HOT BLAST STOVES HIGHER EFFICIENCY AND LONGER CAMPAIGN LIFE THANKS TO ENDOSCOPIC SURVEYS: ”THE REACTOR STRIP-TEASE”[1]

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Abstract
Photography techniques and continuous improvements in camera miniaturizing (endoscope outer Ø 35mm) allow today a pro-active monitoring of inner parts of reactors working at high temperature, such as cowper, glass tanks, incinerators,… This article illustrates and shows answers given by endoscopy regarding high efficiency and good operational conditions issues.
Key words: Endoscope; Blast furnace; Hot blast stoves; Refractory; Control

EFICIÊNCIA MAIS ELEVADA E PROLONGAMENTO DA CAMPANHA DO REGENERADORES AO EXAME ENDOSCÓPICO: “O STRIP-TEASE DO REATOR”

Resumo
As técnicas fotograficas e as melhorias contínuas na miniaturizacão de câmera (endoscópio Ø exterior 35mm) permitem hoje uma monitoração dinâmica das peças internas dos reatores que trabalham a altas temperaturas, tais como o cowper, fornos de vidro, os incineradores,… Este artigo ilustra e provê as respontas dadas pela endoscopia as questões de eficiência elevada e boas condicões operacionais.
Palavras-chave: Endoscópio; Alto-forno; Regeneradores; Refatarios; Controle.

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1 INTRODUCTION

When, in the 19th century Eduard A. COWPER, filed a patent application for a brick-type heater, he should never have imagined the evolution and the complexity of current hot blast stoves system.
In the BOF steelmaking process, the Blast Furnace (BF) remains the “heart” of the said process.
However there is a pre-request for optimal efficiency of the BF:

- Constant delivery of preheated blast air to the BF, within a specific temperature range.

From BF point of view, any disruption or lower hot air supply could lead to weaker BF efficiency with associated technical consequences e.g. thermal state of the BF leading to thermodynamic imbalance, but also economical consequences due to the change of operating conditions leading to higher operating costs (e.g. ratio change of coke injection)
This goal could only be achieved when Hot Blast Stoves (HBS) are operating in “normal/optimal” conditions e.g.:

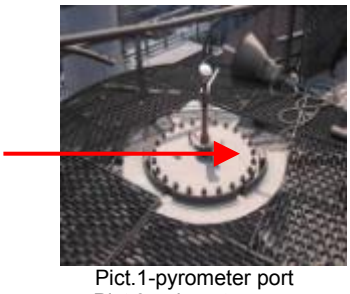
- Heating
- Temperatures
- Air/gases exchanges
- Refractory lining
- Dome condition
- …

Yield and efficiency, energy savings, environmental issues (CO, SO_x, NO_x) have also lead to put higher “pressure” of BF/HBS managing people.
Therefore, any tool driving to optimize the run of the HBS, or to assist in decision-making process, became more than helpful.
It’s now obvious to say that daily HBS operating conditions have been significantly improved since the use of computerized expert-system, feeding by a wide range of data, but also with fuel preheating, combustion improvement with suitable burners, quick O_2 measurement for quick adaptation of combustion conditions and external checks such as thermography technique have led to better operations; BUT something was still lacking: a direct, life VISION of the inner parts of the HBS while operating!

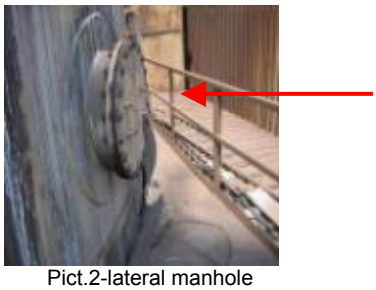
2 MATERIALS AND METHODS

The principle seems obvious or even very simple: let’s put a camera for monitoring the strategic areas INSIDE the HBS. Unfortunately, HBS designs very often, don’t allow this.
Only a few access possibilities have been created by engineering companies:

- 1 or sometimes 2 manholes
- Pyrometer ports
- Ignition device area
- Gas sensor area



