How the Industrial Revolution 4.0 will impact the Glass Industry

Image analysis part of ES 4.0 a key component towards Industry 4.0

GLASS SERVICE

January 2018

CONTENT

- Introduction GS
- What it means to be Industry 4.0
- Present Automation of Glass Production
- Furnace melting automated by Expert System *III* and 4.0
- GS Furnace Camera Identification Techniques
- Outlook

Glass Service Company Structure Worldwide
HQ Vsetin, Czech Republic (total approx 100 employees)

Glass Service USA
USA

Glass Service B.V.
The Netherlands

GS ACT
Slovakia

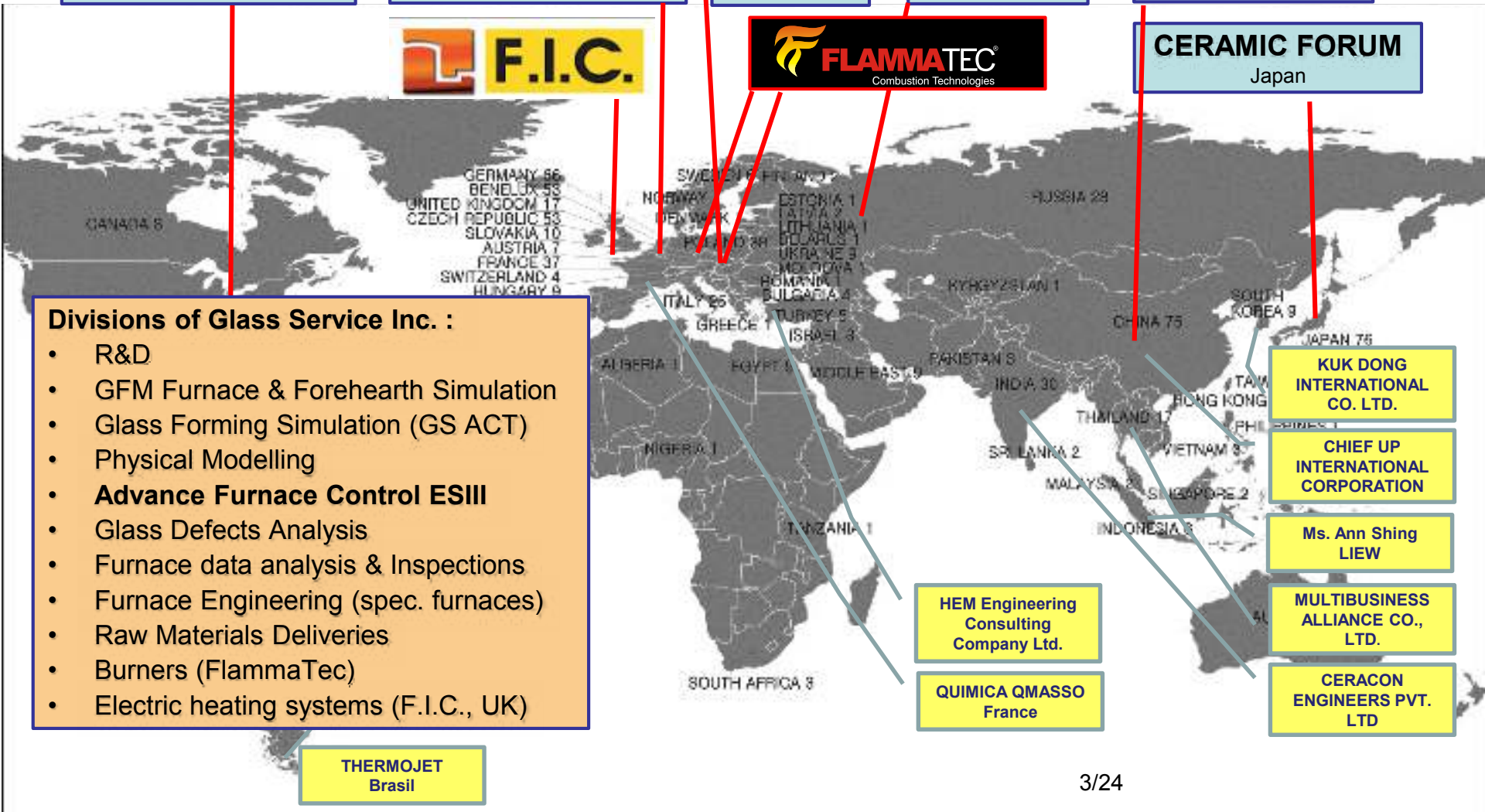
GS Russia
Russia

GS CHINA Ltd.
China

F.I.C.

FLAMMATEC® Combustion Technologies

CERAMIC FORUM
Japan



Divisions of Glass Service Inc. :

- R&D
- GFM Furnace & Forehearth Simulation
- Glass Forming Simulation (GS ACT)
- Physical Modelling
- **Advance Furnace Control ESIII**
- Glass Defects Analysis
- Furnace data analysis & Inspections
- Furnace Engineering (spec. furnaces)
- Raw Materials Deliveries
- Burners (FlammaTec)
- Electric heating systems (F.I.C., UK)

KUK DONG INTERNATIONAL CO. LTD.

CHIEF UP INTERNATIONAL CORPORATION

Ms. Ann Shing LIEW

MULTIBUSINESS ALLIANCE CO., LTD.

CERACON ENGINEERS PVT. LTD

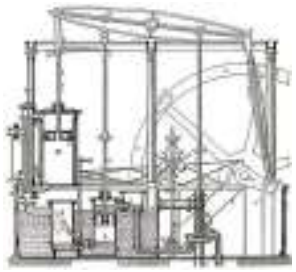
HEM Engineering Consulting Company Ltd.

QUIMICA QMASSO France

THERMOJET Brasil

Total number of GS LABORATORY CUSTOMERS: 790

Industrial (R)Evolution



1. Industrial revolution
Introducing mechanical production machines powered by water and steam

2. Industrial revolution
Introducing mass production lines powered by electric energy

3. Industrial revolution
Through the use of electronics and IT further progression in autonomous production

4. Industrial revolution
Based on cyber-physical-systems

Level of complexity

Industry 1.0	Industry 2.0	Industry 3.0	Industry 4.0
End of the 18th century.	Beginning of the 20th century	Beginning of the 1970s	Today
Steam	Electricity	Computers	Cyber-Physical

Source: DFKI/Bauer IAO

Industry 4.0

A collective term for technologies and concepts of value chain organization. Based on the technological concepts of cyber-physical systems, the Internet of Things, it facilitates the **vision of the Smart Factory.**

Within the modular structured Smart Factories of Industry 4.0, cyber-physical systems monitor physical processes, create a virtual copy of the physical world and make decentralized decisions.

Over the Internet of Things, Cyber-physical systems communicate & cooperate with each other & humans in real time. Via the Internet of Services, both internal & cross-organizational services are offered & utilized by participants of the value chain.

