# Using Systems Theory for Additional Risk Detection in Boiler Explosions in Brazil

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- The presentation reflects the authors views, not the official position of the Brazilian Government.

- Boiler accident aboard the **Norbe VIII drillship** – 2017
- Three workers died, and one was injured

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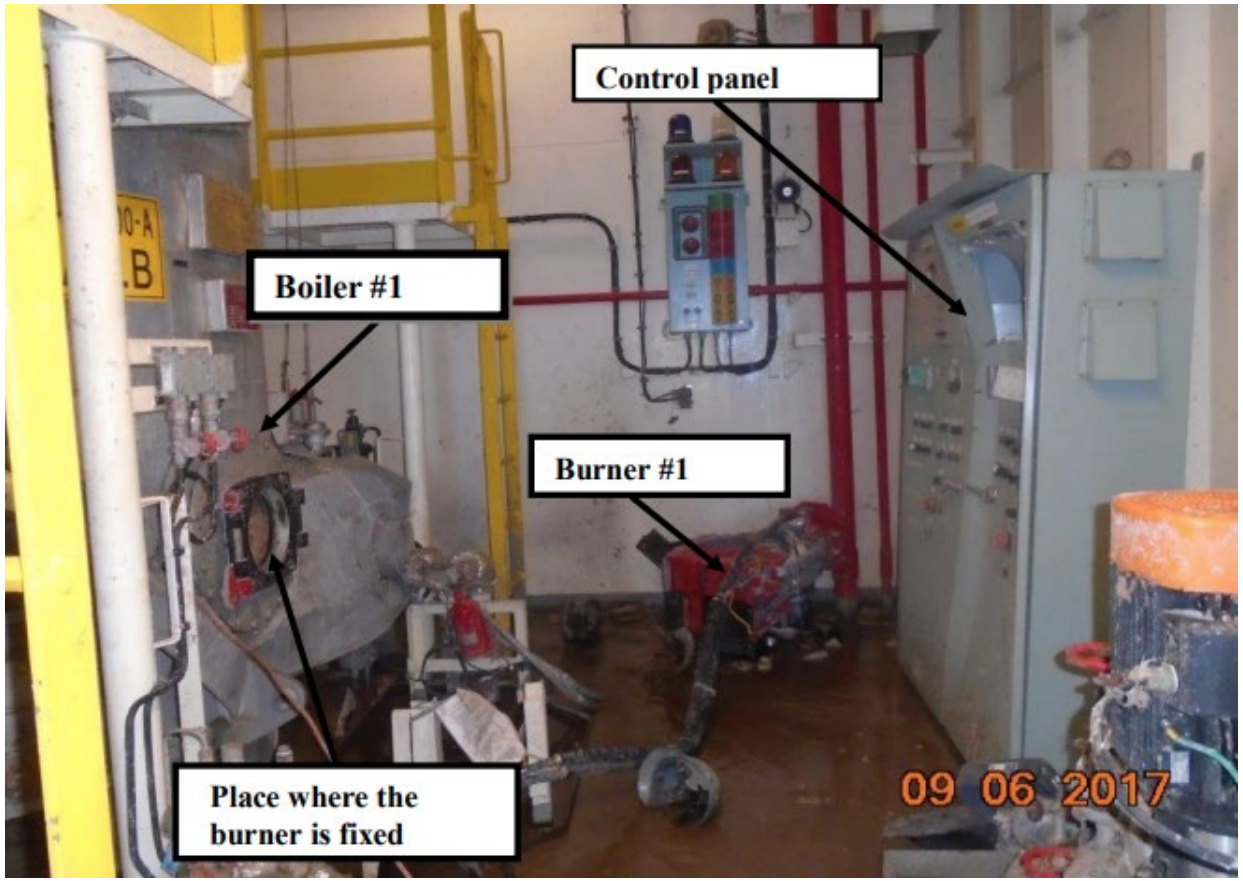
Brent spot $121.24 ▲ +4.67%
Brent futures (1 mo) $121.08 ▲ +2.95%
WTI spot $120.34 ▲ +4.81%