Pict.1-pyrometer port



Pict.2-lateral manhole

Pict.3-exhaust

Pict.4- manhole under burner

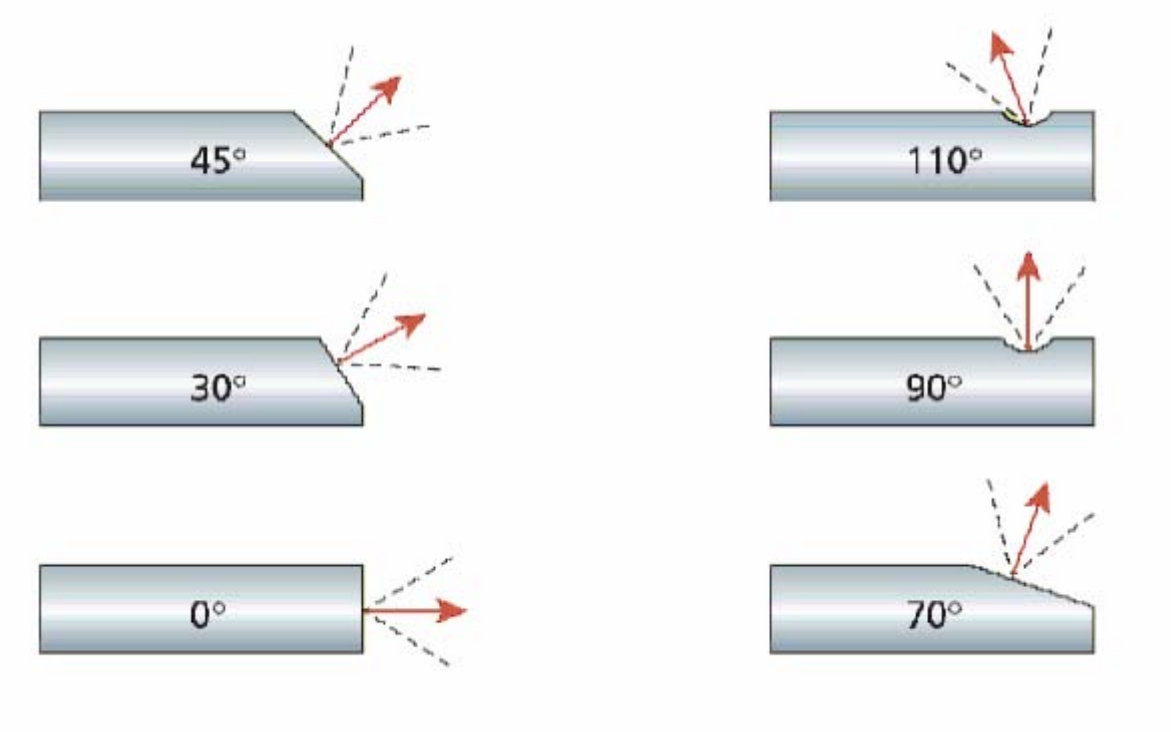
Technology and devices:

Based on the photography techniques, this methodology has been developed for use in COLD conditions, e.g. engine expertise, piping check, medical use (gastroscopy).
Continuous improvements in camera miniaturizing (objective diameter of 7 mm is now common), and better resolution have allowed the record of still photographs or movies even in poor/very poor light conditions.
Endoscopy in HOT conditions was very challenging because of the heat and sometimes atmospheric conditions (acid, soda emissions or smokes f.i.).
Camera upper limit for operating is around 40° to 45°C (104°-113°F).
Cooling down of the devices was the only way to fulfill with this requirement.
Water/air cooling systems with piping assembling (generally stainless steel) have been developed successfully. The device looks then as a “gunning lance” which could be introduced to existing openings through the HBS shell, then through the refractory lining, arriving in the cowper itself (i.e.mixing chamber)
Based on the assumption that water supply will never stop, 2 options are available for camera insertion:

1) The camera remains OUTSIDE but plugged to an optical system (lenses assembling) inserted in the pipes
2) The camera is integrated INSIDE the pipes up to the “head” of the device

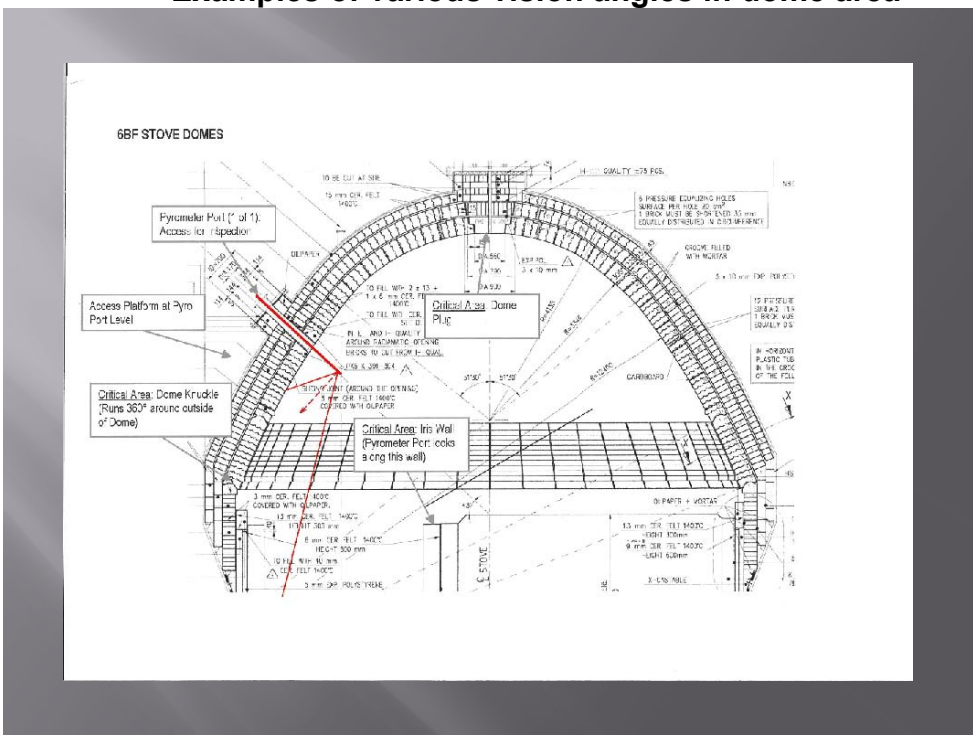
Both systems are working quiet well, the main difference consists in the pipes outer diameter:
INTEGRATED camera requires more water supplies because of its direct contact with high temperature inside the cowper. Water flow has to be high and constant, “after use” water has to be rejected, therefore larger diameter of the device is requested.
Another negative consequence is that when operating, the device becomes quiet heavy due to its own weight but also with the water additional weight.
OUTSIDE camera doesn’t need this apparatus; the optical system (lenses assembly) is much more resistant to high temperature and the cool down requires lower water supplies, allowing thus smaller diameter for the device.
Today, digital cameras give spectacular pictures. The availability of such cameras combined with the water cooled devices allows now the inspection in VERY HOT CONDITION, almost NO LIMIT whether water supplies is not interrupted.