Builds on the Digital revolution

Smaller & powerful sensors

Machine Learning

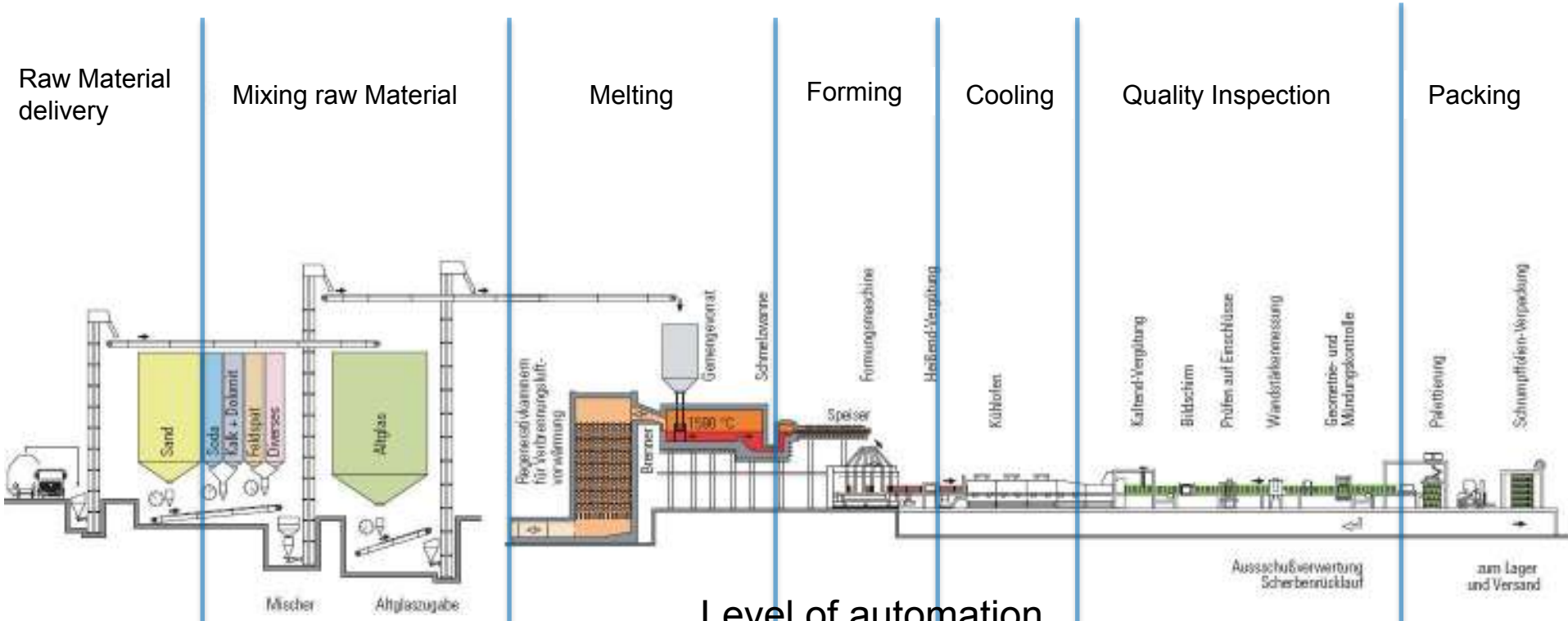
Ubiquitous internet

Artificial Intelligence (AI)

Labor & Energy Cost

Container Glass production

Adding value versus Process Control



Level of automation

70% 90% 40% 60% 70% 95% 90%

Missing is automatic interpretation & interconnection of info exchange & feedback

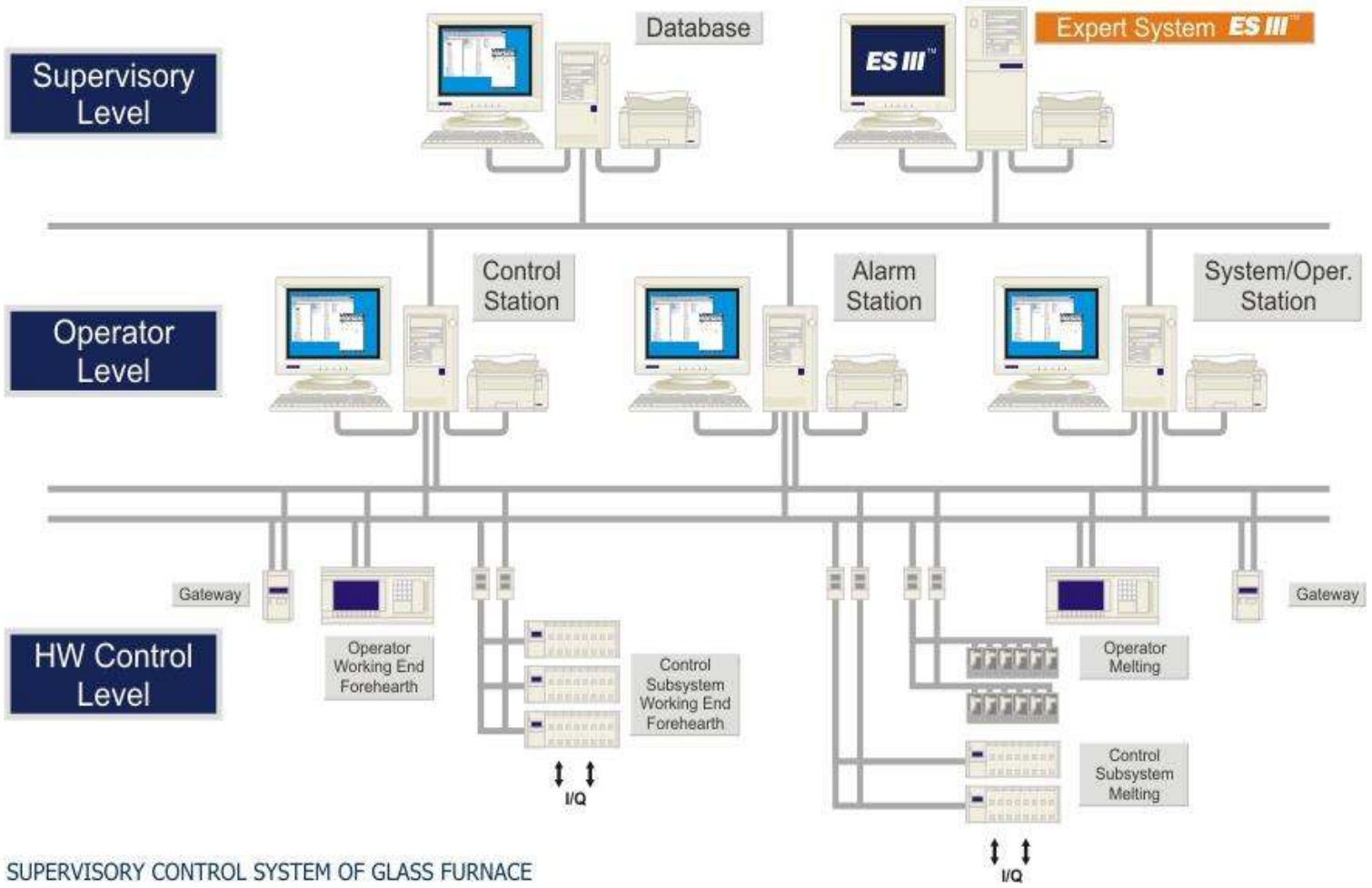
New trends in early data processing (Xpar)

- Hot End IR-D Inspection (Xpar)