**Three workers die in Brazil rig blast**

Explosion occurred on board drillship Norbe VIII



- Several official investigations

The Bahamas Maritime Authority

THE COMMONWEALTH OF THE BAHAMAS

**Norbe VIII**
**IMO Number: 9562568**
**Official Number: 8001689**

**Report of the marine safety investigation into a boiler explosion leading to three fatalities on a drill ship on 09 June 2017**

BRAZILIAN NAVY
Directorate of Ports and Coasts
Marine Safety Superintendence
Department of Inquiries and Investigations of Navigation Accidents
EXPLOSION WITH VICTIMS ON THE "NORBE VIII" PLATFORM
Maritime Safety Investigation Report

**BRAZILIAN NAVY**

**DIRECTORATE OF PORTS AND COASTS**

**EXPLOSION WITH VICTIMS ON THE "NORBE VIII" PLATFORM**

**JUNE 09, 2017**

**MARITIME SAFETY INVESTIGATION REPORT**

Photo 1- Probe platform "NORBE VIII"

**Reference:**
**Casualty Investigation Code, of the International Maritime Organization (IMO) – MSC-MEPC.3 / Circ.2, 13 June, 2008 / Resolution MSC.255 (84).**

**RELATÓRIO DE INVESTIGAÇÃO DE INCIDENTE**

SONDA MARÍTIMA NORBE VIII (NS-32)

anp
Agência Nacional do Petróleo, Gás Natural e Biocombustíveis

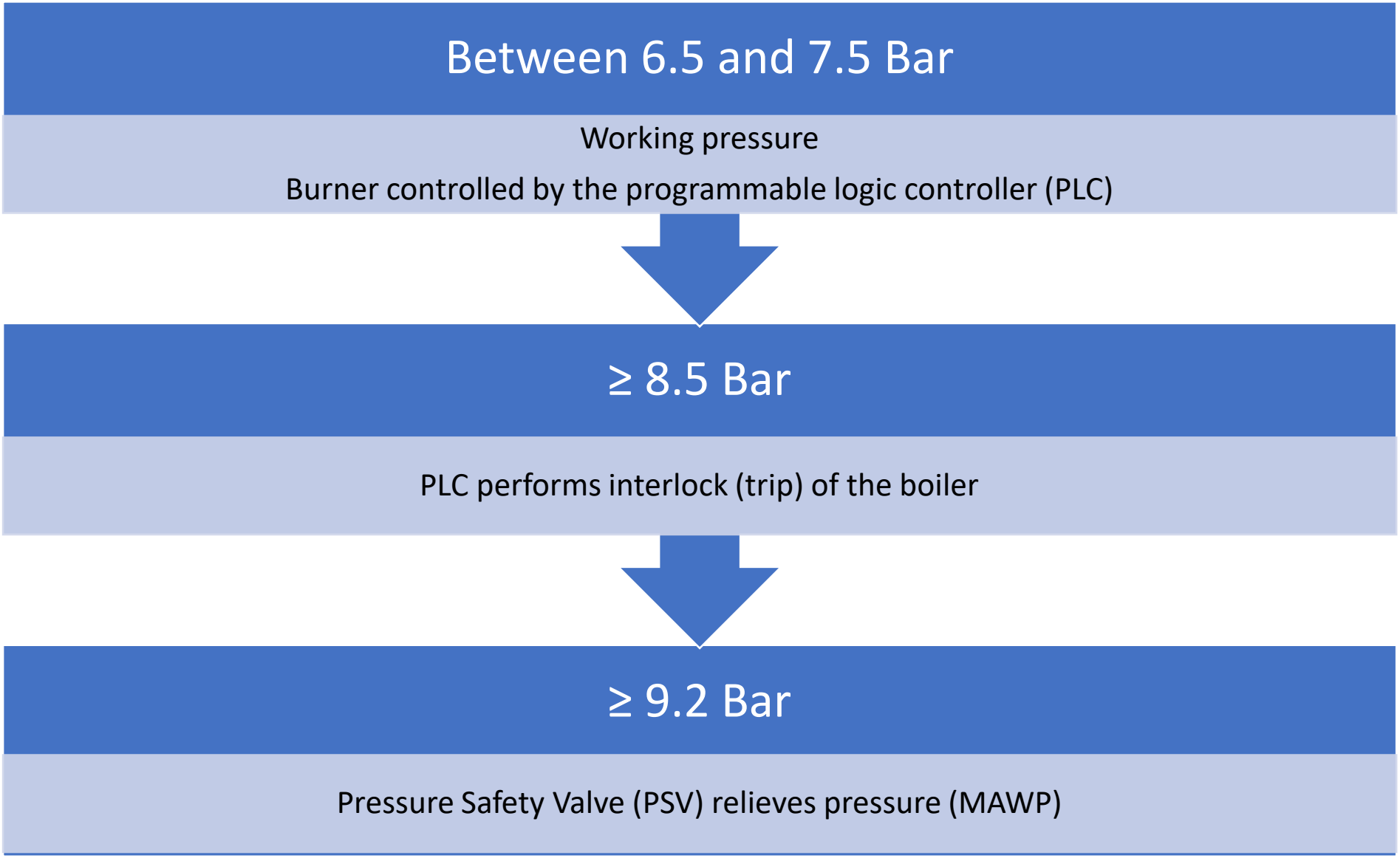
SUPERINTENDÊNCIA DE SEGURANÇA OPERACIONAL E MEIO AMBIENTE (SSM)

