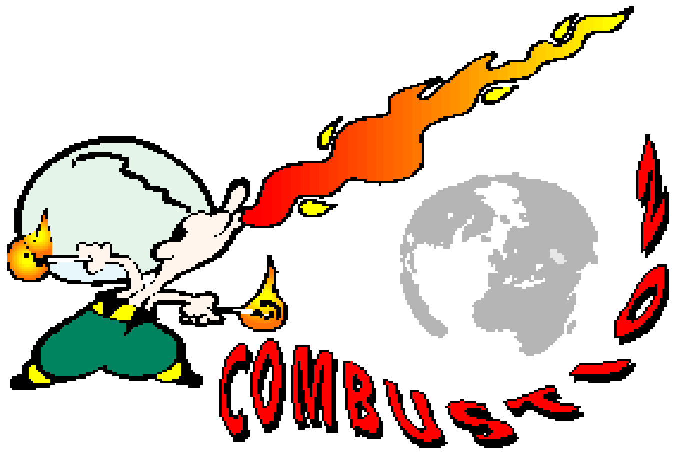
LAFARGE



Combustion Audit

COMBUSTION AUDIT

1. COMBUSTION AUDIT CONTENT

1. INTRODUCTION

In the introduction, the expert will mention:

- the context of the plant in which the combustion audit was made (who, when, where)
- the objective and scope of the audit, and the people involved
- the conduct of the audit and the particular areas investigated.

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2. RECOMMENDATIONS

On the basis of the results and observations made, the expert will set up the recommendations. They should include an action plan describing what should be done in terms of combustion to bring the plant closer to the Technical Plan targets and will define the priorities.

The expert will indicate what actions are required and will give an estimate of the costs involved and the work schedule.

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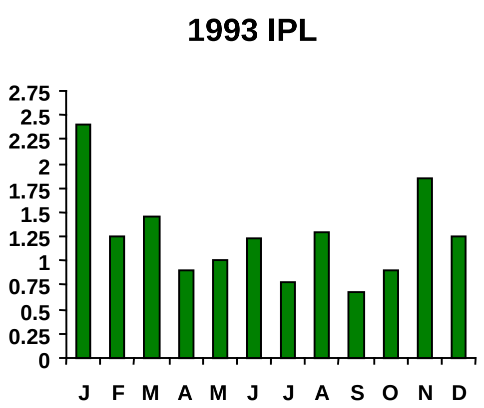
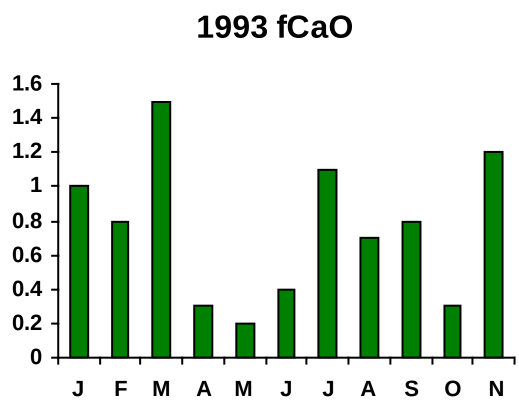
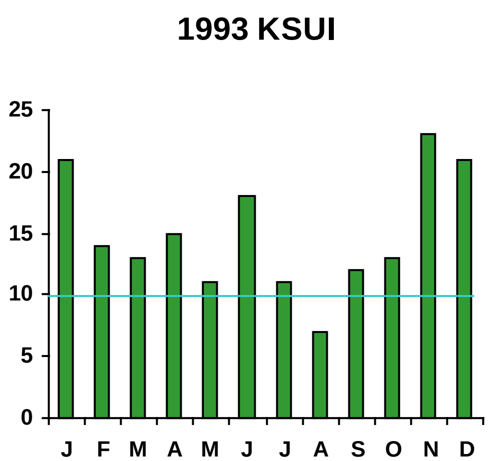
3. SUMMARY OF THE MAIN RESULTS

