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REPORT ON TESTS CARRIED OUT DURING USE OF THE "SUPER CATALYZER" MANUFACTURED BY VOSGES C/O TECHNICAL INSTITUTE PIERRE ET MARIE CURIE - MENTON DEPARTMENT : ELECTRICAL/GAS LABORATORIES - REGULATION - AIR CONDITIONING

TRANSLATED FROM THE FRENCH ORIGINAL

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super catalyzer ®™

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PART 1

INSTALLATION OF THE SUPER CATALYZER (CATALYZER SERIES 3000)

Installation is simple and rapid.
Male-female gas threads on the joint.
The equipment is installed in series on the feed line bringing gas to the burner, below the partialiser, regulation, control and safety units.

INFLUENCE OF OPERATION ON THE ENVIRONMENT

CONDUCT OF OPERATIONAL CYCLES

The influence of the magnetic field (10000 Gauss) on two important parameters has been examined :

1. the effect of magnetic field on the ionizing current, which is critical for good operation of the safety system in the presence of the burner flame;
2. the effect on the fuel of the magnetic field of the Catalyzer before and during combustion.

RESULTS OF INFLUENTIAL PARAMETERS - IONIZATION

The action of the magnetic field in terms of value and spectrum of the ionization current of the flame does not exert any modifying effect on these two parameters.

NOTE

- According to the manufacturer the emission of the magnetic field of the Super Catalyzer stops at a distance of ± 5 cm from the equipment.
- The equipment conforms with EEC norms (Directive n. 80 / 778 of the EC Council, 15 July 1980) for technological systems.

PARAMETERS EXAMINED DURING THE TESTS

COMBUSTION

- appearance of gas flames
- ionization current
- ambient temperature

- temperature to emissions of gas burnt
- percentage of residual O_2
- percentage of CO_2
- quantity of excess air
- CO content in ppm (parts per million) and in mg / mc
- NOX content in ppm (parts per million) and in mg / mc
- power supply used
- combustion losses
- combustion performance

OPERATION

- duration of tests
- quantity of sanitary hot water produced
- inlet temperature of cold water
- outlet temperature of sanitary hot water
- Δ t obtained
- quantity of gas used
- calorific power (inserted)
- useful power (recovered)
- operational performance
- gain

PART 2

A. REFERENCE TO NOTIONS OF COMBUSTION - EFFECT OF MAGNETIC FIELD ON COMBUSTION

1. USUAL COMBUSTIBLE GASES

<u>Nature of the gases forming one or more fuels :</u>

1. Hydrogen (H_2).
2. Saturated hydrocarbons [Methane (CH_4) - Ethane (C_2H_6) - Propane (C_3H_8) - Butane and Isobutane (C_4H_{10}) - Pentane (C_5H_{12})].
3. Unsaturated hydrocarbons [Ethylene (C_2H_4) - Propylene (C_3H_6) - Butene or Butylene (C_4H_8)].
4. Unsaturated hydrogens, not identified during analysis, of old production.

COMMENT

In gaseous fuels in feed pipelines, sulphur and its compounds are present only in trace quantities and they do not interfere in the combustion process, in contrast to what happens in the case of solid and liquid fuels.

Nature and composition of the gaseous fuels in the feed pipeline :

Natural Gases

- composed essentially of methane, they do not contain carbon monoxide and are not toxic;
- natural gases are classified in two types :
    1. those of type H, with calorific power > 10 Kwh / mc $_{(n)}$
    2. those of type B, with calorific power < 10 Kwh / mc $_{(n)}$

COMMENT

In the next decade all natural gases will be of type H.
They will always be used in the gaseous phase for combustion at 10,2 Kwh / mc $_{(n)}$ PCI.

Petroleum gases or LPG (liquefied Propane Gas)

Butane and Propane are produced mainly during crude oil refining, but they are also present in moderate quantities in some natural gas wells.

COMMENT

Commercial Butane and Propane are not pure compounds, but mixtures.
They do not contain carbon monoxide and are not therefore toxic.

2. THEORETICAL COMBUSTION TEMPERATURE

Definition
The theoretical combustion temperature is defined as that which the combustion products would attain if all the heat produced by the reaction were used to heat them.