Dezembro/2018

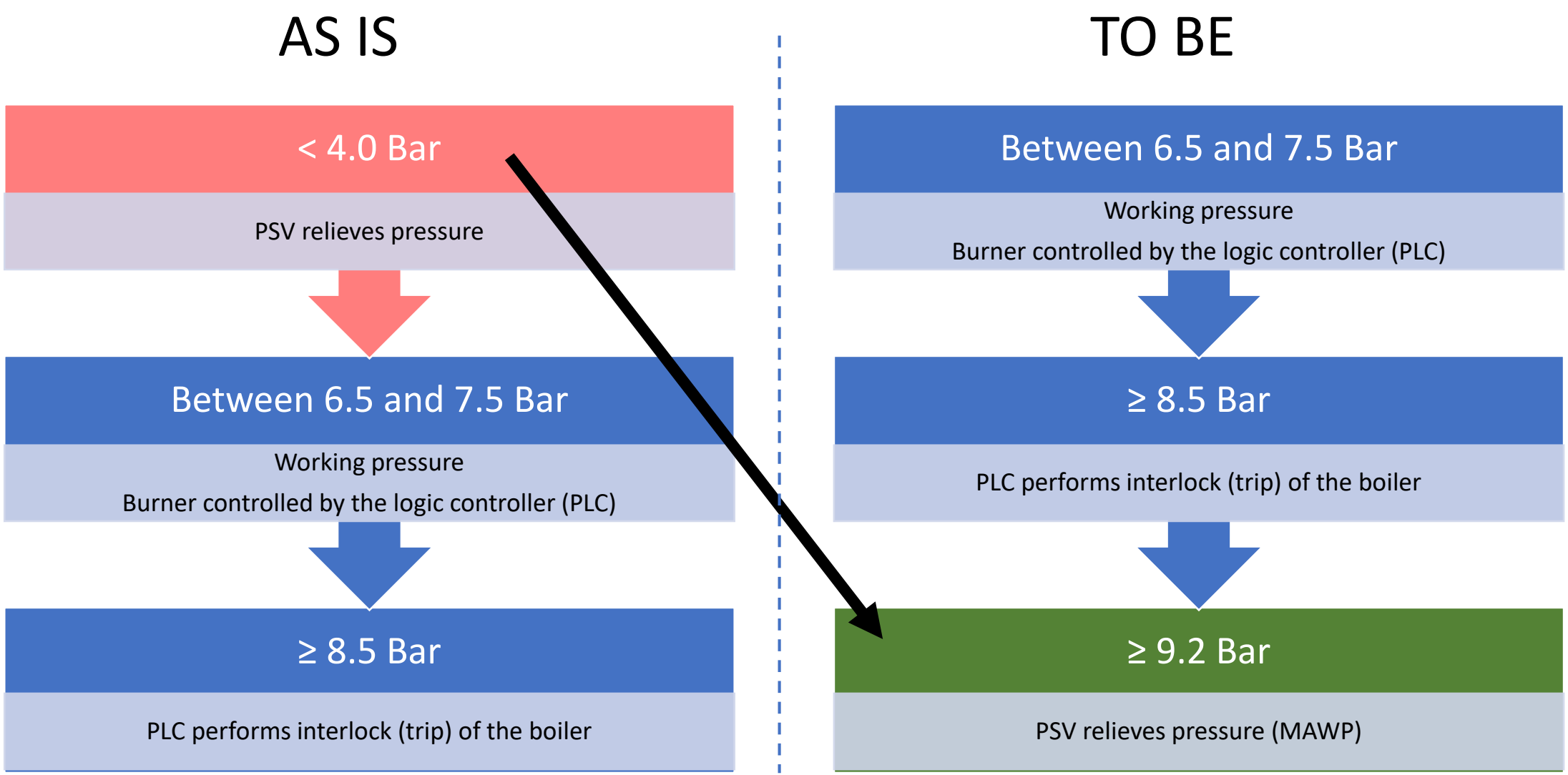
| Date | Time | Event |
|---|---|---|
| 6 June 2016 | - | Last periodic safety inspection of boiler #1 |
| 6 June 2017 | - | The calibration certificate for pressure gauges and safety valves (PSV) and the safety inspection of boilers expires |
| 7 June 2017 | Afternoon | Technicians from IMI embark on the Norbe VIII and require the Chief Engineer (day shift) to place the boilers in normal operating conditions |
| 7 June 2017 | Afternoon | The Chief Engineer requests the night shift team to heat and start the boilers to carry out the inspection service |
| 7 June 2017 | 20hs | Heating of the boilers |
| 8 June 2017 | 2:00 - 3:00 am | The boilers are started by the Second Engineer (night shift), who identifies that the PSV of both boilers were relieving at pressures below the set pressure. |
| 8 June 2017 | Daybreak | The Chief Officer (night shift) starts the boilers and confirms the relief of the PSV below the pressure set. Turn off both boilers and return to the Machine Control Room (ECR). |