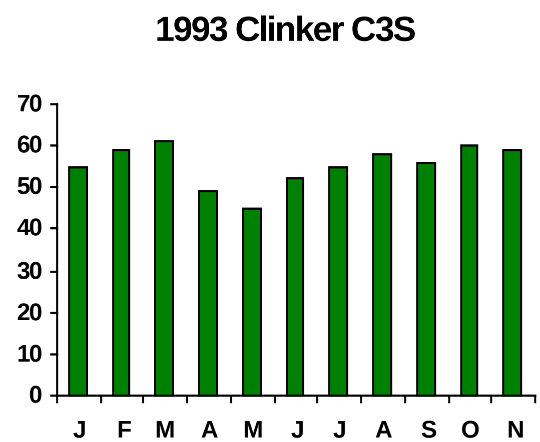
Audit areas	**Favorable**	**Unfavorable**	**Plant Results**	**Comments**
Raw mix combination capability	> 80	< 50		
Sulfur / alkali molar ratio	< 1.2	> 1.2		
Free lime average	> 0.8	< 0.5		
Raw mix C_3S IPL / last 12 months	< 12	> 16		
% of solid fuel 200µm rejects	< 0.1	> 1		
Use of kiln outlet SO_2 or kiln inlet SO_3	yes	no		
Use of Shell/T scanner	yes	no		
24 hour measurements	**Good**	**Poor**	**Plant Results**	**Comments**
Kiln outlet O_2 standard deviation	< 0.3	> 0.5		
Average kiln outlet CO in ppm	< 150	> 500		
Number of peaks > 1000 ppm (kiln outlet)	< 3	> 10		
Results	**Very good**	**Need to be improved**	**Plant Results**	**Comments**
Clinker C_3S IPL of the audit month	< 10	> 14		
Clinker C_3S variance of the audit month	< 14	< 18		
IRSO3 of the audit month	< 10	> 14		
Free lime standard deviation of the audit month	> 0.2m + 0,1	> 0.4 + 0.1		
Clinker reactivity in terms of R7/W	> 1.2	< 1		
How many kiln shut-downs due to refractory	≤ 1	> 2		
Annual number of electrofilter releases on CO peaks	< 33	> 10		

4. MAIN INDICATORS









APPENDICES

	OBTAINED	NOT OBTAINED
1. MATERIAL TESTING		
1.1 RAW MIX Kiln feed (sampling during audit)		
1.1.1 Parameters		
Elemental composition		
SiO_2	....	....
Al_20_3	....	....
Fe_20_3	....	....
CaO	....	....
MgO	....	....
t SO_3	....	....
K_2O	....	....
Na_2O	....	....
F	....	....
C_3S	....	....
LSF, Δbc, KST, KH	....	....
S/A+F	....	....
A/F	....	....
Average sample and fuel ash combination capability	....	....
Fineness > 90 µm	....	....
> 200 µm	....	....
1.1.2 C_3S IPL UNIFORMITY		
On daily grab sample:		
Monthly SiO_2 Standard deviation over 12 months	....	....
Monthly Al_20_3 Standard deviation over 12 months	....	....
Monthly Fe_20_3 Standard deviation over 12 months	....	....
Monthly CaO Standard deviation over 12 months	....	....
Monthly evolution of raw mix C_3S PLI – Comment over 12 months	....	....
1.1.3 Others		
Are mineralizers or substitution materials used?	....	....
Does raw mix contain carbon or combustion matters?	....	....
Particle-size distribution of quartz in raw mix	....	....

	OBTAINED	NOT OBTAINED
1.2. Clinker An average audit sample		
1.2.1 Chemical analyses		
SO_3	....	....
K_2O	....	....
TiO_2	....	....
Na_2O	....	....
SO_3/Alcali	....	....
Free CaO	....	....
Delta K, LSF, KST, KH, MS	....	....
LSF	....	....
KST	....	....
C_3S	....	....
C_3A	....	....
C_2S	....	....
C_3S variance	....	....
1.2.2 Microscopy		
% Alite	....	....
% Alite/C_3S	....	....
% Belite	....	....
C_3A	....	....
d25µm alite	....	....
d25µm belite	....	....
d50µm alite	....	....
d50µm belite	....	....
d75µm alite	....	....
d75µm belite	....	....
ONO alite	....	....
ONO belite	....	....
1.2.3 Fineness		
Passing 20 mm mesh	....	....
Passing 50 mm mesh	....	....
Passing 80 mm mesh	....	....
Fines smaller than 2.5 mm	....	....