Determination
Combustion always takes place in the presence of heat loss : therefore the subject temperature is in practice never attained (it can only be calculated).

COMMENT

Starting from 1700°C the products of complete combustion CO_2 and H_2O, partly dissociate and CO, H_2 and O_2 appear.

The degree of dissociation depends of the temperature and the amount of inert substances present (CO_2 - N_2). Theoretical combustion temperature is as follows :

natural gas	1950°C	in air and 2780°C in oxigen
LPG	≈ 2010°C	in air and 2840°C in oxigen

3. FUNDAMENTAL DEFLAGRATION VELOCITY

Detonation or deflagration

The combustion chain reaction can be propagated in two ways :

1. ***Detonation***

   This does not take place with mixtures of air and combustible gases distributed in a normal way.

COMMENT

This phenomenon, due to heating of gaseous layers by the compression created in the reacting layers, gives rise to significant detonation (propagation) velocities (often in the order of many Km / s.

2. ***Deflagration***

   This is the phenomenon usually met with in gas flames, it is much less rapid than detonation and starts off two processes :

   a) heating by conduction (between layers of mixture undergoing reaction and those nearby, composed of mixture not yet unburnt),

   b) diffusion of free radicals (diffusion towards the layer not yet unburnt).

COMMENT

The deflagration velocity depends on the diffusion of free radicals (group of active and unstable atoms) and their attitude towards stopping the reactions.

EXAMPLE

Deflagration velocity of an air-gas mixture in state of laminar flow (expressed in m / s, simbol V_F) :

	V_F (air - gas) m / s	V_F (oxigen – gas) m / s
Methane	0,38	3,20
Carbon monoxide	0,45	1,00
Propane	0,43	3,60
Hydrogen	2,50	8,90

Note the higher velocities in the mixtures of combustible gases with oxigen.

COMMENTS

The variation in the deflagration velocity depends therefore :

1. the air factor
2. the temperature of combustible gas - air (or oxigen)
3. the diffusion velocity of the free radicals.

COMMENTS

A. Increased risk of backfire on a burner with premixing at high temperature (above all with gases having a high fundamental deflagration velocity).

B. Difficulty in cold starting the flame in a closed space where it enters and becomes stable when stabilizes at hot (for gases with a low deflagration velocity).

C. Mixture flow velocity too low as compared with deflagration, leading to ignition at the level of the injector (atmospheric burner).

D. Mixture flow velocity too high as compared with deflagration, leading to removal of the flame.

B. EFFECT OF MAGNETIC FIELD ON THE FUEL

1. **SCIENTIFIC** PRINCIPLES

Before the combustion process, the effect of the magnetic field is felt through a reduction in the energy of the link between atoms of carbon and hydrogen.
This reduction signifies a greater availability of these atoms in a particularly reactive mode, which is defined as “radical” (free radicals).
During the process of combustion with the oxigen of the air, intermediate compounds are formed, the “peroxides”, which react further with the unburnt gas and bring other energy to the system, increasing the deflagration velocity.
This deflagration velocity is critical in fixing the length of the flame (greater velocity and shorter the flame).

<u>NOTE</u>

The value of the temperature of the flame, it will be more perfect than the theoretical maximum temperature as the flame will be more concentrates.

2. PRACTICAL EFFECTS ENVISAGED

As a consequence of any modification (in deflagration velocity) the following effects are obtained :

- reduction in flame length
- modification of emission properties
- oxidation of eventual unburnt substances
- recovery of any chemical energy still available in the unburnt substances
- combustion process with a smaller excess of air
- less notable formation of unburnt substances which affect the level of CO (carbon monoxide)
- a similar effect on formation of nitrogen oxides (NOX) in certain burners
- improved combustion and operational performance.

3. COMMENTS

All this may be considered as an improvement of the practical reaction conditions in the combustion process, such as to obtain a more complete and effective recovery of energy,

without this improvement being affected by negative secondary effects.
In this way an improvement in the usual value of the lower calorific power (LCP) on the fuel is obtained, this latter is an index used by combustion technicians.