| Date | Time | Event |
|---|---|---|
| **8 June 2017** | Before the shift change | The Chief Officer (night shift) informs the Chief Engineer (day shift) about the PSV problem. Then both go to the boiler room and restart the boilers to confirm the problem. Boilers #1 and #2 PSV were relieved at higher pressures than in the previous test, but still below the set pressure. |
| **8 June 2017** | 5:30 am | The IMI team was informed that the boilers were not ready for inspection due to the problem found with the PSV. |
| **8 June 2017** | Morning | The second Engineer (day shift) and the IMI team enter the boiler room. The boilers were started and the premature actuation of the PSV of boiler #1 was observed. |
| **8 June 2017** | 5:30 pm | At the shift change meeting, the night team is instructed not to perform boiler service during the shift, as IMI would perform boiler service on the morning of the following day. The Second Engineer (night shift) advises that the PSV would have to be removed and manually tested. The Second Engineer (day shift) informs the Chief Engineer that the following day the boilers would be ready for PSV removal. |
| **9 June 2017** | 7:00 am | The boiler heating process starts. The Second Machine Officer and the IMI team are in the boiler room. |
| **9 June 2017** | 7:38 am | Boiler #1 explodes during the heating process. |

# BOILER'S BACKUP PROTECTION SYSTEM



# OPERATOR'S MENTAL MODEL



# OPERATOR'S MENTAL MODEL

## AS IS

< 4.0 Bar

PSV relieves pressure

Between 6.5 and 7.5 Bar

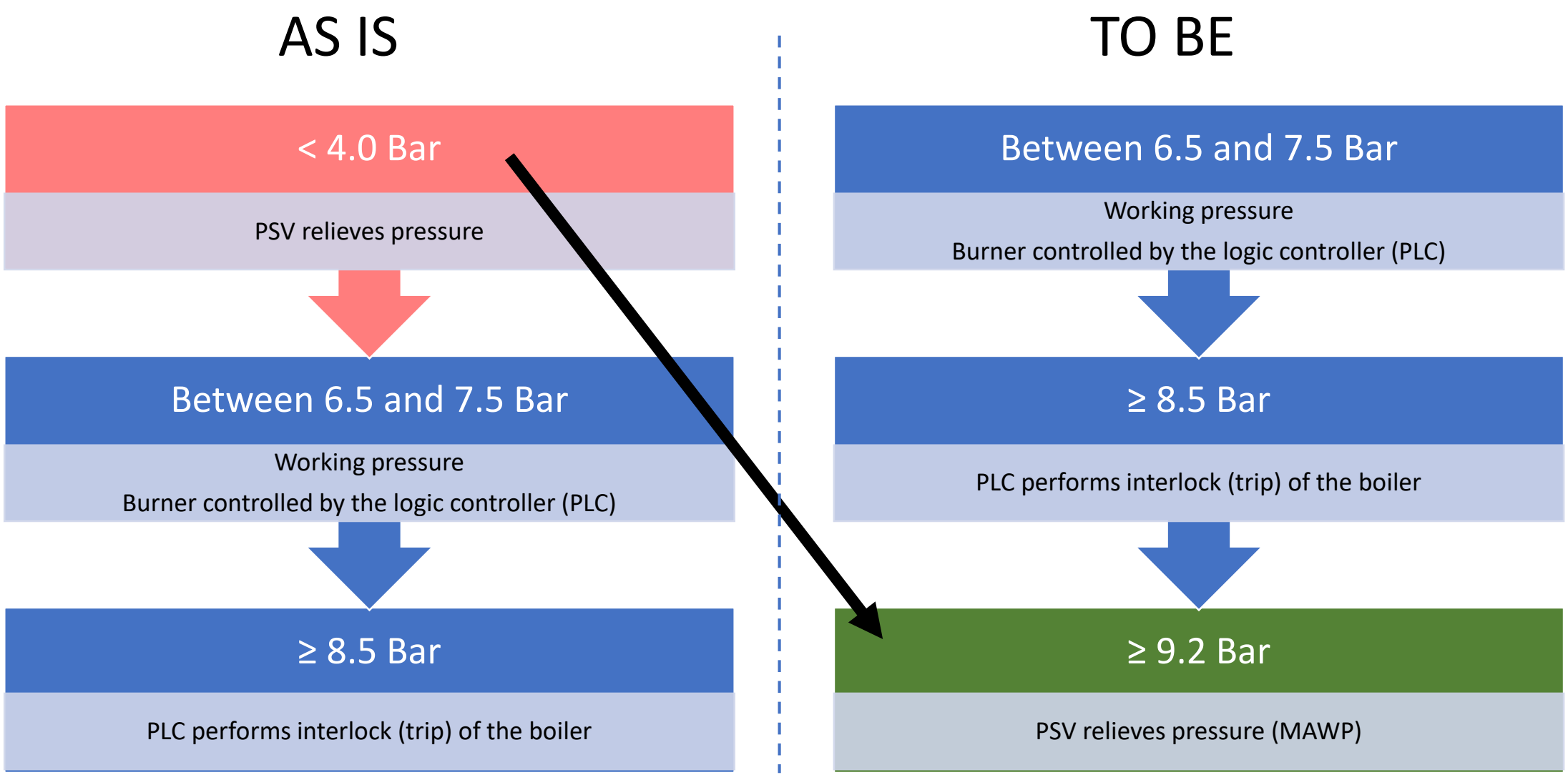
Working pressure

Burner controlled by the logic controller (PLC)