	OBTAINED	NOT OBTAINED
1.2.4 BB10 grindability, strength, reactivity		
Laboratory tests : (*)		
kWh/t 2500 BSS	....	....
kWh/t 3000 BSS	....	....
kWh/t 3500 BSS	....	....
kWh/t 3800 BSS	....	....
R7/W evolution	....	....
Production R28/W evolution for the purest cement (indicate type and percentage of additions)	....	....
1.2.5 Strength		
1-d	....	....
2-d	....	....
7-d	....	....
28-d	....	....
1.2.6 IRSO3, free lime, clinker SO_3		
Average monthly values over last 12 months:		
IRSO3	....	....
Free lime mean	....	....
Clinker C_3S IPL (**)	....	....
C_3S mean	....	....
Free lime standard deviation	....	....
Clinker C_3S variance	....	....

(*) R/7W with gypsum-added grinding aid.

(**) calculated on fictitious raw mix having no LOI (without coal ashes) and no fCaO.

	OBTAINED	NOT OBTAINED
1.3 Fuels		
1.3.1 Liquid fuels		
Characteristics:		
Type	....	....
Temperature for 370 cSt viscosity	....	....
Temperature for 25 cSt viscosity	....	....
LHV	....	....
Water content	....	....
Sulfur content	....	....
Nitrogen content	....	....
Chlorine content	....	....
Flash point	....	....
Solid particle content	....	....
% thermal units (l/h)	....	....
1.3.2 Residual liquid fuels		
Characteristics:		
Type	....	....
Injection temperature	....	....
LHV	....	....
% water	....	....
% sulfur	....	....
% nitrogen	....	....
% chlorine	....	....
Flash point	....	....
% solid particle	....	....
% thermal units (l/h)	....	....
1.3.3 Gaseous fuels – Gas characteristics		
Type	....	....
Available pressure (bar)	....	....
Intake temperature	....	....
LHV	....	....
Regulator feed pressure (bar)	....	....
Regulator temperature, °C	....	....
Usual injector feed pressure (bar)	....	....
min	....	....
max	....	....

	OBTAINED	NOT OBTAINED
1.3.4 Solid fuels		
1.3.4.1 Elemental analysis		
Type (indicate the existence of a mix or impurities)	....	....
LHV	....	....
VM	....	....
Raw ash content (on dry pulverized coal)	....	....
Ash analysis	....	....
C	....	....
H	....	....
O	....	....
N	....	....
S	....	....
Hardgrove Index	....	....
1.3.4.2 Burner pipe fuel fineness		
Grading		
> 63 µm	....	....
> 90 µm	....	....
> 200 µm	....	....
> 1 mm	....	....
1.3.4.3 Uniformity		
Assessment of the supply variations determined from the analysis on as-received or dry product (standard deviation of ashes, LHV / monthly values over 1 year)	....	....
Check and integrate the drying gas dust impact on the ash volume	....	....
1.3.4.4 Moisture		
Average raw fuel water content	....	....
Average kiln inlet fuel water content by differentiating between surface moisture and bound water	....	....
Are there any drying problems, even occasionally ?	....	....
Are there any pulverized coal silo extraction problems (bridging, sticking) ?	....	....

	OBTAINED	NOT OBTAINED
1.4 Conclusions		
General impression of raw material uniformity: If the raw material is irregular, it will be difficult to qualify combustion and burning If the fuel is irregular, it is likely that poor combustion will result		
1.4.1. Strong points		
Provide a list of the good points of the raw materials :		
1.4.2 Weak points		
Are the raw materials known to be difficult to burn (quartz) or irregular or both? Is fuel preparation difficult?		
2. SHOP DESCRIPTION		
2.1 Burning		
Installation characteristics (flow-sheet required):		
Supplier...	....	....
Type	....	....
Production (t/day) (CKHC	....	....
Kiln dimension (L/D)..	....	....
Heat distribution :		
Kiln	....	....
Precalciner or grate	....	....
Others..	....	....
Cooler type..	....	....
Number of grates...	....	....
Heat consumption, kJ / kg of clinker (CKHC)..	....	....