IMPORTANT COMMENT

- The compounds NO and NO_2 are grouped under the same symbol NOX (nitrogen oxides).
- The NOX are produced by the reaction between nitrogen (N_2) and oxigen (O_2) contained in the air involved in the combustion, during the oxidation reaction.
- The NOX vary in quantity depending on flame temperature, excess of air, journey time through the flame front (deflagration velocity).

REGULATION OF NOX EMISSIONS

The European norm EN 297 divides burners into 4 groups, according to their NOX emissions.

Example :

for the domestic G.20

CLASS	NOX CONTENT mg/Kwh	ppm	NOTE
1	260	147	Currently, these classes have no legal value; they only give an indication of the quality of combustion provided by the equipment.
2	200	113	
3	150	85	
4	100	57	

C. ANALYSIS AND CALCULATIONS

Control materials used

For calculation of the trials and combustion tests an electronic calculator, type 2000CD MRU Delta, was used.

THE FOLLOWING PARAMETERS WERE MEASURED BY THE EQUIPMENT

- O_2 (oxigen) as %
- CO (carbon monoxide) in ppm and mg/mc
- NO (nitric oxide) in ppm and mg/mc
- NOX (nitrogen oxide) in ppm and mg/mc
- temperature of ambient and of burnt gases, in °C

THE FOLLOWING PARAMETERS WERE CALCULATED BY THE EQUIPMENT

- CO_2 (carbon dioxide) as %
- Combustion losses as %
- Eta (combustion efficiency) as %
- Lambda (excess of air) as %

NOTE

The values obtained have been grouped in a single document, to facilitate comparisons and the relief of their eventual evolutions.

PART 3

First series of tests

A. MATERIALS AND EQUIPMENTS

For the first series of tests, the materials and equipments were those normally used on the Electrogas platform.
The use of low-output equipment was our choice.

EQUIPMENT :
ground-level boilers, fitted with forced air gas burners.

STATION 1

- Ground-level boiler, Viessman make, Rotola type, heating and SHW (sanitary hot water) (SHW produced with an integrated 70 l accumulator in the lower part of the boiler, with recirculation pump). Nominal power : 60 Kw.

- Forced air gas burner, Korting make, VTO-G type with adjoining gas block system. Nominal power : 50 Kw.

STATION 2

- Ground-level boiler, Weishaupt make, Pyria type, heating and SHW, (sanitary hot water) (SHW produced with a 60 l accumulator). Nominal power : 35 Kw.
- Forced air gas burner, Cuenod make, C5 type. Nominal power : 35 Kw.

STATION 3

- Ground-level boiler, Sacamatic make, heating and SHW, (sanitary hot water) (SHW produced with an integrated 60 l accumulator). Nominal power : 28 Kw.
- Forced air gas burner, Joannès make, AZ GAZ 5 type.
  Nominal power : 50 Kw.

COMPARATIVE TESTS WITH AND WITHOUT CATALYZER
FOR COMBUSTION EFFICIENCY

	EQUIPMENTS WITHOUT CATALYZER			EQUIPMENTS WITH CATALYZER					
				w/o reg.	with reg.	w/o reg.	with reg.	w/o reg.	with reg.
PARAMETERS	Station 1	Station 2	Station 3	Station 1	Station 1	Station 2	Station 2	Station 3	Station 3
Temp. of burnt gases	241°C	220°C	220°C	230°C	210°C	218°C	210°C	214°C	190°C
O_2 content in %	1,3%	2,4%	4,4%	5,5%	1%	3%	0,9%	5,7%	2%
CO_2 content in %	11%	10%	9%	9%	11,4%	10,5%	11,4%	8,7%	10,7%
Excess air in %	6%	10%	26%	30%	5%	20%	4%	36%	10%
CO content in ppm and mg/mc	22 ppm 27 mg/mc	20 ppm 24 mg/mc	79 ppm 98 mg/mc	35 ppm 43 mg/mc	25 ppm 30 mg/mc	23 ppm 28 mg/mc	16 ppm 19 mg/mc	84 ppm 104 mg/mc	40 ppm 50 mg/mc
NOX content in ppm and mg/mc	44 ppm 60 mg/mc	49 ppm 67 mg/mc	30 ppm 40 mg/mc	30 ppm 41 mg/mc	30 ppm 40 mg/mc	46 ppm 60 mg/mc	39 ppm 59 mg/mc	26 ppm 35 mg/mc	21 ppm 30 mg/mc
Combustion losses	9,5%	10%	10%	10,4%	8%	9%	8%	9,7%	7,5%
Combustion efficiency	90,5%	90%	90%	89,6%	92%	91%	92%	90,3%	92,5%
Temp. heating water	80°C	75°C	70°C	80°C	80°C	75°C	75°C	70°C	70°C
Nominal power	60 Kw	35 Kw	28 Kw	60 Kw	60 Kw	35 Kw	35 Kw	28 Kw	28 Kw
Regulated power	50 Kw	25 Kw	28 Kw	50 Kw	50 Kw	25 Kw	25 Kw	28 Kw	28 Kw
Ionization current in mA	25	22	7	23	23	21	21	5	6
Relative gas pressure	18 mb	18 mb	18 mb	18 mb	18 mb	18 mb	18 mb	18 mb	18 mb
Dynamic pressure	13 mb	15 mb	16 mb	13 mb	13 mb	15 mb	15 mb	13 mb	13 mb