- XMIS xpar Process data analysis
- Or Swabbing Robots from eg Heye

ES III™ INTRODUCTION

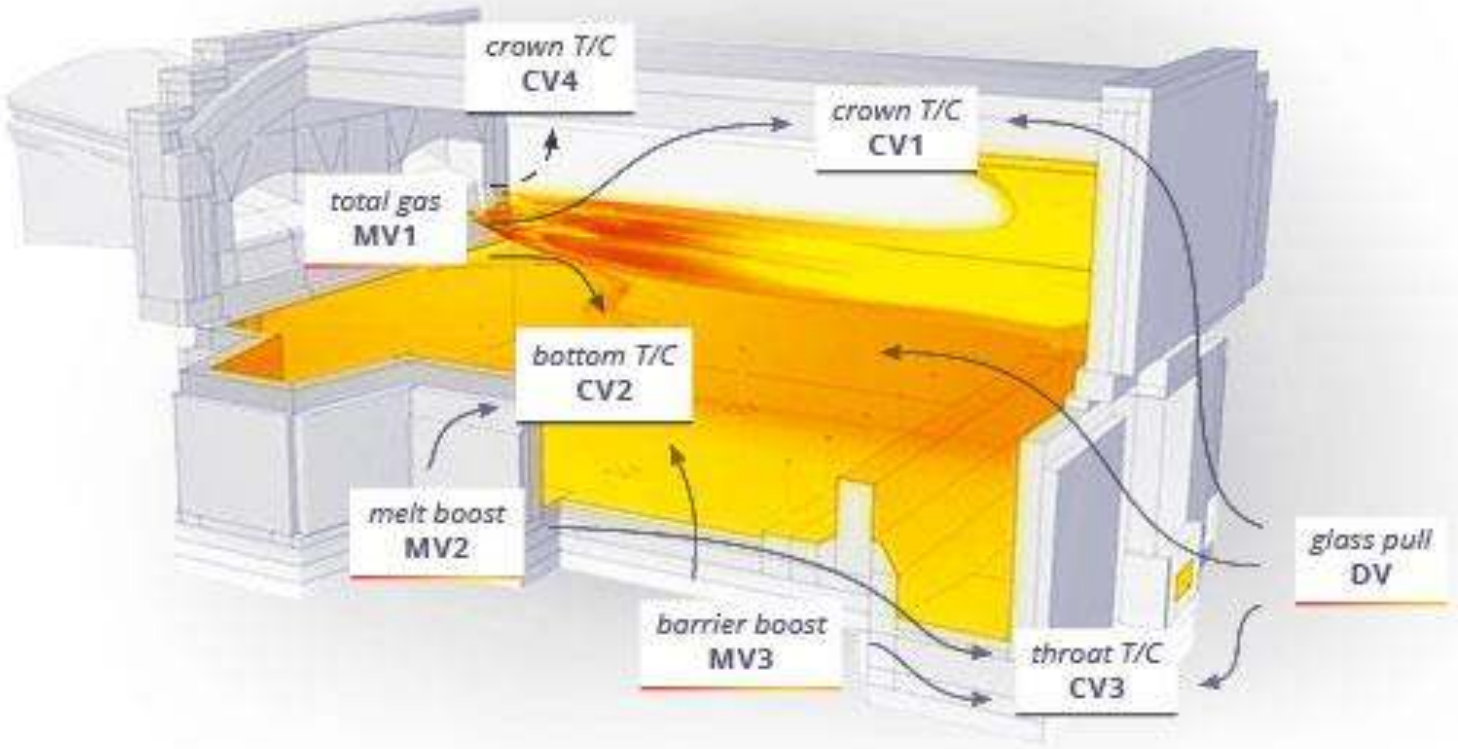
Additional PC computer with OPC/DDE communication is only necessary HW addition to run ESIII. Original control equipment is used:



SUPERVISORY CONTROL SYSTEM OF GLASS FURNACE

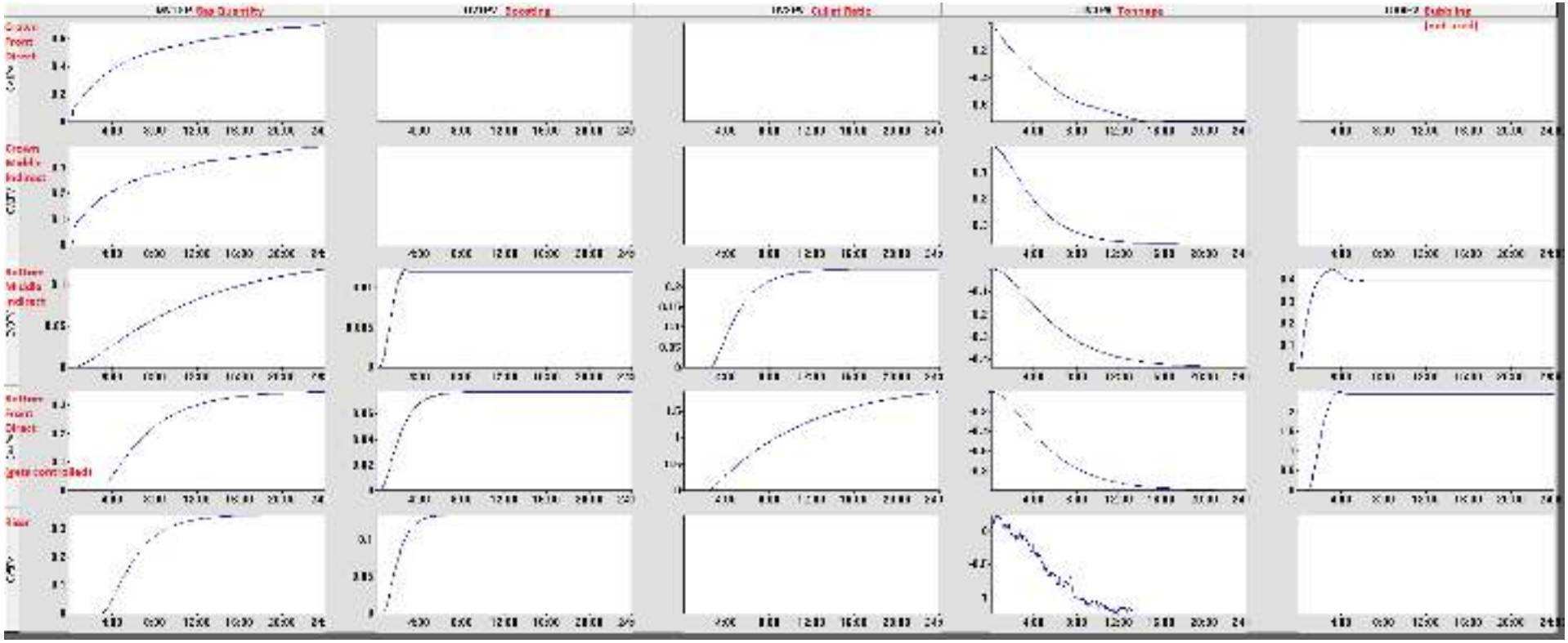
FULL AUTOMATIC TEMPERATURE CONTROL OF END-FIRED FURNACE BY GS Expert System

- Standard PID control loops are used for fast processes with single input/output variables (almost entire glass production line).
- Strong correlations between multiple input and output variables, incl. disturbance variables.
- GS ESIII state of the Art with about 5% of glass furnaces worldwide installed