Various vision angles are available 60°-90°-110°(“rear vision”) allowing a direct 360° view as well as close-up (zoom) or wide angle view.

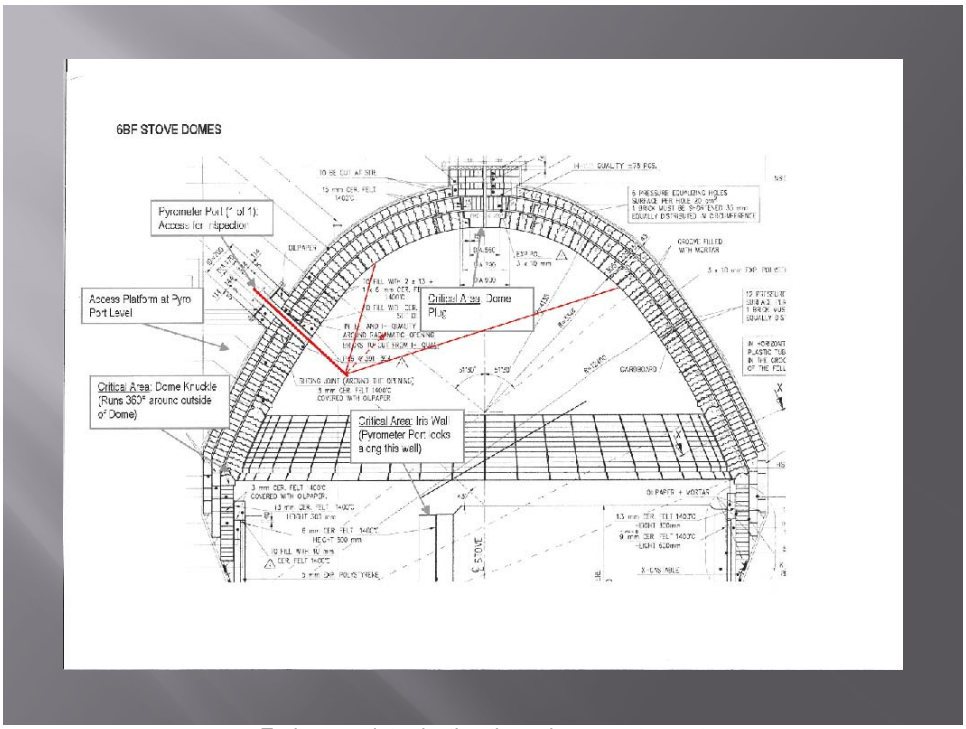


Various working length are available (from 1000 mm to 2500 mm - longer also available)

Examples of various vision angles in dome area



Endoscope introduction through pyrometer port



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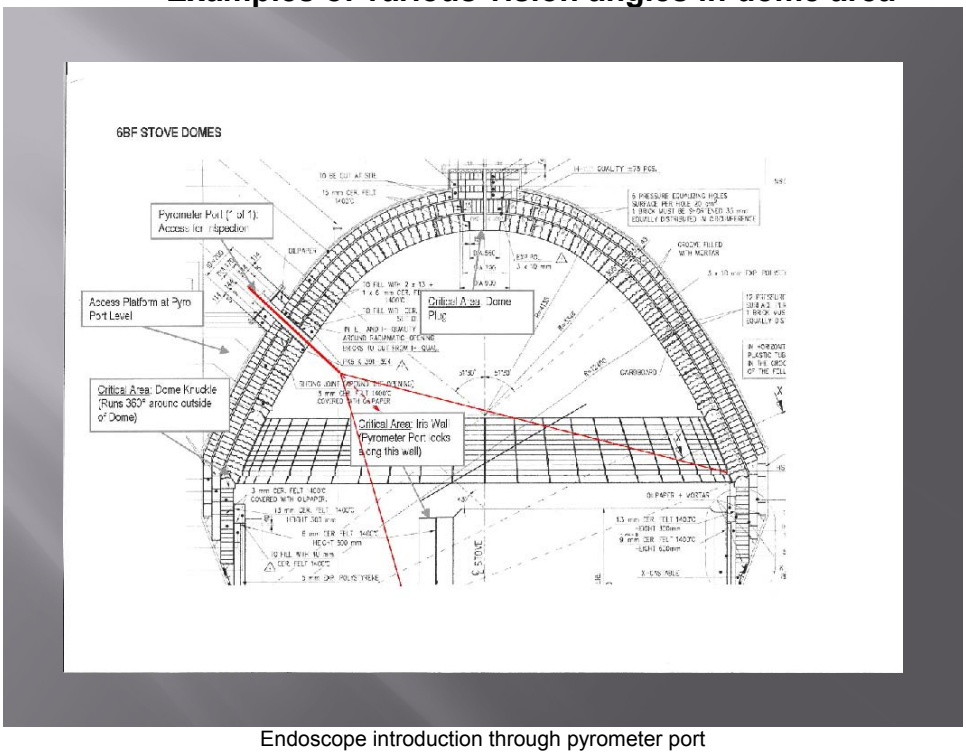