NOTE

Regulation is understood to mean regulation with a simple air partializer.
The equipments are in a good state of maintenance.

Second series of tests

B. MATERIALS AND EQUIPMENTS

STATION 4

- Wall boiler, manufacturer Styx, Duo Compact/Codex type.
  Category II 2-3 BIIs, natural gas.
  23/45 I : mixed ionized heating with 45 l SHW accumulator, atmospheric burner. Class 1.
  Nominal power 23 Kw.

STATION 5

- Wall boiler, manufacturer Chaffoteaux and Maury, Nectra CF type.
  Category II 2-3 BIIs, natural gas.
  Instantaneous SHW production with plate-type exchanger.
  Nominal power 23,25 Kw.

STATION 6

- Wall boiler, manufacturer Frisquet, Hydro TGP type (Very High Performance). Category II 2-3 BIIs, natural gas.
  SHW production.
  Nominal power 23 Kw.

NOTE

The above generators were in excellent operational condition.

RESULTS OF COMBUSTION TESTS ON WALL-TYPE BOILERS

1B* 2B 3B

1B* WALL-TYPE BOILER, MANUFACTURER STYX, COMPACT/CODEX TYPE

COMPARATIVE TESTS WITH AND WITHOUT CATALYZER FOR COMBUSTION EFFICIENCY

STATION 4

PARAMETERS	WITHOUT CATALYZER	WITH CATALYZER	NOTES
Burnt gas temperature	156°C	120°C	Reduction in temperature of burnt gases (36°C).
O_2 content in %	5,7%	6,8%	Increase in O_2 content (≈ 1%).
CO_2 content in %	8,7%	8,1%	Reduction of CO_2 content (0,6%).
Combustion losses	7%	5,6%	Reduction of combustion losses (1,4%).
Combustion efficiency	93%	94,5%	Increase in efficiency (+1,5%).
CO content in ppm and mg/mc	52 ppm 64 mg/mc	24 ppm 30 mg/mc	Reduction of CO content.
NOX content in ppm and mg/mc	73 ppm 110 mg/mc	70 ppm 100 mg/mc	Negligible negative evolution.
Excess air in %	35%	50%	Increase in excess air (+15%).
Ionization current, mA	10 mA	11 mA	Stable ionization current.
Temp. at inlet	21°C	19°C	
Δt SHW	55°C	57°C	
Accumulator capacity	45 l	45 l	
Temp. increase time, SHW	7 mn	7 mn	Improved Δt function.

NOTE

No improvements or adjustments were made, only the Catalyzer was installed.

This is a new-generation boiler, with only a few hours' operation.