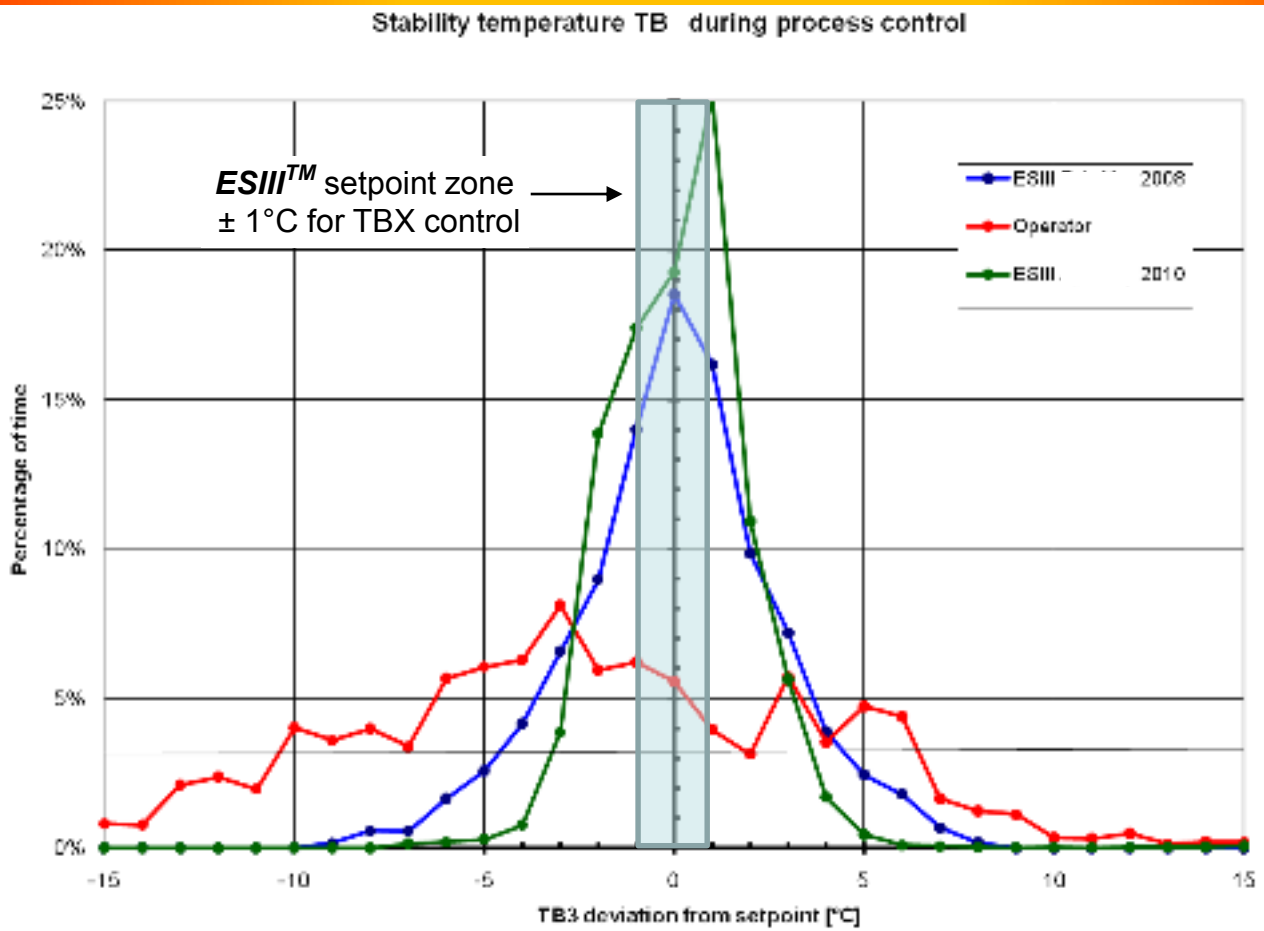


MPC PROCESS MODELS EXAMPLES

Gas Boosting Cullet Ratio Pull Bubbling



Temperature stability Improvement, with energy savings 3%



Data sample 2 months

ESIII™ was in control for 96% of the time

Data sampling 5 minutes

TBX tolerance	Operator	ESIII™ (old furnace)	ESIII™ (new furnace)
± 2 °C	19.6%	64.8%	74.4%
± 4 °C	44.5%	91.6%	97.4%

Percentage of time TBX is within tolerances ± 2 °C and ± 4 °C during entire process control, including pull changes

Why GS Camera turns ES/// into ES 4.0

- Present Trend of Industry 4.0 is motivating glass production for further automation of the glass melting process with less need of operators
- Part of the glass melting process such as the batch blanket spread in most furnaces and Glass Ribbon in Tin Float baths relies on operator visual regular inspection and his personal interpretation, followed by some decision making
- Even your TOP management understands that this cannot continue like this in the near future