	OBTAINED	NOT OBTAINED
## 2.2 Fuel preparation installation		
### 2.2.1 Liquid fuels		
Flow-sheet required	....	....
Tank drawing-off condition		
Temperature °C..	....	....
Filtration mesh, µm..	....	....
First pumping stage discharge pressure	....	....
Pulverization conditions:		
2nd stage filtration mesh, µm	....	....
2nd stage discharge pressure	....	....
2nd stage reheating temperature	....	....
Pressure range used : min. Bar..	....	....
max. Bar	....	....
Flow range used (excluding firing):		
min. kg/h	....	....
max. kg/h...	....	....
Injector type (mechanical or assisted)...	....	....
Are the injector ends modified to produce the proper flow?..	....	....
How?..	....	....
Eventual pulverization fluid, kg/h...	....	....
Pulverization fluid pressure	....	....
Pulverization fluid flow (specify measurement conditions)...	....	....
Injection condition stability (with respect to instructions)..	....	....
Is the flow regular?	....	....
Liquid injection pressure, bar...	....	....
Injection temperature, °C	....	....
Flow, %..	....	....
Any burner flushing, cleaning, during short-duration kiln shot-downs?	....	....

	OBTAINED	NOT OBTAINED
2.2.2 Residual liquid fuels		
% of thermal units	....	....
l/h	....	....
Flow sheet required (preparation, mix, conveying, injection point)	....	....
Report any residue utilization problem	....	....
Frequent supply shortage	....	....
Type of injector	....	....
Type of pump	....	....
Range of residue flow variations	....	....
Variability of the residue characteristics	....	....
Variability of the proportion used in the burner pipe	....	....
The burner pipe particle content and size should be carefully noted	....	....
Probable flow evolution(in the future)	....	....
Probable characteristic evolution (in the future)	....	....
2.2.3 Gaseous fuels		
Flow-sheet required	....	....
Regulator feed pressure, bar	....	....
Temperature, °C	....	....
Usual injector pressure, bar	....	....
Min.	....	....
Max.	....	....
Temperature, °C	....	....
2.2.4 Solid fuels		
Flow-sheet required		
Fuel preparation shop characteristics:		
Drying Kiln gas, furnace,…	....	....
Grinding direct firing	....	....
indirect firing	....	....
semi direct firing	....	....
semi indirect firing	....	....

	OBTAINED	NOT OBTAINED
2.2.5 Residual solid fuels		
Types, supply regularity..	....	....
Flow-sheet required	....	....
Specify preparation method and mean	....	....
Supply regularity..	....	....
Injection regularity...	....	....
Report any use problem		
2.2.6 Safety		
Do the installations meet safety standards?	....	....

	OBTAINED	NOT OBTAINED
2.3 Feed installation for solid fuels		
Flow-sheet...	....	....
Feed system (screw, air lock, Pfister or others...)	....	....
Type of weighing (impact plate, coriolis, conveying line pressure drop, weight loss ?) ..	....	....
Flow control (measuring device acting by regulation on which motor?).........................	....	....
Calibration (weight loss, filling level,...)..	....	....
Opinion on feed stability, observations of kiln outlet O2 and conveying line pressure variation	....	....
- when residual solid fuels are used (tires, plastics, …) specify the items characterizing the fuel feed..	....	....
- process injection method and mean	....	....
- uniformity of this supply	....	....
- any use problem...	....	....
2.4 Main burner pipe		
Burner pipe diagram, flow, % thermal units	....	....
Detailed plan with dimensions of the burner pipe tip	....	....
Position with respect to kiln (kiln axis, kiln center, kiln penetration)..............................	....	....
Position controlling device...	....	....
Burner pipe cooling during ventilator shut-downs..	....	....
Burner pipe air gun	....	....
Number of air circuits	....	....
Number of ventilators, pressure boosters (with or without variable gear transmission) ...	....	....
Primary air flow, ratio with respect to combustion air (total primary air)	....	....
Conveying air flow, ratio with respect to fuel..	....	....
(comb kg / m3 of air)	....	....
Impulsion, swirl	....	....
Describe wear areas (concrete, conveying circuits)	....	....
Tip temperature control...	....	....