RESULTS OF COMBUSTION TESTS ON WALL-TYPE BOILERS

1B 2B* 3B

2B* WALL-TYPE BOILER, NECTRA CF TYPE - HEATING + SHW

COMPARATIVE TESTS WITH AND WITHOUT CATALYZER FOR COMBUSTION EFFICIENCY

STATION 5

PARAMETERS	WITHOUT CATALYZER	WITH CATALYZER	NOTES
Burnt gas temperature	128°C	110°C	Reduction in temperature of burnt gases.
O_2 content in %	6%	7,3%	Increase in O_2 content.
CO_2 content in %	7,8%	7,5%	Reduction of CO_2 content.
Combustion losses	8%	5%	Reduction of combustion losses.
Combustion efficiency	92%	95%	Increase in efficiency.
CO content in ppm and mg/mc	23 ppm 28 mg/mc	18 ppm 22 mg/mc	Reduction of CO content (slight).
NOX content in ppm and mg/mc	85 ppm 116 mg/mc	80 ppm 110 mg/mc	Reduction of NOX content (slight).
Excess air in %	45%	54%	Increase in excess air.
Ionization current, mA	1,5 mA	1,5 mA	Stable ionization current.

NOTE

No improvements or adjustments were made, only the Catalyzer was installed.

This is a new-generation boiler, with only a few hours' operation.

<u>RESULTS OF COMBUSTION TESTS ON WALL-TYPE BOILERS</u>

1B 2B 3B*

3B* ***WALL-TYPE BOILER, HYDRO TGP TYPE***

COMPARATIVE TESTS WITH AND WITHOUT CATALYZER
FOR COMBUSTION EFFICIENCY

STATION 6

PARAMETERS	WITHOUT CATALYZER	WITH CATALYZER	NOTES
Ambient temperature	18,6°C	19°C	
Burnt gas temperature	106°C	95°C	Reduction in temperature of burnt gases.
O_2 content in %	4,1%	5,6%	Increase in O_2 content.
CO_2 content in %	9,6%	8,8%	Reduction of CO_2 content.
Combustion losses	4,5%	3,7%	Reduction of combustion losses.
Combustion efficiency	95,5%	96,3%	Increase in efficiency.
CO content in ppm and mg/mc	5 ppm 6 mg/mc	3 ppm 3 mg/mc	Reduction of CO content (slight).
Tenore in NOX ppm e mg/mc	120 ppm 165 mg/mc	118 ppm 162 mg/mc	No practical effect.
Excess air in %	25%	36%	Increase in excess air.

<u>NOTE</u>

No improvements or adjustments were made, only the Catalyzer was installed.

This is a new-generation boiler, with only a few hours' operation.

SUMMARY OF OPERATIONAL EFFICIENCIES DETERMINED

4B* 5B 6B

4B* Equipment HYDRO TGP (Very high performance) 23 Kw

NOTE

3 operational tests were run, for a duration of 3 x 60 min. (3 hours).

	WITHOUT CATALYZER		WITH CATALYZER
Parameters measured	Manufacturer specification	Operation	Operation
Lenght of test	60 mn	60 mn	60 mn
SHW quantity produced	12,5 l/mn 750 l/h	15 l/mn 900 l/h	15 l/mn 900 l/h
Cold water temperature		17°C	17°C
Hot water temperature		42°C	45°C
Δt	30 k	25 k	25,3 k
Gas consumed	2640 l/h	2661 l/h	2526 l/h
Burner power	31,32 Kw	31,57 Kw	29,97 Kw
Useful power installed	26,1 Kw	26,1 Kw	26,4 Kw
Combustion efficiency	94%	95,6%	96,3%
Operational efficiency	83% - SHP	82,7% - SHP	88% - SHP
% gain in SHP		- 0,3	+ 5,3

IMPORTANT NOTE

Gain in operational efficiency - SHP

- In report to the manufacturer's data - without Catalyzer - 0,3%
- In report to the manufacturer's data - with Catalyzer + 5,0%
- In report to tests with and without Catalyzer + 5,3%

SUMMARY OF OPERATIONAL EFFICIENCIES DETERMINED

4B 5B* 6B

5B* Equipment WALL-TYPE GENERATOR 5, MANUFACTURER STYX, CODEX TYPE - HEATING + SHW

NOTE

3 operational tests were run, for a duration of 3 x 60 min. (3 hours).