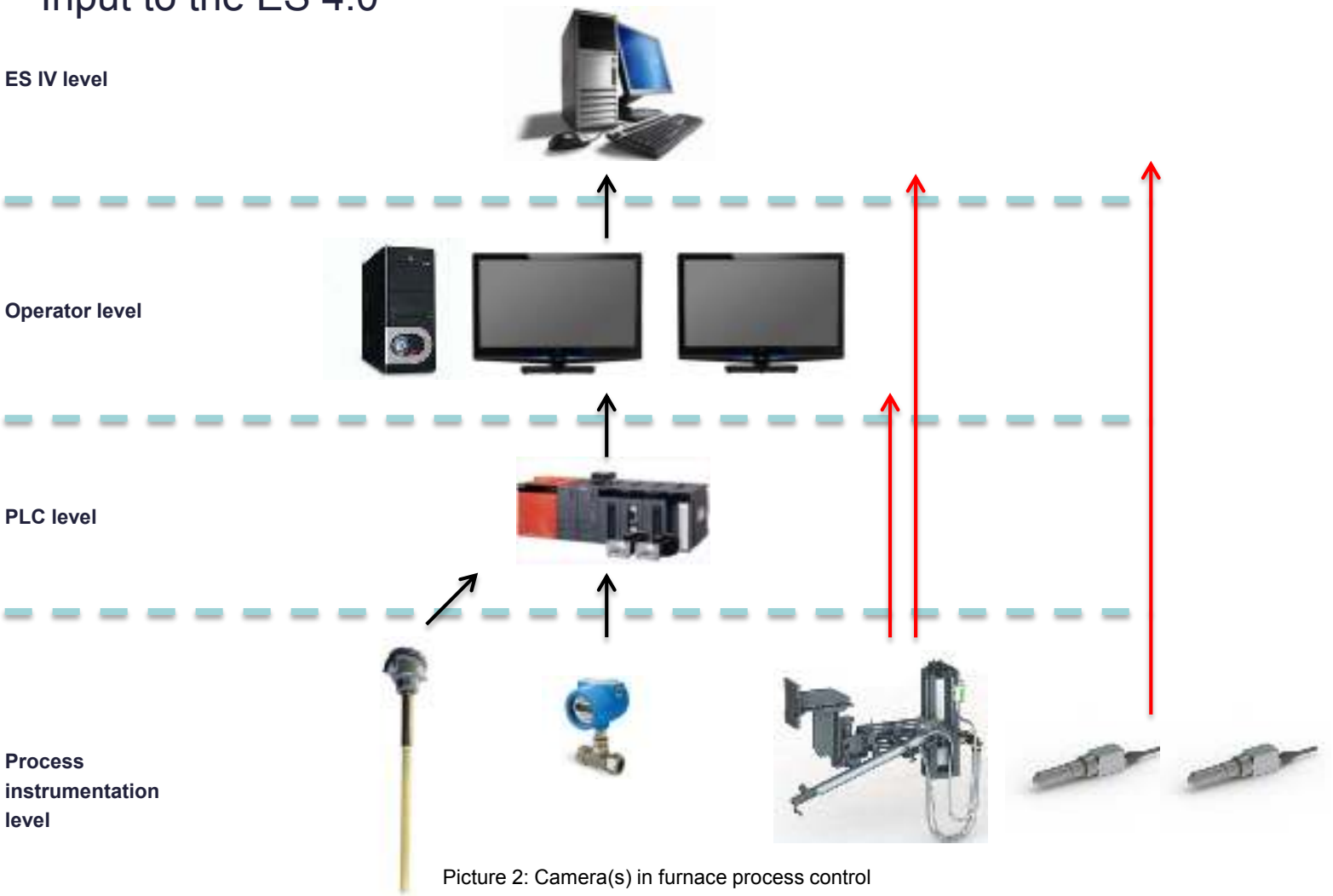
GS Visual & INFRARED CAMERA

- GS IP HD Visual & Infrared cam with electronic retraction system

Picture 1a: GS New Furnace camera system

CAMERAS IN FURNACE PROCESS CONTROL

- Monitoring
- Input to the ES 4.0

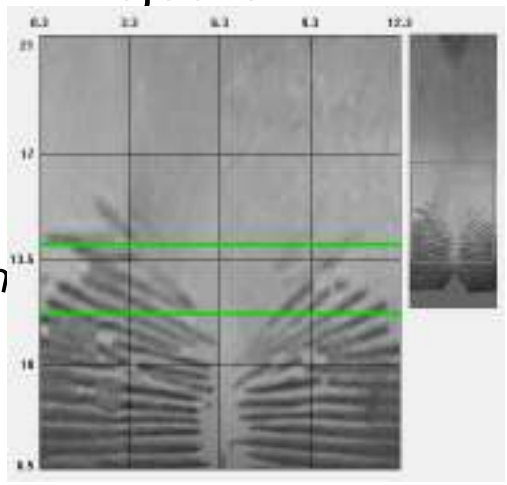


Picture 2: Camera(s) in furnace process control

ES III™ CAMERA - OVERVIEW

+

Projection



Correspondence between the real world and the images

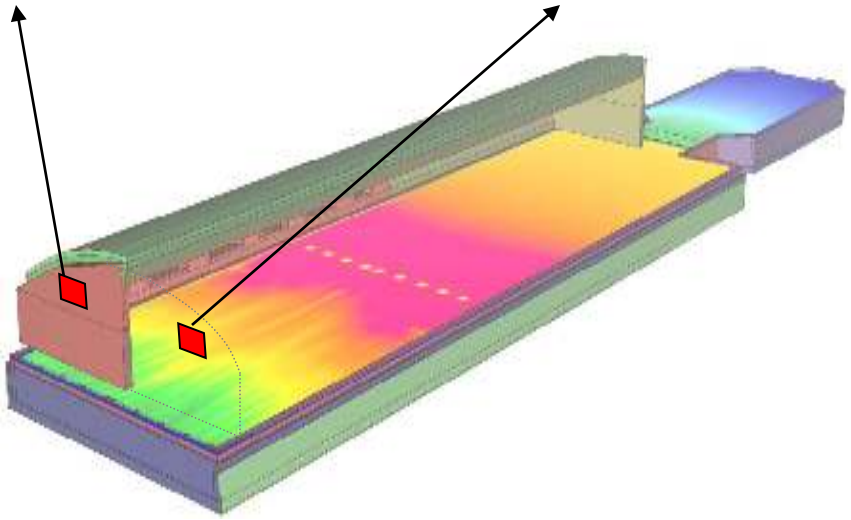
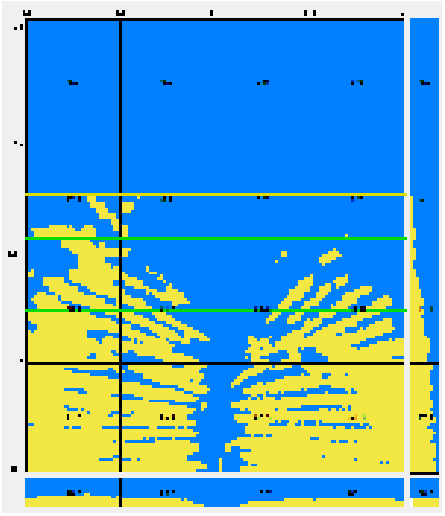


Image processing

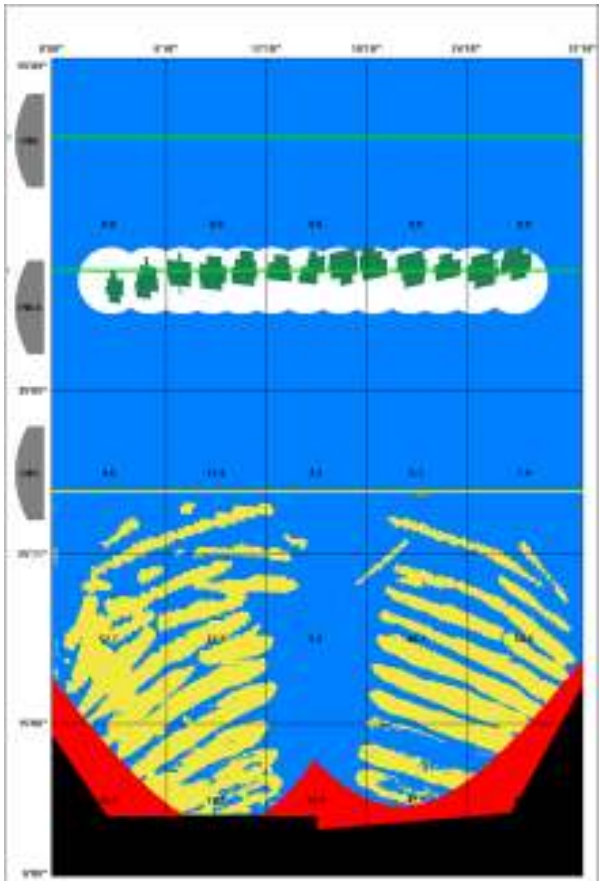


Measured data, statistics, analysis

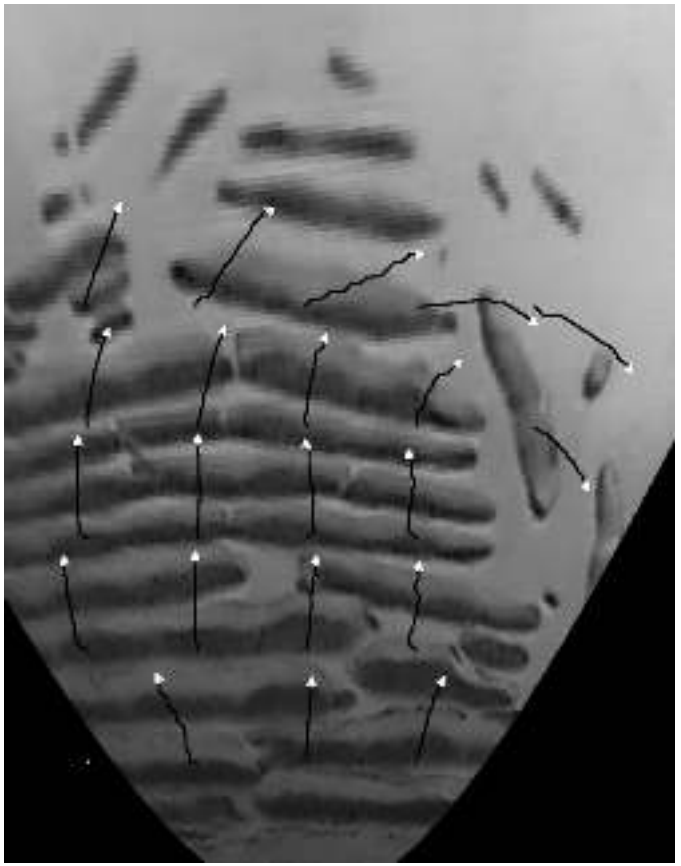
Analyzing via picture archive easy long term video