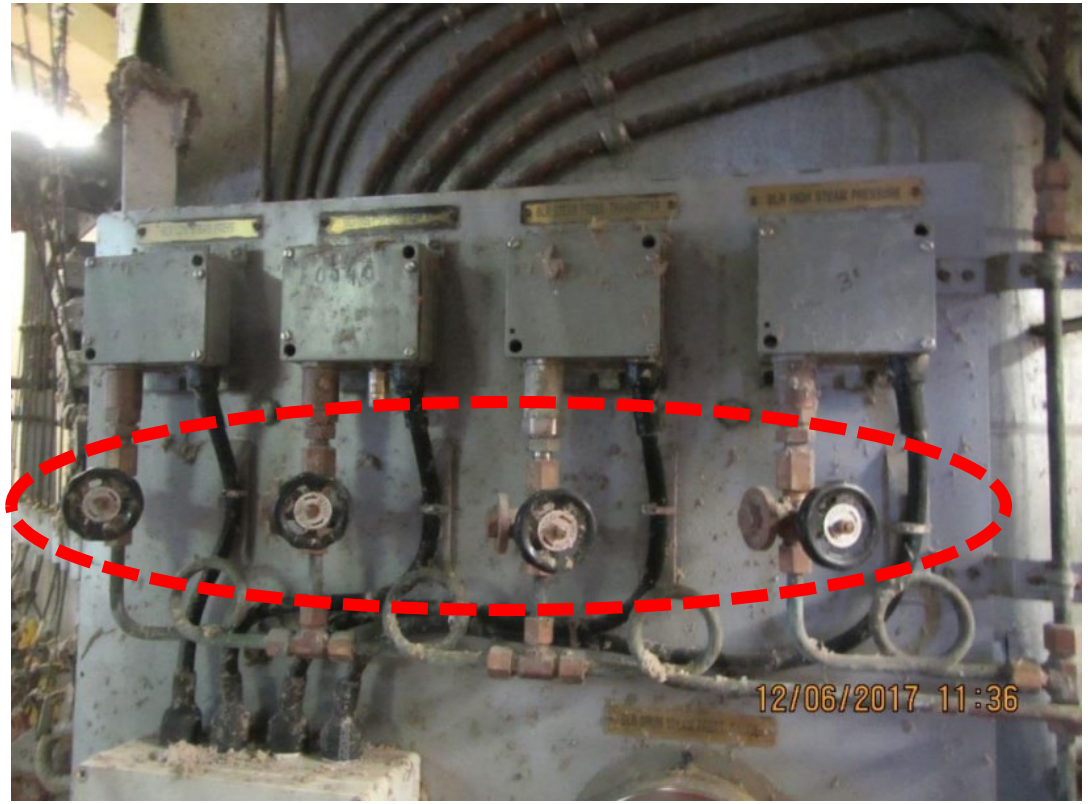
≥ 8.5 Bar