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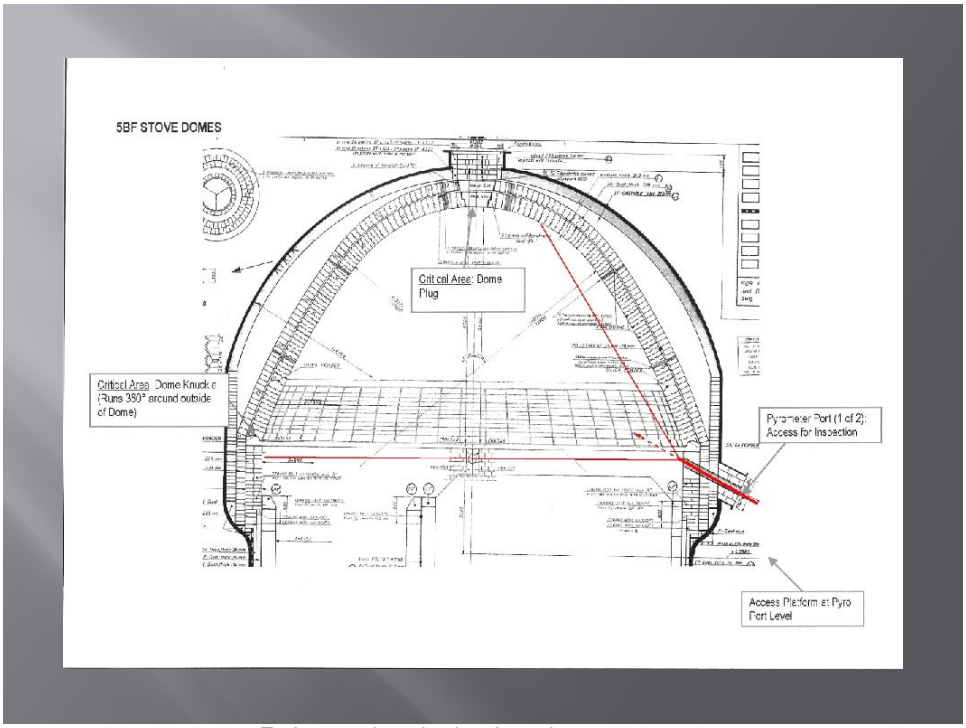
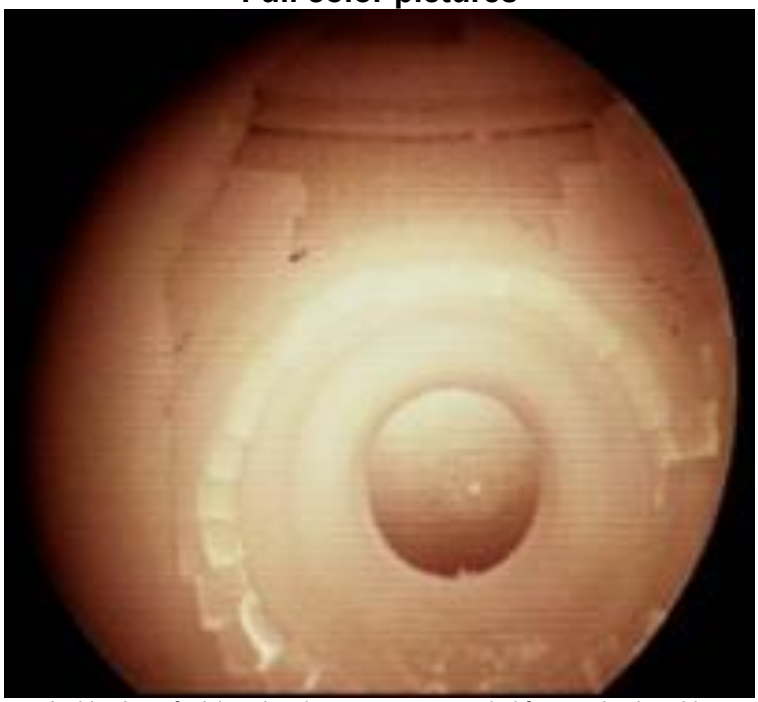


Endoscope introduction through pyrometer port

Despite the fact that modern cameras are very sensitive and could operate in poor light conditions, best results are still reached when the light source (radiation) coming from the hot refractory lining ("red" colored) is optimum, thus when HBS are at operating temperature. (→NO BLAST FURNACE SHUT DOWN IS REQUESTED!!!)