FLOAT FURNACE BATCH MEASUREMENT

- Bubblers position and size detection
- Batch flow direction and velocity

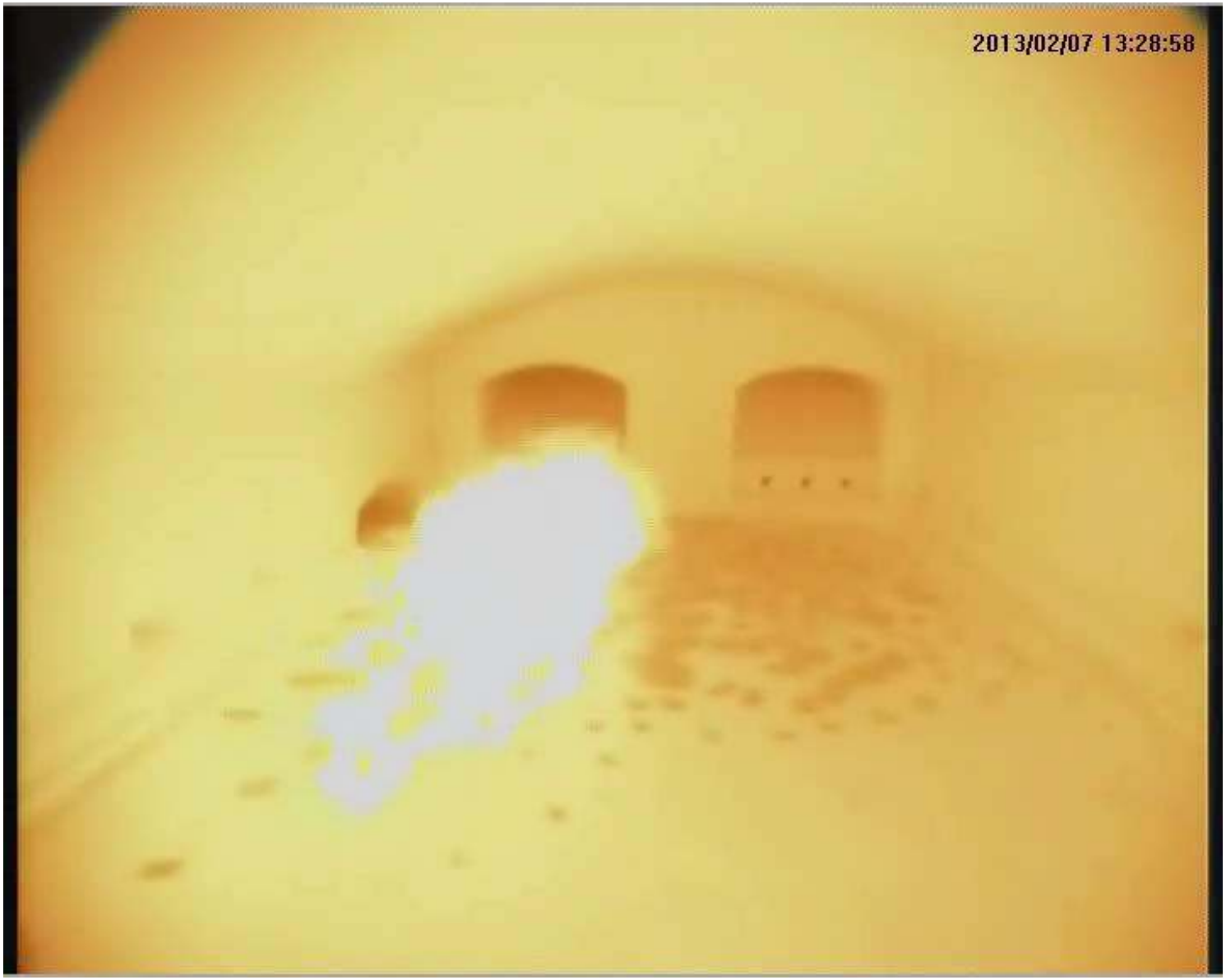


Picture 5: Bubblers measurement



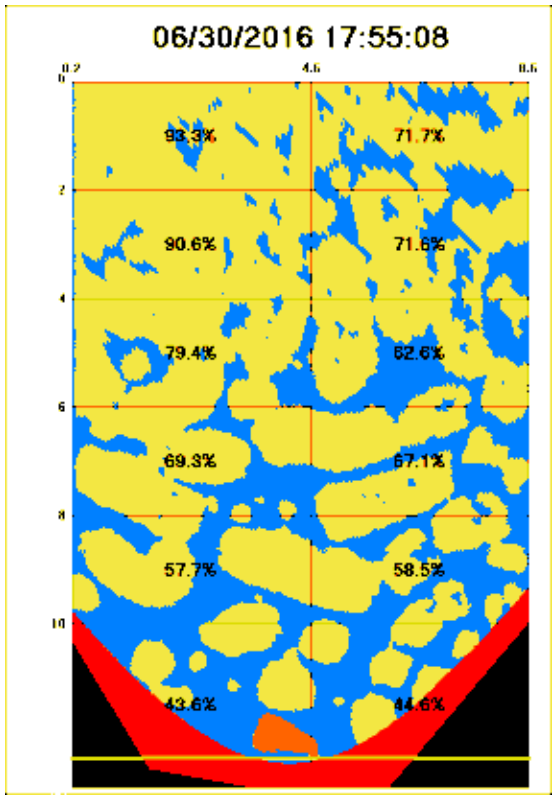
Picture 6: Batch flow measurement

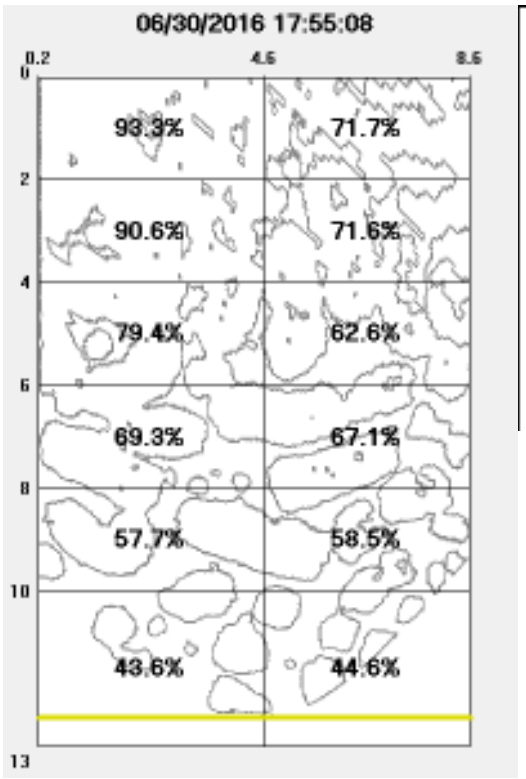
Analyzing via picture archive (easy) long term video