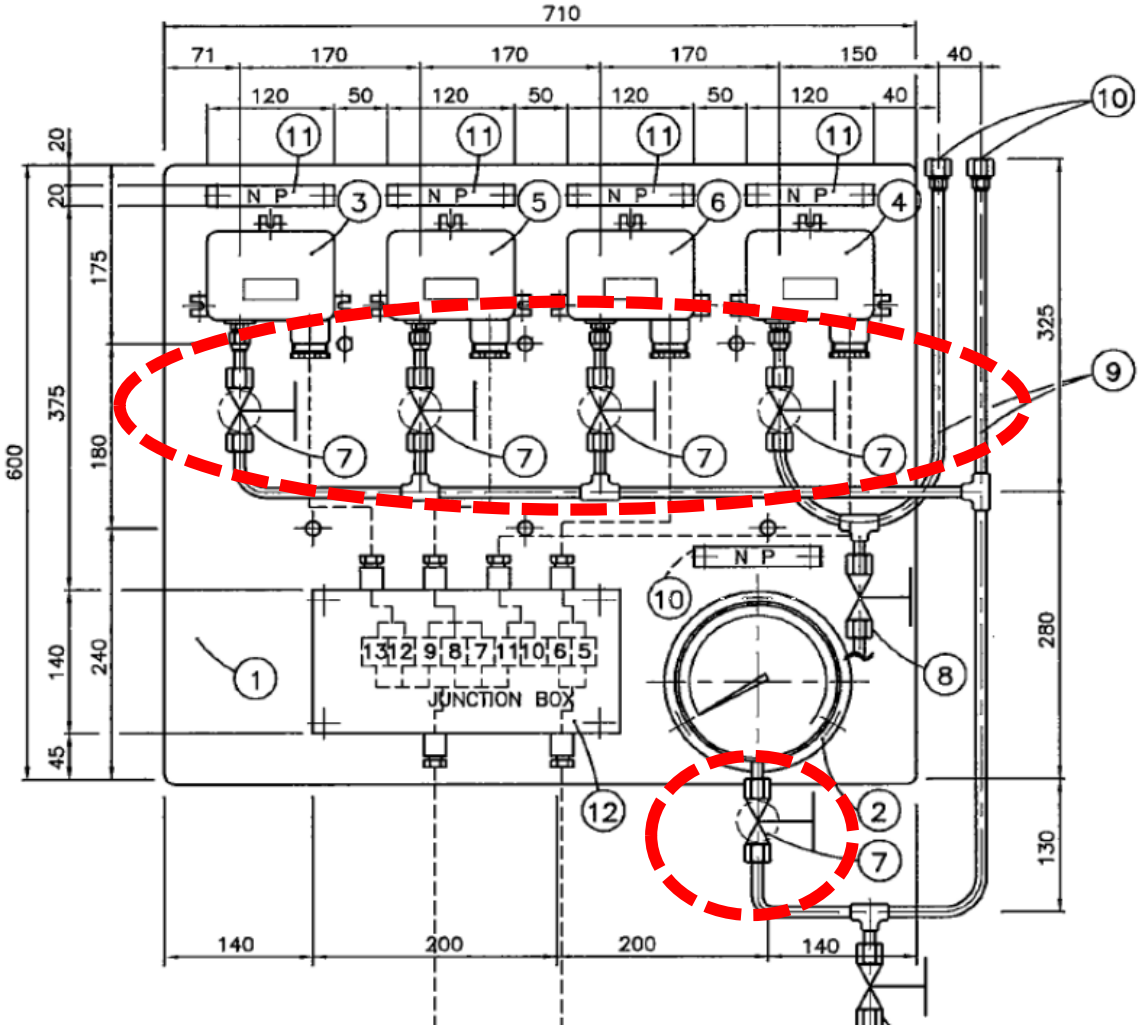
PLC performs interlock (trip) of the boiler