Full color pictures


Inside view of mixing chamber + cowper recorded from main pipe side

However, pressure from the HBS while operating is very high. Coming back to almost atmospheric pressure is a pre-request, which could be achieved by burners switch off

for a short period of time, without any negative consequences on refractory lining as endoscopic survey in 1 area of the HBS will not last a long period of time.
Utilities requirements are: (BF shop deliveries)

- Water (20°C/52°F – no PH – P = 3-6 bars/44-88 Psi) – for cooling
- Air (dry and clean P = 5 bars/73 Psi) for "non stop" cleaning and cooling of the vision devices avoiding dust deposit
- Electricity (220V – 16A – single phase) for electronic devices and computer

Methodology/Procedure:

1) At earlier stage, checking of access possibilities (which will determine the feasibility of the entire endoscopic survey)
2) Connecting endoscopic devices to water/air and electricity plant networks
3) By-pass from the HBS complex of the HBS which has to be inspected
4) HBS pressure adjustment
5) Opening of existing access (manhole, pyrometer or gas sensor removal, …)
6) Insulation with thermal blankets to keep the temperature as high as possible
7) Introduction of the endoscopic devices into the cowper
8) Equipment set up and picture quality adjustment
9) Facing to a monitor screen selection of the areas to be inspected
10) Recording DIGITAL pictures and saving on computer for further forwarding
11) Withdrawing of the endoscopic devices and move to other inspection area

3 RESULTS AND DISCUSSIONS

Purposes of ENDOSCOPY for "another vision":

- Clear and accurate vision INSIDE a reactor (HBS, Glass furnaces, incinerators, other reactors, …) or pipes (BF tuyeres, hot blast system bustle pipe, cooling staves, hollow, …) at working temperature !
- "Life" diagnostic of current status of the cowper
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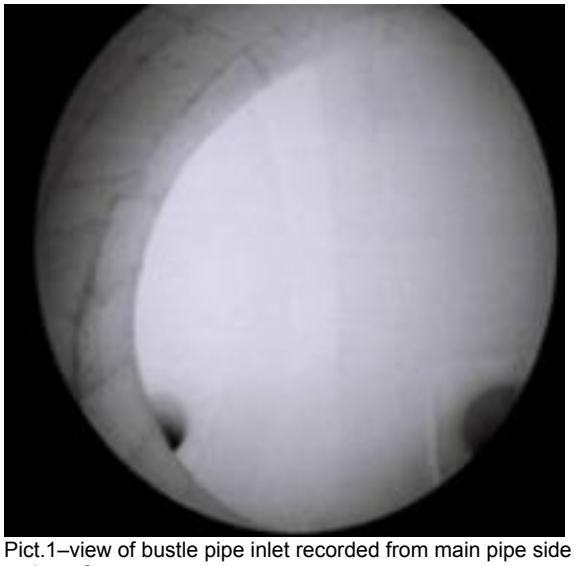
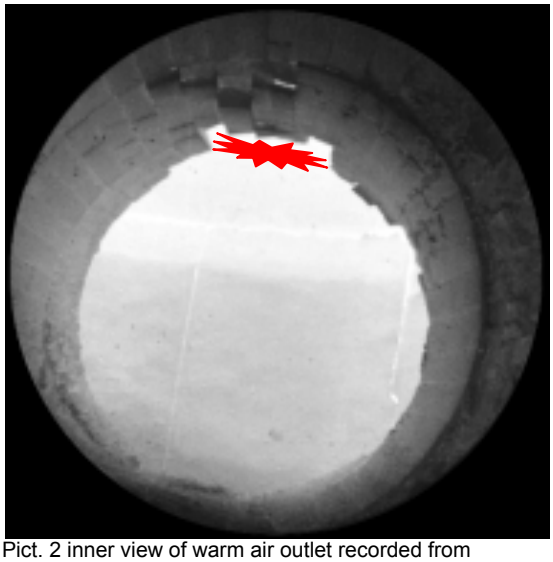
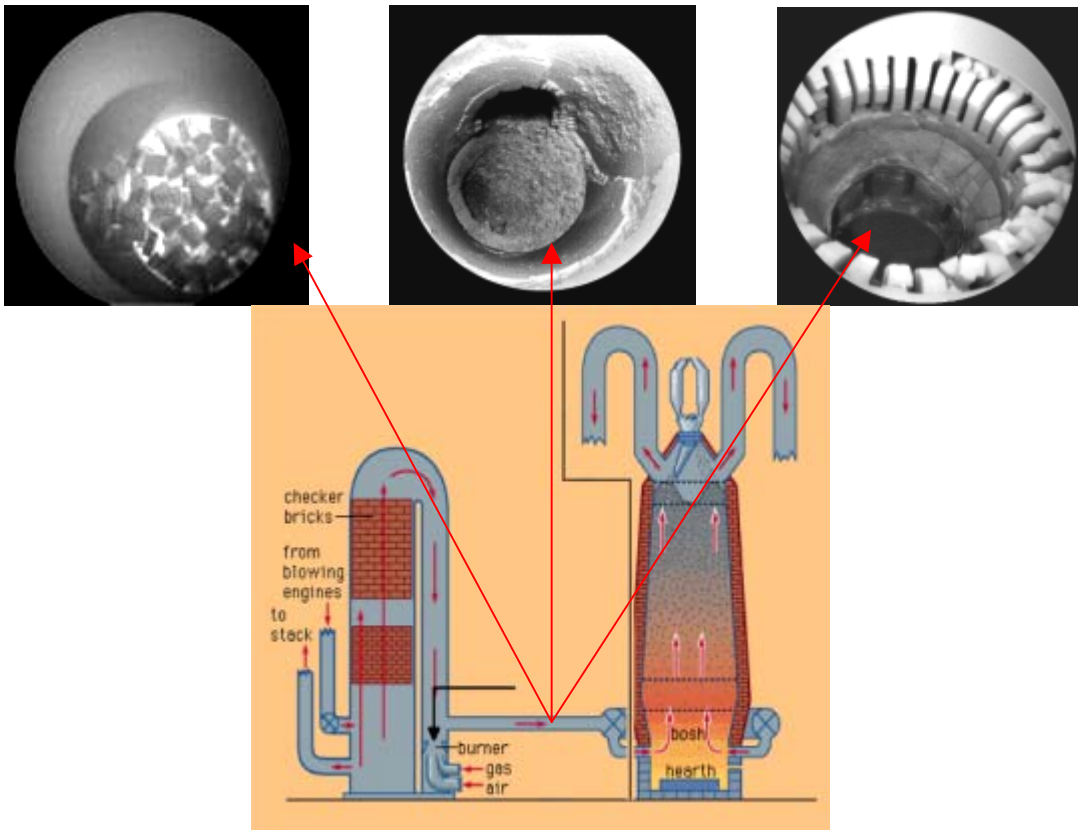