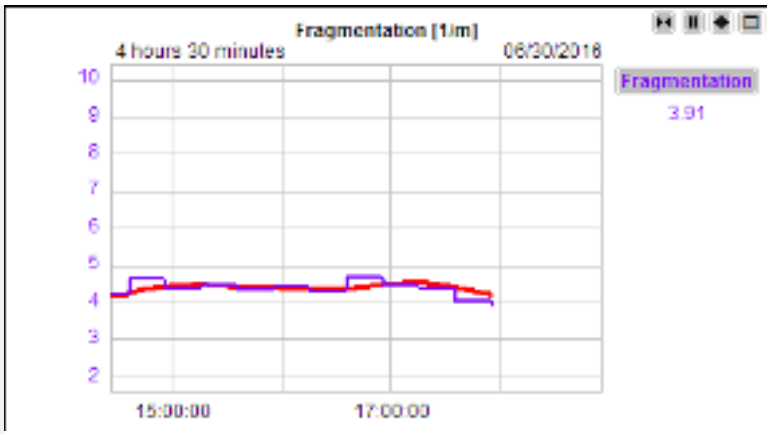


CONTAINER FURNACE MEASUREMENT

- Batch coverage / Batch periphery = Batch fragmentation



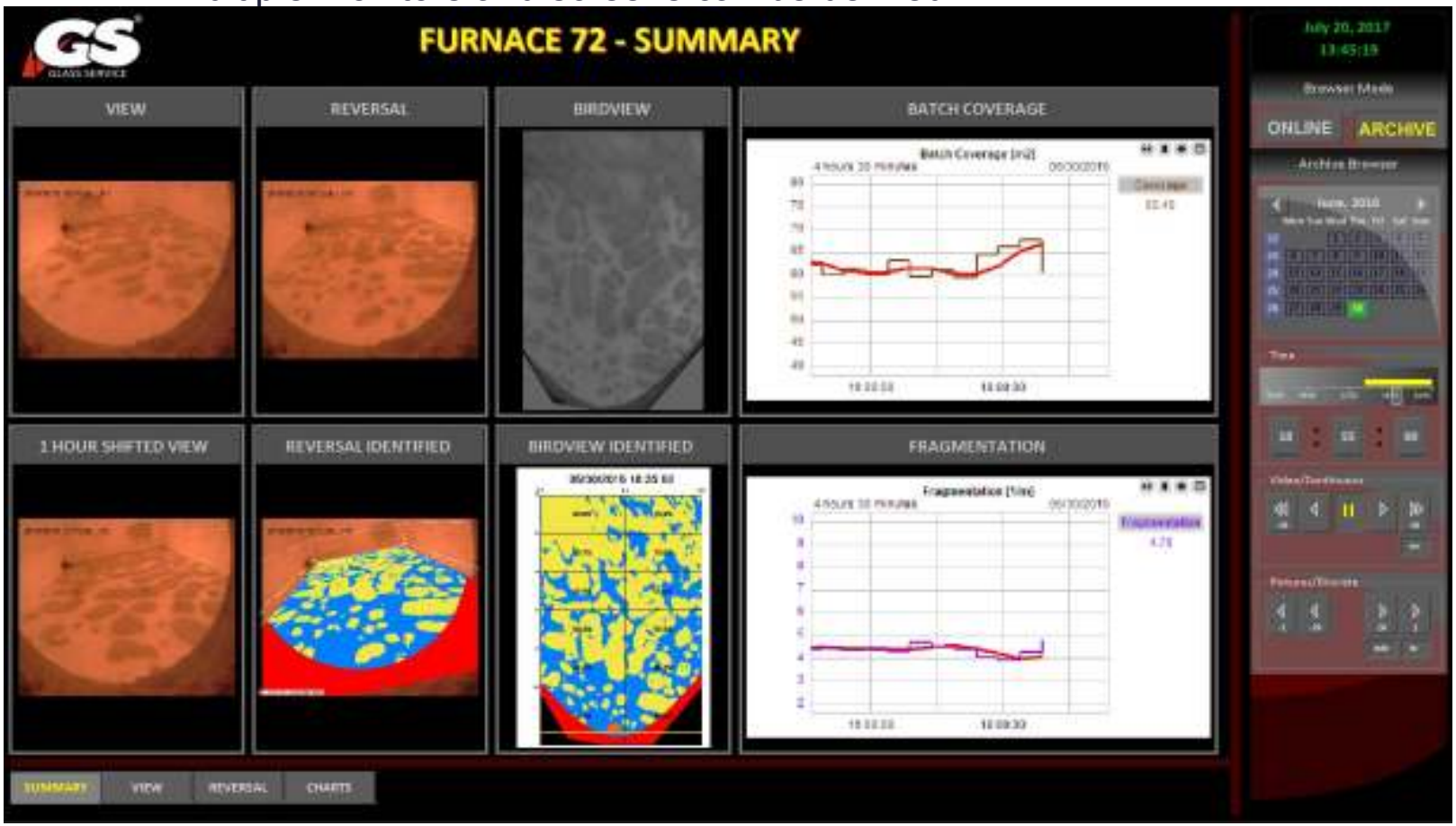




Picture 7: Container furnace measurement

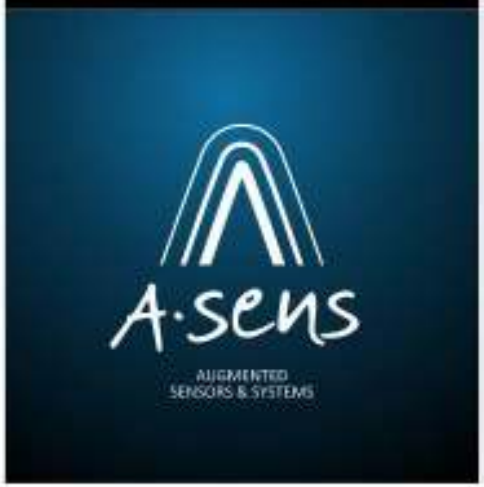
BROWSER

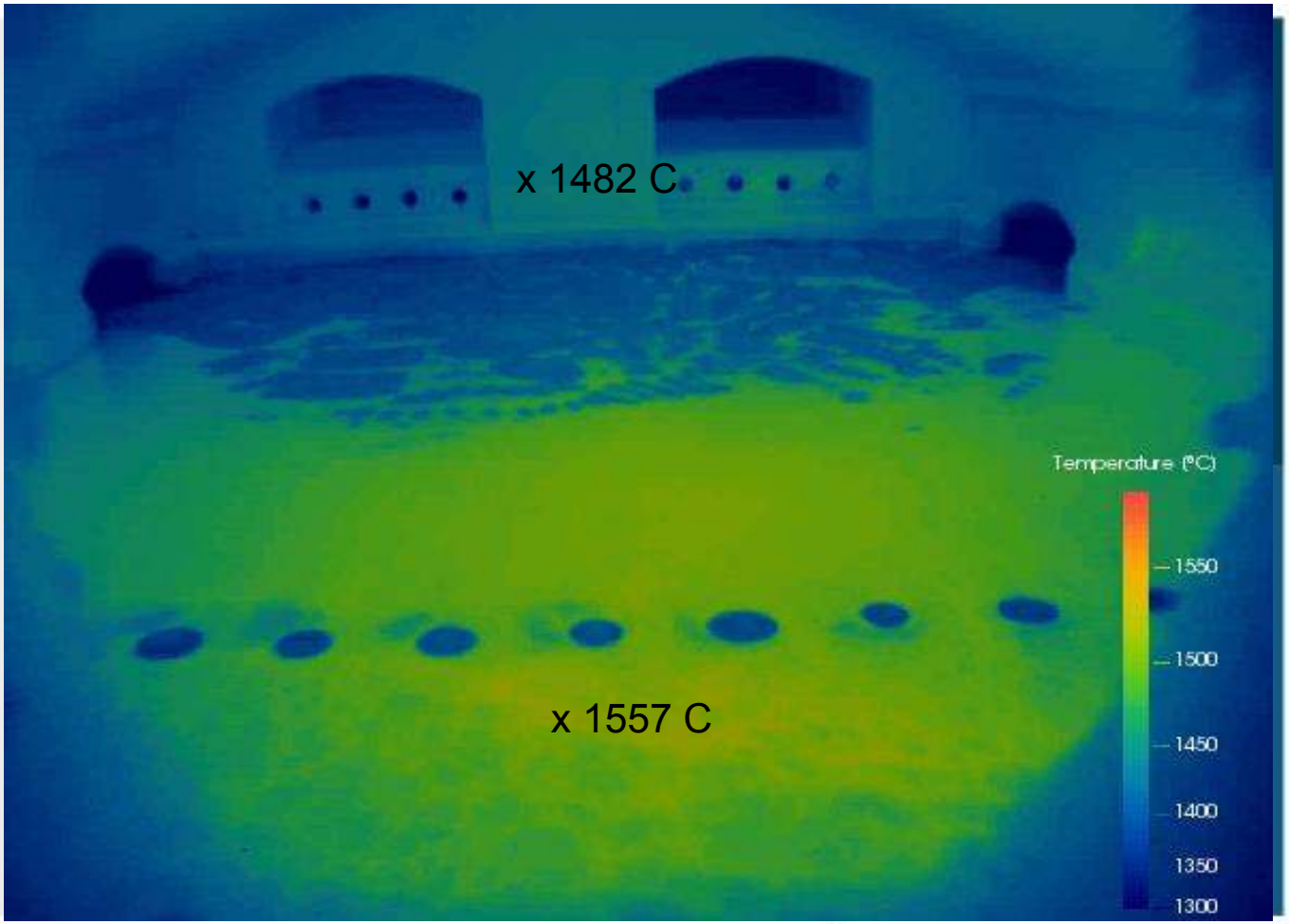
- TCP/IP client integrated in ES IV
- Might be used separately also
- Viewing and history browsing pictures and videos
- Fast playing forward and backward possibility
- Multiple monitors and screens can be defined