	OBTAINED	NOT OBTAINED
2.5 Secondary burner		
Diagram, fuel flow, % thermal units	....	....
Description, number, set up	....	....
Position (precalciner, grate, miscellaneous)................................	....	....
Number of air circuits	....	....
Number of ventilators	....	....
Primary air flow, ratio with respect to combustion air................................	....	....
Conveying air flow, ratio with respect to fuel	....	....
(comb kg / m3 of air)	....	....
Coal ejection rate (m/s)	....	....
2.6 Solid waste incineration		
Detailed description of injection (air intake, uniformity, problems, …)..........................	....	....
2.7 Instrumentation		
2.7.1 Gas analysis		
Sampling probe	....	....
Type (dry, humid) stirring frequency................................	....	....
Location, position (diagram)................................	....	....
Automatic retro-blowing................................	....	....

Types of analyzers and measuring scale		Kiln Outlet values	Lower cyclone outlet (if precalciner)	Tower outlet Grate		
O_2						
CO						
NO						
SO_2						
Others						

The type of analyzer (UV, RI, paramagnetic, zircon sensor, …) should be mentioned

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	OBTAINED	NOT OBTAINED
The SO_2 signal is used mainly relatively and offers little comparison between plants. It is very sensitive to overburning, reducing atmospheres, poor combustion in the precalciner. Low values (2,000 – 4,000 ppm) may indicate an internal recirculation of sulphates in the kiln and therefore a propensity to ring formation (tower kiln and Lepol grate).		
2.7.2 Temperature control		
Is there a scanner available to monitor the kiln shell temperature?..................................	....	....
How is it used, how is data kept?		
Is there a flame zone pyrometer available?...	....	....
How is it used, how is data kept?		
Is the secondary air temperature recorded and on-line calculated?..................................	....	....
Are there zone ventilators available (number, characteristics and installations)?............	....	....
2.7.3 Flow measurement		
How is the primary air flow measured or calculated?..	....	....
Primary air ventilator calibration curves..	....	....
Primary air flow modification frequency...	....	....
2.7.4 Clinker control		
Type of free CaO analyzer..	....	....
Free lime on-line analyzer or gammadensimeter or both..		
Free lime control frequency (analyzer calibration or density refitting or both)	....	....
2.8 Conclusions		
What is the instrumentation extent of the plant in terms of combustion control?............	....	....
What are the strong and weak points of the fuel preparation, ...		
feed, conveying?	....	....
of injection (burner pipe, upstream, precal., …)	....	....
Are there high deviations from Lafarge standards?	....	....
Anomalies	....	....

	OBTAINED	NOT OBTAINED
3. OPERATION		
3.1 Combustion adjustment		
How is combustion optimized?		
Use of existing adjustment tools, burner pipe scanner, instrumentation, O_2, NO, CO, SO_2, gas analysis	....	....
Tests conducted in this area (reports)........	....	....
3.2 Kiln operation adjustment		
What is the kiln intensity level and the deviation with respect to the motor power?	....	....
Can zone length information be derived from it?........	....	....
Appreciation of kiln outlet temperature and heat profile	....	....
What is the long zone start-up frequency (translating into the decorrelation of NO and kiln intensity?........	....	....
What method is used to make corrections?........	....	....
NOx level observed........	....	....
Current NOx variation range........	....	....
3.3 Clinker quality adjustment - Observations		
Effect of raw mix uniformity on burning efficiency Free lime or density control Dust management during raw mix mill shut-downs Is it a cause of raw mix and burning problem? Clinker SO_3 : source of variability Alkali sulfate and early strength uniformity Comments on microscopy tests Traces of reducing atmosphere		
3.4 Conclusions		
Evaluation of combustion, burning and clinker quality control		

		NOT

	OBTAINED	OBTAINED
4. STUDY OF UNSTABILITIES AND OPERATION PROBLEMS		
4.1 Raw mix		
Without going back to the chemical uniformity of the raw mix already evaluated, the hidden fluctuation causes that the raw mix could be the source of should be investigated (kiln feed, variable carbon content, moisture, busting of pellets, dust, cascades…) as they, in particular, generate draft variations (hence CO peaks).		
4.2 Tower or grate		
Of particular concern, when noticed, are rings, build-ups, air-flow variations................	....	....
Establish the stirring or ring formation frequency (with or without production loss).......	....	....
Obtain information on the number and position of air guns	....	....
Evaluate the impact, on the formation of CO and NO, of the residual fuel combustion in the smoke box or in Lepol grate hot chamber.	....	....
Does a feed curtain exist and is it efficient?..	....	....
4.3 Kiln inlet material		
Review analysis, covering several weeks, of SO_3, alkalis, Cl content in the kiln inlet material (grate inlet chute or lower cyclone) Both uniformity and level provide a good image of volatilization SO_3 values above 2 to 2.5 times the average value of clinker SO_3 indicate high volatilization For dry processes, values can be compared between themselves For Lepol grates, the same interpretation problem as for SO_2 may exist Measure unburnt solids in the kiln inlet material to qualify the kiln upstream combustion		
4.4 Precalciner		
Review the precalciner combustion performance, in particular the unburnt concentration of the kiln inlet material (on wet sample) and unburnt gas (CO and others) A poor combustion in the precalciner means an increase in volatilization Describe the fuel flow regulation and note the location of the temperature sensor		