# OPERATOR'S MENTAL MODEL



# Manual valves in the pressure taps of safety devices were closed!




All the safety devices controlled by the PLC disabled!

- Anti-tamper seals removed
- Not documented
- Springs fully compressed

## OPERATOR'S MENTAL MODEL

< 4.0 Bar

PSV relieves pressure

Between 6.5 and 7.5 Bar

Working pressure

Burner controlled by the logic controller (PLC)

≥ 8.5 Bar

PLC performs interlock (trip) of the boiler

## WHAT WAS REALLY HAPPENING

~~Between 6.5 and 7.5 Bar~~ DISABLED

Working pressure

Burner controlled by the programmable logic controller (PLC)

~~≥ 8.5 Bar~~ DISABLED

~~PLC performs interlock (trip) of the boiler~~

≥ ~~9.2~~ 39 Bar!

Pressure Safety Valve (PSV) relieves pressure (MAWP)

# Official report recommendations regarding the accident on board Norbe VIII

| # | Description |
|---|---|
| 1 | Provide a qualified professional to oversee the operation and maintenance of the boilers. |
| 2 | Improve contractor due diligence, including technical expertise, regulations, and scope of services. |
| 3 | Establish audit procedure for contractors |
| 4 | Establish procedures for boiler inspection in accordance with the manufacturer's instructions |
| 5 | Implement the use of a checklist for the startup and operation of boilers |
| 6 | Include a specific health and safety culture program in the leadership training matrix. |
| 7 | Implement a procedure to perform hazard analysis and control when performing non-routine tasks. |
| 8 | Implement a procedure to issue a hazard analysis and control when performing non-routine tasks. |
| 9 | Establish a shift change procedure (changelog, lockout & tagout, ongoing interventions etc.). |
| 10 | Review the boiler start procedure considering the prior verification of valves, instruments, and pressure taps of the control system, through a checklist. |
| 11 | Create a procedure for disabling boiler control and protection systems. |
| 12 | Implement training in change management and related procedures. |
| 13 | Implement a training program to value the safety culture and behavioral attitude of the workforce. |
| 14 | Establish a documented form of communication between leadership and its team |
| 15 | Establish a safe work system to keep only qualified professionals directly involved in the activity in the place of execution of operations |
| 16 | Issue notification to the manufacturer about the failure identified in the Boiler Manual: Lack of a step-by-step procedure to perform the gradual heating of the boiler adequately. |
| 17 | Provide updated Boiler Operation Manual in Portuguese. |