	WITHOUT CATALYZER		WITH CATALYZER
Parameters measured	Manufacturer specification	Operation	Operation
Lenght of test	60 mn	60 mn	60 mn
SHW quantity produced	13,3 l/mn 798 l/h	15 l/mn 900 l/h	15 l/mn 900 l/h
Cold water temperature		20°C	19°C
Hot water temperature		40,5°C	39,5°C
Δt	25 k	20,5 k	20,5 k
Gas consumed	2720 l/h	2600 l/h	2373 l/h
Burner power	32,27 Kw	30,8 Kw	28,15 Kw
Useful power installed	23,14 Kw	21,4 Kw	21,4 Kw
Combustion efficiency	91,3%	93%	94%
Operational efficiency	71,27% - SHP	70% - SHP	76% - SHP
% gain in SHP		- 1,27	+ 4,73

IMPORTANT NOTE

Gain in operational efficiency - SHP

- In report to the manufacturer's data - with Catalyzer + 4,73%
- In report to tests with and without Catalyzer + 6%

SUMMARY OF OPERATIONAL EFFICIENCIES DETERMINED

4B 5B 6B*

6B* Equipment NECTRA GENERATOR, 23 KW, HEATING + SHW

NOTE

3 operational tests were run, for a duration of 3 x 60 min. (3 hours).

	WITHOUT CATALYZER		WITH CATALYZER
Parameters measured	Manufacturer specification	Operation	Operation
Lenght of test	60 mn	60 mn	60 mn
SHW quantity produced	11 l/mn 660 l/h	14 l/mn 840 l/h	14 l/mn 840 l/h
Cold water temperature		25°C	25°C
Hot water temperature		50°C	50°C
Δt	30 k	25 k	25 k
Gas consumed	2,73 mc/h	2,7 mc/h	2,46 mc/h
Burner power	32,40 Kw	32 Kw	29,18 Kw
Useful power installed	23 Kw	24,36 Kw	24,36 Kw
Combustion efficiency	90%	92%	95%
Operational efficiency	71% - SHP	76% - SHP	83,5% - SHP
% gain in SHP		+ 5	+ 12,5

IMPORTANT NOTE

Gain in operational efficiency - SHP

- In report to the manufacturer's data - without Catalyzer + 5%
- In report to the manufacturer's data - with Catalyzer + 12,5%
- In report to tests with and without Catalyzer + 7,5%

PART 4

CONCLUSION OF THE FIRST SERIES OF TESTS

GROUND GENERATORS - FORCED-AIR GAS BURNERS

From the examination of the tests and comparisons carried out on ground-level boilers and forced-air burners, it can be concluded that the "Super Catalyzer by VOSGES" (series 3000) in all the cases studied has allowed :

I. Significant modification and increase of the residual O_2 content.

II. Reduction of the exit temperature of burnt gases (without modifying gas flow).

III. Reduction or maintenance of the CO and NOX content in the original values of the equipment.

IV. No modification of the spectrum and value of the ionization current (very important for flame safety systems).

V. Improvement of combustion efficiency, after modifying the volume of air admitted to support combustion.

NOTE

The tests were carried out on equipment in good operational condition and of recent conception.

- The only modifications effected : regulation of air flow without supplementary accessories.

CONCLUSION OF THE SECOND SERIES OF TESTS

WALL-TYPE GENERATORS - INDUCTION BURNERS

From the examination of the tests and comparisons carried out on wall-type generators fitted with “Super Catalyzer by VOSGES” (serie 3000), it can be concluded in most of the cases studied the following results are obtained :

- Reduction of the exit temperature of burnt gases.
- Increase of the residual O_2 content.
- Reduction of the CO_2 content.
- Reduction of the CO content.
- Slight reduction of the NOX content.
- Increase in the excess of air.
- A stable value of the ionization current.
- An improvement in combustion efficiency.

The operational gains are in the range :

5 to 12,5% depending on the model of generator.

These were obtained without modifying the regulation, and without supplementary accesories of any type.

This summary demonstrates therefore the positive influence of the Catalyzer on the set of problems connected with the improvement of combustion in general, that is, with the environment.
A further improvement is obtained, of significant importance, in the operational gains for the equipment and systems for heating purposes and sanitary hot water production.

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Menton, 6 May 1998