	OBTAINED	NOT OBTAINED
4.5 Kiln		
Find out about the performance of the zone refractory (quality, durability, brick-laying plan). Find out about the alkali attack of the bricks (cooler, kiln hood, tertiary air duct) Long-zone start-ups that can be triggered by large heat transfers at the back of the kiln during intense volatilization phases in the condensation zone at the back of the kin.		
4.6 Cooler		
It is important to qualify the cooler stability in the recovery zone, hence the efficiency of the first grate adjustments. Observing the grate velocity and undergrate pressure offers a good indication. Large variations of heat recovered in secondary air adversely affect combustion.		
4.7 Flame heat profile		
The flame heat profile provided by the scanner gives a good picture of the coating and burning zone variability.		
4.8 Environment		
Find out the number of electrofilter releases on CO peaks during the last 12 months......	....	....
Obtain results of the plant atmospheric emissions through the kiln stack (mg/Nm3 at 10% dry O_2)	....	....
Study the emission sources	....	....
4.9 Conclusions		
Make a summary of the operation difficulties in order to determine ways of improvements..	....	....
Distinguish the combustion between the main burner pipe, the precalciner, the upstream kiln.	....	....

	OBTAINED	NOT OBTAINED
5. MEASUREMENTS		
5.1 Gas analysis		
Record over a period of at least 24 hours of kiln operation (stable) the gas analysis to produce a statistical interpretation: average standard deviation for O_2, CO and NO and SO_2 if possible..	....	....
In particular kiln outlet but also precalciner or grate	....	....
Burning circuit outlet control provides worthwhile addition		
Compare the results against Lafarge standards		
5.2 Burner pipe		
Dimensions of:		
- axial circuit	....	....
- radial circuit..	....	....
- coal circuit	....	....
axial air flow (Nm3/h)..	....	....
radial air flow (Nm3/h)	....	....
conveying air flow (Nm3/h)...	....	....
central air (Nm3/h)...	....	....
axial air static pressure (Pa)	....	....
radial air static pressure (Pa)...	....	....
central air static pressure (Pa)	....	....
% axial air / combustion air	....	....
% radial air / combustion air	....	....
% transport air / combustion air	....	....
% central air / combustion air	....	....
primary air / combustion air..	....	....
Impulsion $N.h.GJ^{-1}$	....	....
Swirl..	....	....
On-line calculation (yes / no)?	....	....

## 5.3 Clinker	OBTAINED	NOT OBTAINED
Clinker microscopy with search for traces of combustion (reducing or not) impact .... Examination of clinker FeO (in addition)	....	....
5.4 Volatile balance		
To do according to the proposed diagram in the appendix over a period of 48 hours.		

	OBTAINED	NOT OBTAINED
6. SUMMARY		
6.1 Where are the difficulties?		
Synthesis of the operating problems encountered in terms of low performance of the burning unit...	....	....
Ways of improvements, training need, combustion problem awareness..........................	....	....
6.2 Measurement interpretation		
Synthesis of measurement-related results	....	....
Do they confirm the failures discovered through the overall review of the combustion shop performances?	....	....
Ways of improvements	....	....
6.3 Is combustion well controlled?		
Explanation	....	....
6.4 Production results		
Study of the positive or negative combustion impact on cement production performances..	....	....
- Refractory life span..	....	....
- Clinker reactivity	....	....
- Kiln reliability..	....	....
- Production loss	....	....
- Eventually, combustion shop maintenance cost	....	....