thickness of 3" (three inches), fixed with stainless steel pivots AISI 310.

For the project operational temperature of 850$^oC$ in the isolation area with 03" the maximum external temperature foreseen will be of 124$^oC$.

The two admission valves of combustion / dilution air are controlled by a thermopar, in the 8.500mm level, that sends a signal for the temperature controller existent in the electric panel supplied, which sets in motion automatically the serving motor of the mentioned valves.

The available pressure in the gas compressors air exit was considered at most of 500 mmCa, in the enter of the side connection of gas distribution in the interior of the flare system.

Each one of the burners will have the burning capacity of 1.000$m^3$/h releasing up to 5.100.000 Kcal/h .

On the level of the six burning points, with external diameter of 8", aiming a better gases burning, is installed a diffusion ring, for a higher air / gases mixture, in the external chamber perimeter, with 100mm width, manufactured in stainless steel AISI 316. The distribution lines in the burners upstream part, in the enclosed inside part were manufactured is carbon steel schedule 40.

For the necessary purge of the system and eventually induction of a secondary combustion of air, was installed a centrifugal fan of high efficiency and low noises (max. of 85 dbA), with pipes linking to the inferior enclosing part, with maximum length of 1.500mm, started-up by electric engine of 03cv, with a project flow of 3.000$Nm^3$/h at static pressure of 120mmCa, having a clearing up time in the chamber from 03 to 05 minutes.

This fan is started through pulleys and belts by electric engine of 3cv, 04 poles, 380V, 60Hz.

The ignition system is done by a **continuous pilot of pre-mixture** and externally removable, working with LPG/biogas with capacity up to 80.000kcal/h, with an independent fan of

combustion air, installed transversally to the gas distribution line. The mentioned pilot can be removed for maintenance without needing to stop the flare operation.

The biogas for the pilot system must be supplied at pressure from 250 to 300 mmCa.

The verification of a existent flame is done by two photocells type “UV“, from Honeywell, operated automatically through a controlling programmer type “Honeywell“ series 7500 installed on the command and controlling panel.

In case of non ignition or flame failure, the photocell automatically will send a signal to the electronic programmer of the burner, which will stop the gas exit and will signalize a problem occurring in the pilot. After the light of the main flame with biogas, the second photocell, adequately disposed for that function, will monitor the main flame.

In the beginning of the operation, the programmer enters in the normal sequence of start, turning on the purge fan of the chamber, in which has its time pre-adjusted to 4 minutes. After the purge, the gas is released to the pilot and then the ignition spark is done. Once the flame is on and stabilized, the programmer will keep the pilot on and will send a signal for the progressive release of the gases to be burned, which is done through PLC and valves systems existent in the installation.

The project temperature for the oxidation is 850$^{o}$C, which will be made through burning of the landfill gas until the inferior limit of 30% of methane.

The 6 burners operate in regime of “on-off“ in function of the gas pressure/flow in the system upstream. The adjusted temperature of oxidation will be controlled by termopar and automatic action of the two valves of air dilution, each one with area of 2,16m$^{2}$ (1.800x 1.200mm).

The security system through the electronic programmer will be installed in our local panel, considered as a non classified area.

The counter pressure considered in the exit of the enclosed flare chamber will be (-) 80 to (-)100 mmCa.

**BASICS DIMENSIONS OF ENCOLSED FLARES**

**Total height of the set..........................................................................................15.000 mm**

**External diameter...................................................................................................3.400 mm**

**Isolation material – ceramic fibers 94 kg/m$^{3}$ of density, with total thickness 03”.**

External carcass .......................................................................................... carbon steel
Internal pipes ........................................................................................ carbon steel

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External pipes ........................................................................................ carbon steel
Burners ..................................................................................Stainless AISI 316
Rose-shaped of combustion air ................................................... Stainless AISI 316

**Burners basics characteristics**

| | |
|---|---|
| Application | Chamber of enclosed flare |
| Internal depression | (-) 50 to (-) 80 mmCA |
| Quantity of burners | 06 (six) |
| Maximum thermal capacity per burner | 5.100.000 Kcal/h |
| Type of fuel | Landfill gas (max. 55% and min. 30% methane) |
| Heat power of the gas at 55% of methane | 5.100 kcal/Nm$^3$ |
| Flame sensor | **"UV" photocell** |
| Modality | automatic |
| Operation | **on- off** |
| thermo par / temperature adjustment | Adjusted in the zone from 800 to 950$^o$C (max. 1.100$^o$C) |
| Working pressure for the landfill gas | 300 mmCA (in the entry of the flame arrestor) |
| Command tension | 220V - monophasic, 60Hz. |
| Action tension | 440V - triphasic , 60 Hz. |
| Action engine of the purge fan | 03 C.V. 04polo . 380V. |

**BIOGAS THERMO OXIDATION**

The calculation for each flare was made in order to obtain 100% of destruction of the methane in project and for that it was considered the minimum resistance time of biogas at a project temperature of 850$^o$C of 0.3 seconds.

Hence, for the passage area of 8,14m$^2$ and the available volume of 105,8m$^3$ (13.000mm x 3.222mm), considering 2.400 m$^3$/h methane gas, we would have in the estechiometry condition a heat release of 19.198.468 kcal/h.

The above heat quantity indicated has considered the project efficiency of 100% and the biogas with 40% of methane, corresponding to 2.400 m$^3$/h of $CH_4$ .