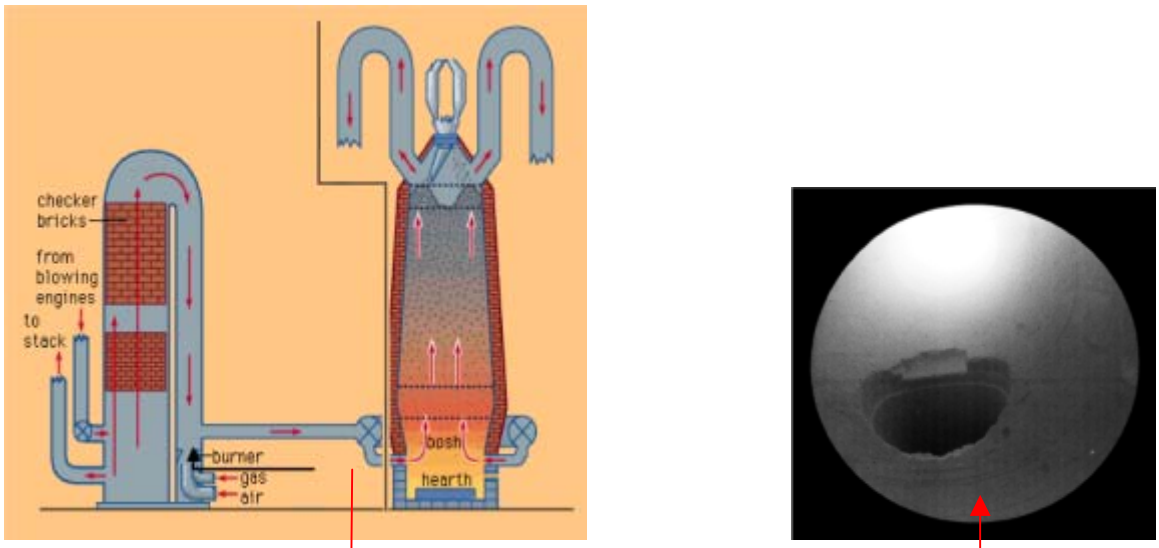
Pict.1–view of bustle pipe inlet recorded from main pipe side + view of tuyeres



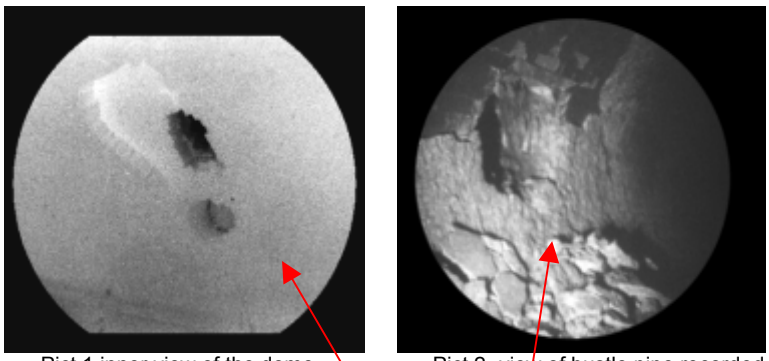
Pict. 2 inner view of warm air outlet recorded from pipe leading to main pipe



3 differents views of burners



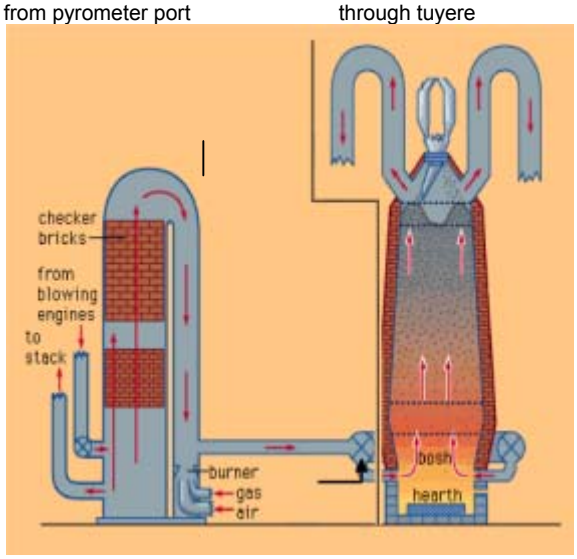
Warm outlet view recorded from inside the cowper