A-Sens new camera solution

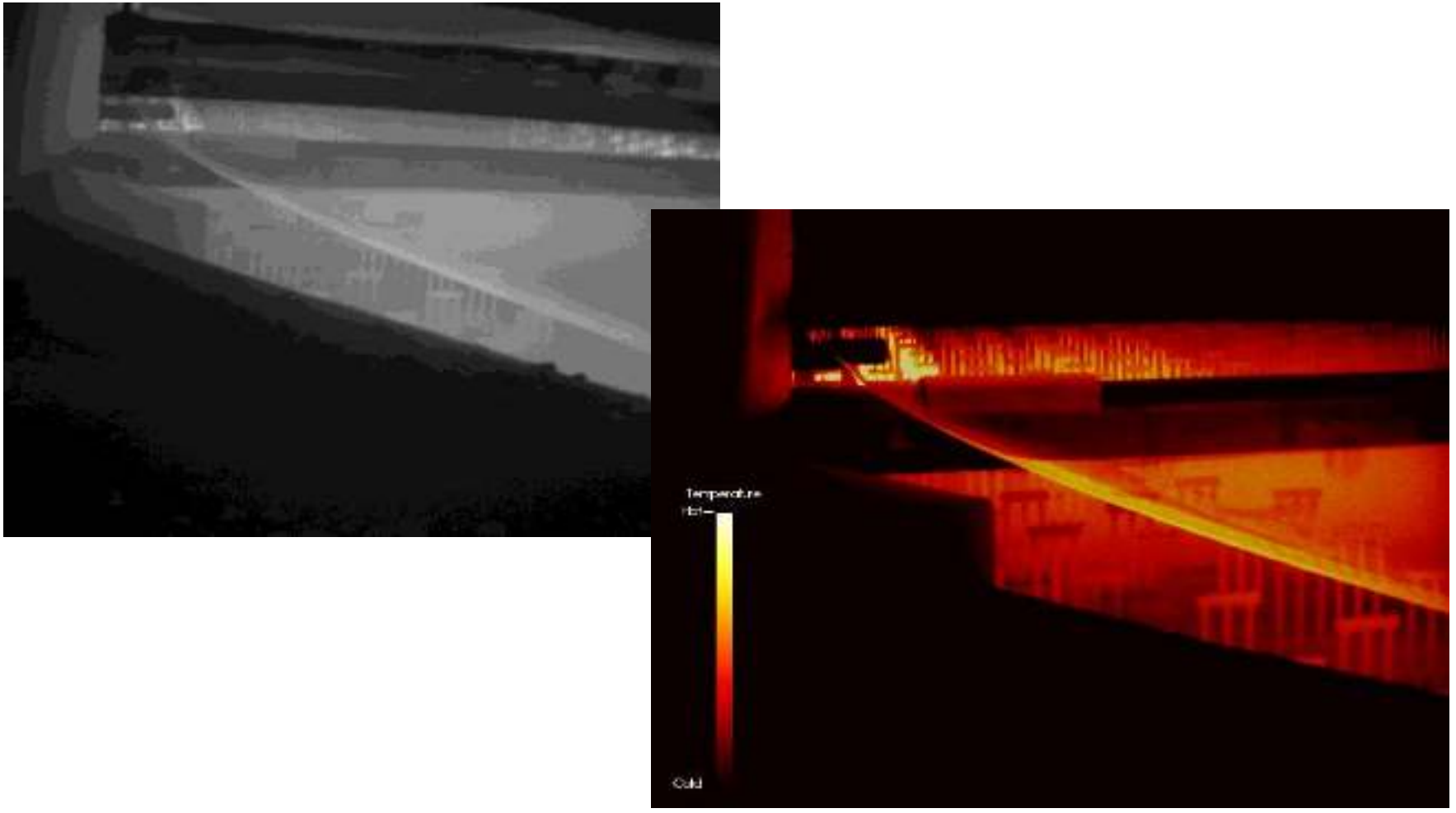
- New GS Augmented-Sens camera provides 2 video streams: regular vision information plus calibrated temperatures using Infrared parallel





TIN BATH MEASUREMENT

- Using IR camera for spread detection, improved detection



Picture 12: Ribbon Spread detection IR camera

Adding Intelligent "Vision" to the process in the near future

New (available) sensors

Existing standard sensors

Batch/Cullet Humidity

LIBS
Laser Induced Breakdown Spectroscopy

Batch preparation

Disturbances

Batch Line

BTU

Melter

Operators

Corrosion

Oxygen sensor

Temperature sensor

Mass Spec Fuel & Flue gas

Glass level sensor

ESIII Feedback

Working end

Neural Network Defect recognition

ESIII Feedback

Oxygen sensor

Viscosity sensor

Forehearth

Forehearth

Gob Image

Mould temp Thermo vision

Forming

Forming

Annealing

Annealing

Online stress

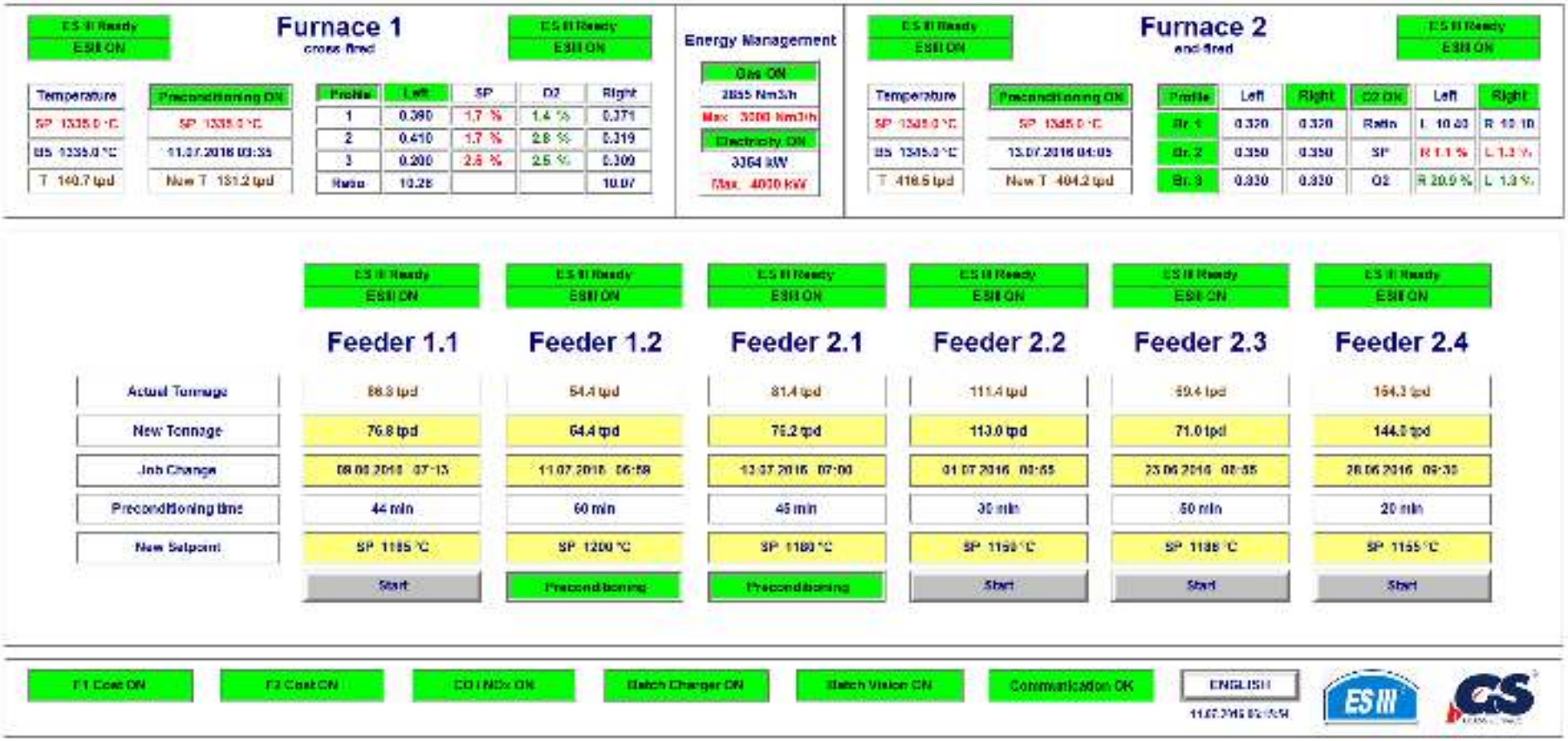
Inspection

Inspection

Defects imaging

Defects Mass Spec

Final HMI process overview for advanced control, 2 melters and 6 forehearths example



ESIII™ Advanced Process Control for Glass Production

1. is a comprehensive supervisory advanced control tool – keeps existing PID loops
2. Models are made in most cases from historical database or step testing
3. is designed for glass melting and conditioning processes
4. stabilizes long and short term processes
5. provides full automatic control of glass production temperatures
6. brings consistent furnace operation to furnace – 24/7 independent on operator
7. uses energy sources efficient – saving energy and costs
8. stabilizes glass forming conditions – increase yield
9. optimizes combustion – emission control
10. stable furnace operation – impact on furnace lifetime
11. Customer can use just Runtime License or Developer License

ES*III* References till mid 2017

THANK YOU FOR ATTENTION !

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