**Heat $Q_l$ = 1,523 kg/h x 12.600 kcal/kg = 19.198.468 kcal/h.**

**Where :** 2.400 m$^3$/h x 0,63487 = 1.523 kg/h of $CH_4$
Density of $CH_4$ = 0,63487 kg/m$^3$ (at 50°c and 50 mBar)
Specific heat above of the $CH_4$ = 13.265 kcal/kg
Specific heat inferior of the $CH_4$ = 11.942 kcal/kg
Average specific heat considered for $CH_4$ = 12.600 kcal/kg

For the estechiometric combustion of the $CH_4$ it's necessary 15,73kg of air for 1kg of $CH_4$.

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Resulting:

2.55 Kg of $CO_2$
2,03 kg of $H_2O$
12,17 Kg of $N_2$

Considering the project efficiency of 100%, we have as effluent gases of the flare:

AIR from estechiometric combustion - 1.523 kg/h x 15,73 = 23.967 Kg/h
N2 - 1.523 kg/h x 12,17 = 18.543 Kg/h (entering the combustion air)
$H_2O$ - 1.523 kg/h x 2,03 = 3.093 Kg/h (generated in the burning)
$CO_2$ - 1.523 kg/h x 2,55 = 3.885 Kg/h (generated in the burning)

**Considering the exit temperature of the gases in the project as 850$^o$C, we have:**

**Absorbed heat in the gases resulted from combustion**

$H_2O$ – 3.093 kg/h x1 kcal/ kg x70$^o$ C = 216.517 kcal/h (heating of the water up to 100$^o$C)
3.093 Kg/h x 2,036 kcal/ kg x 750 $^o$ C = 4.723.178 kcal/h (heat of water steam from 100 to 850$^o$C)
3.093 Kg/h x 540 kcal/Kg = 1.670.279 Kcal/h (water steaming at100$^o$C)

Where $C_{esp.\ average}$ = 2,036 kcal/ kg of $H_2O$ ($C_{esp.\ at\ 100°C}$ =1,759 kcal/ kg and $C_{esp.\ at\ 850°C}$ = 2,313 kcal/ kg)
*Obs: $C_{esp}$ = specific heat*

**Total heat absorbed by the water generated = 6.609.975 kcal/h.**

$CO_2$ – 3.885 kg/h x 0,305 kcal/ kg x 820$^o$ C = 971.746 kcal/h

$N_2$ - 18.543 kg/h x 0,275 kcal/ kg x 820 $^o$ C = 4.181.543 kcal/h

Where $C_{esp.\ average}$ = 0,275 kcal/ kg of $H_2O$ ($C_{esp.\ at\ 30°C}$ = 0,26 kcal/ kg and $C_{esp.\ at\ 850°C}$ = 0,29 kcal/ kg ).
*Obs: $C_{esp}$ = specific heat*

**Hence, the total theoretic heat absorbed in the gases generated in the combustion is: 11.763.264 kcal/h.**

**The heat generated in the burning of $CH_4$ -** $Q_t$ = 1.523 kg/h x 12.600 kcal/kg = 19.198.468 kcal/h.

Having the difference between the generated heat and the absorbed heat by the gases:

19.198.468 – 11.763.264 = 7.435.204 kcal/h (in each one of the flares)

For that residual heat absorption ($Q_r$) and to get the project temperature of 850°C it must be adopted in the system as dilution air in the flow of:

$Q_r$ =7.435.204 = $m_{air\ of\ dilution}$ x 0,25 kcal/kg x 820°C

$m_{air\ of\ dilution}$ = 36.269 kg/h of air of dilution.

Corresponding to the volume of 43.523 $Nm^3/h$ of air of dilution.

**As the estechiometric air of combustion is 23.967 Kg/h , the total mass of air will be adopted as 67.490 kg/h, corresponding to an excess of air of 181,6%.**

For a minimum time of remaining of the gases at 850°C, we have :

$N_2$ = 18.543 kg/h corresponding to 850°C at volume of = 18.543 Kg/h x 1,026 $m^3$/kg x 4,111 = 78.214 $m^3$/h at 850°C

$H_2O$ = 3.093 kg/h corresponding to 850°C at volume of = 3.093 Kg/h x 5,32 $m^3$/kg = 16.455 $m^3$/h at 850°C

$CO_2$ = 3.885 kg/h corresponding to 850°C at volume of = 3.885 Kg/h x 1,53 $m^3$/kg x 4,11 = 24.432 $m^3$ /h at 850°C

Air of dilution = 36.269 Kg/h corresponding to 850°C at volume of = 36.269 Kg/h x 1,2 kg/$m^3$ x 4,111 = 178.923 $m^3$/h at 850°C

As it was considered the biogas at a flow of 32% of $CO_2$ (biogas with 40% of methane) we will have a volume of $CO_2$ of 1.715 $Nm^3/h$ ; i.e. at 850°C :

1.715 x 4,111 = 7.050 $m^3$ /h at 850°C.

**Corresponding to a theoretic total flow of gases of: 305.076 $m^3$/h at 850°C.**

**Considering a safe coefficient of 15%, we have the project flow of gases = 350.000 $m^3$/h at 850°C.**

The free area of passage in the flare is:

$A = 3,14 \times D^2/4 = 0,785 \times D^2 = 8,14\ m^2$ (a free diameter of 3,22m).

The **total trajectory length of gases is 13m** and considering 2/3 of that length at an effective temperature of 850°C, we have a **minimum and safe time of remaining of**:

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Gases flow = 97 $m^3$/sec. at 850$^oC$.
Area of passage = 8,14$m^2$
Ascending gases velocity = 97 / 8,14 = 12 m/sec.

**Trajectory made = 13 x 2/3 = 8,66m resulting a minimum remaining time of 0,72 sec.**