Pict.1 inner view of the dome

Pict.2- view of bustle pipe recorded

taken from pyrometer port through tuyere

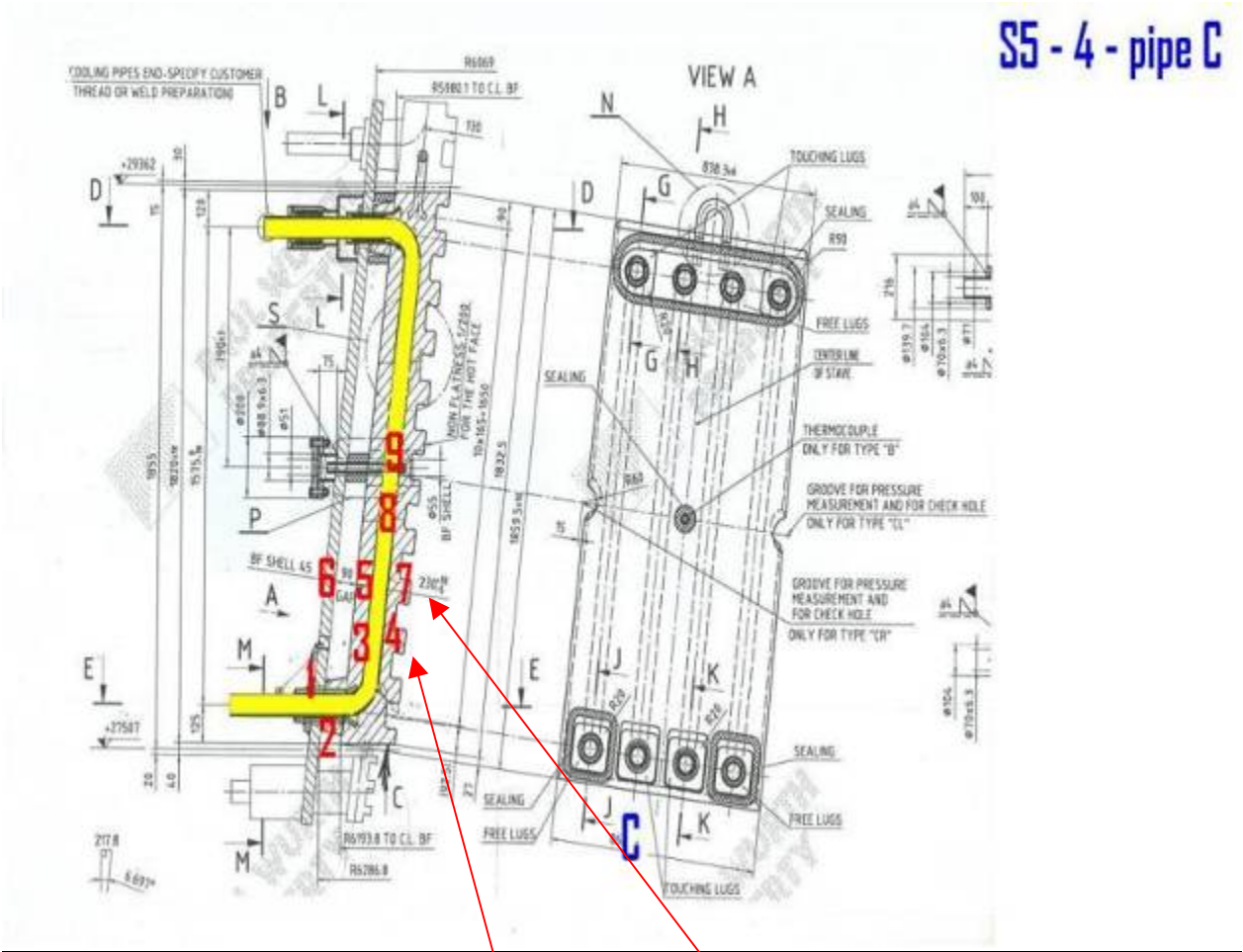


ADVANTAGES

Referring to recorded pictures

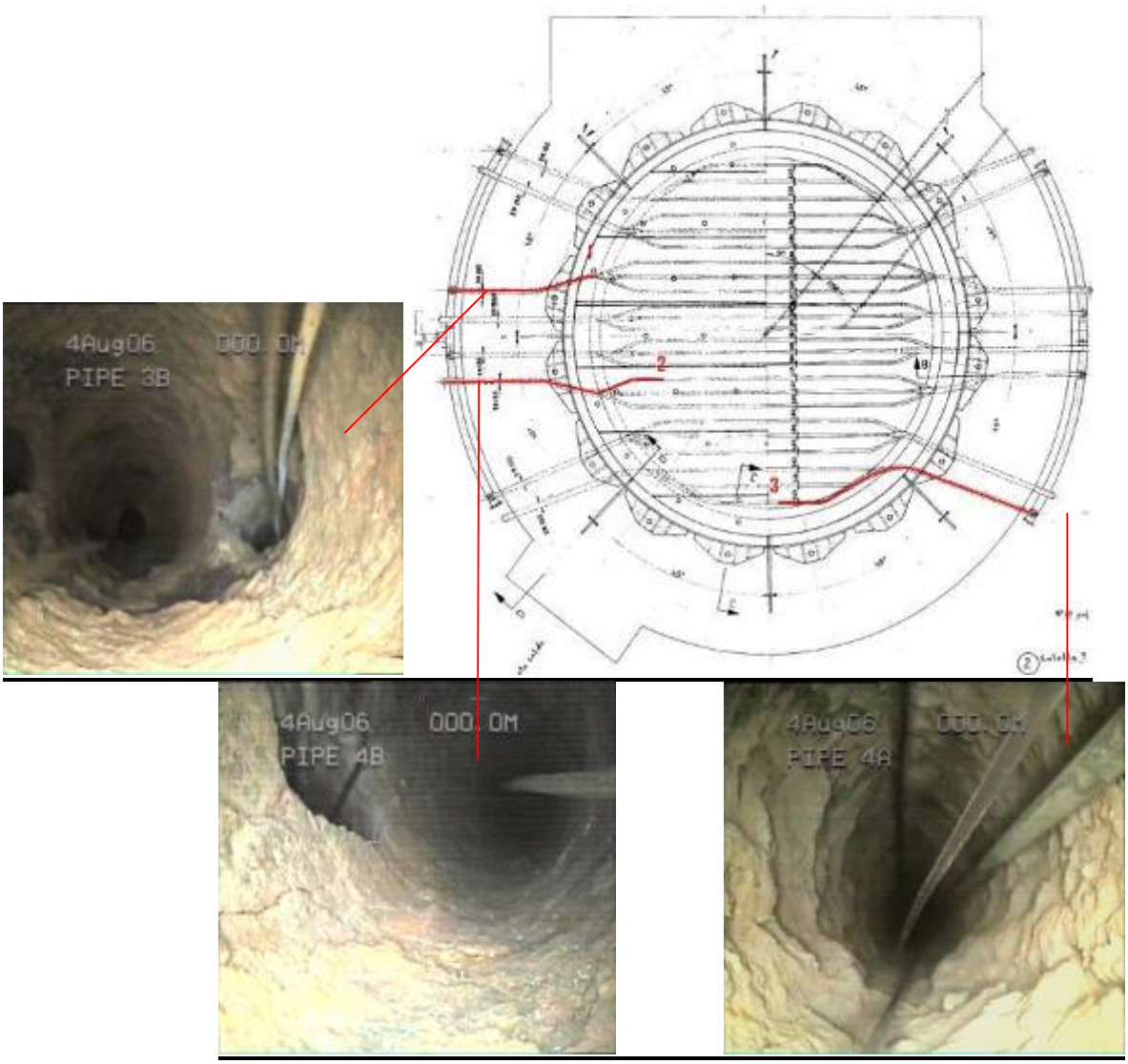
- Decision-making tool for preventive or corrective actions,
- Knowledge improvement for operators,
- Possibility of further monitoring (survey once or twice a year included in a preventive maintenance program), computing data and comparison sheets.

OTHER OPERATIONS IN BF AREA: COOLING STAVES



Inside view of cooling staves tubing showing piping damages

ASSISTANCE DURING OPERATION (thermocouples installation under the hearth):



Inside view helping to the proper installation of the thermocouples in the suitable hole

Choosing a solution?

Of course, “ready to use” endoscopes are available on the market for purchase, unfortunately it will very often respond to one single issue, and will show very quickly its “limits” considering its scope of possibilities:

- Too short,
- Outer Ø too large
- Accurate view angle not available ...
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SELECTION CRITERIAS:

- Added value of operators providing endoscopy services comes from the fact that they design and manufacture their own endoscopes, tackling almost local situation or customer’s needs.
- Option “OUTSIDE CAMERA” allows VERY SMALL DIAMETER for piping assembly (outer diameter Ø 35 mm-1.38”) multiplying thus introduction possibilities
- Innovation capabilities by implementing a methodology supported by updated digital equipment

- Large experience of images analysis, and the benefits withdrawn from internet.

Main assets withdrawn from a skilled operator:

- NO investment for customer ++
- NO maintenance or repair costs for customer ++
- Compact & light equipment for EASY transport & handling +
- ACURATE equipment tackling to current situation +++
- Ø 35mm endoscope for easy introduction +++
- digital pictures (immediate availability) ++
- team flexibility (2 operators) ++
- pictures analysis EXPERTISE +++
- DATA catalogue management available « in house » or management at «corporate » level +

4 CONCLUSIONS

ADVANTAGES withdrawn from ENDOSCOPY at local (L) and “corporate” (Co) level:

- DATA « Catalogue » creation (L + Co)
- KNOWLEDGE improvement (L + Co)
- EXPERIENCE sharing →Knowledge Management Program (L + Co)
- KPI accurate definition (L + Co)
- Creation of «standard» concepts for Investment process OPTIMIZATION (Co)
- Setting of a «in real time» MONITORING (twice a year recommended) (L)
- ACTIONS SCHEDULING (preventive maintenance) (L)

SOME REFERENCES:

- Belgium	ArcelorMittal Seraing/Zelzate
	Carsid (Duferco) Charleroi
- France	ArcelorMittal Dunkerque/Fos sur mer
- Germany	Thyssen Duisburg
- India	Tata Jamchepur
- Italy	Ilva (Riva group) Taranto
	Lucchini (Severstal group) Piombino
- Romania	ArcelorMittal Galati
- Turkey	Isdemir (Erdemir Group) Iskenderun