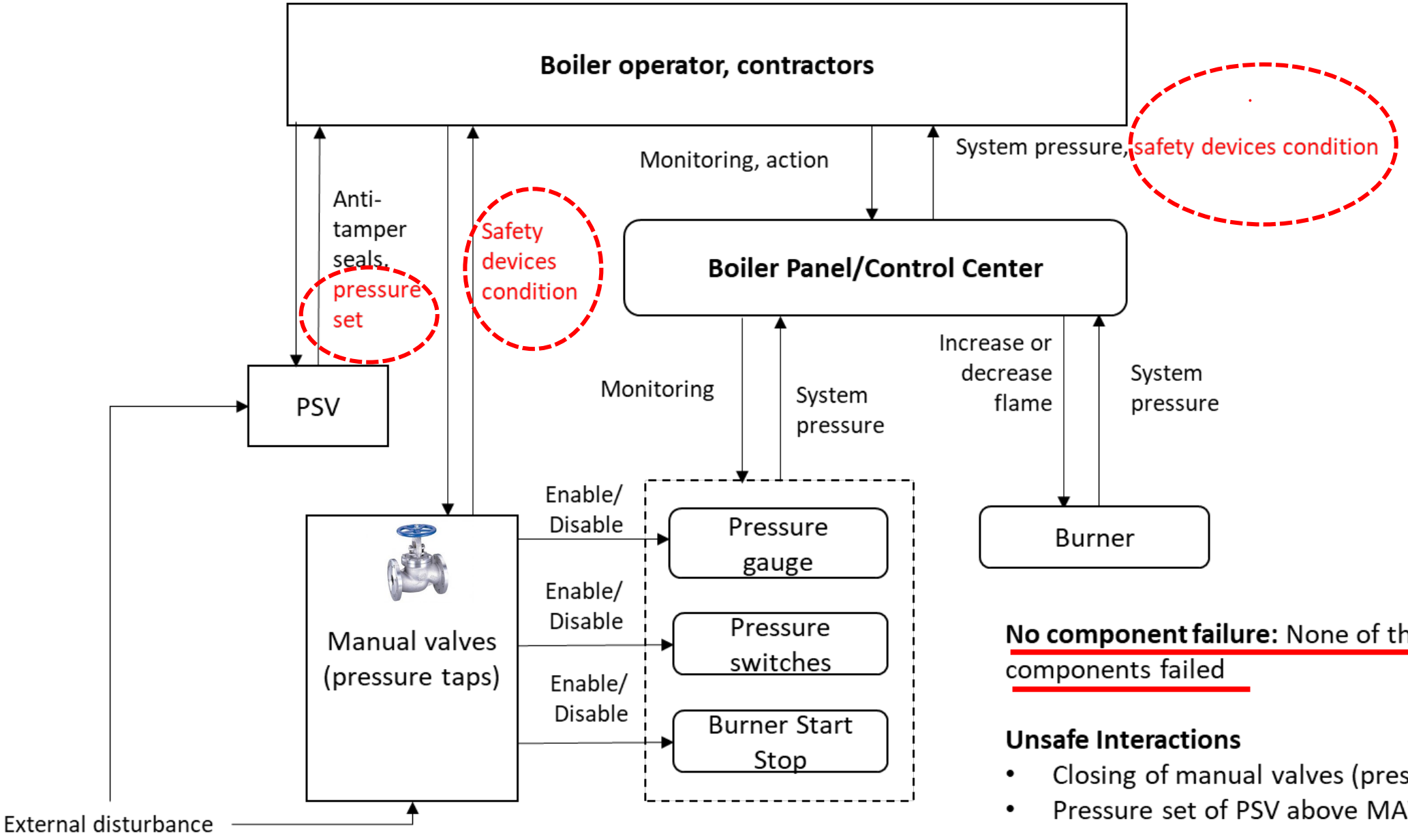
**Procedures / Training:**

- symbolic and incorporeal barriers
- low efficiency
- not sufficient for safety-critical tasks
- difficult to evaluate their effectiveness
 -highly dependent on humans during operations

(Hollnagel, 2008)

Rather than striving to control behavior by fighting procedure deviations, to improve safety, the focus should be on control of the behavior by making the boundaries of safe operations explicit and known to actors

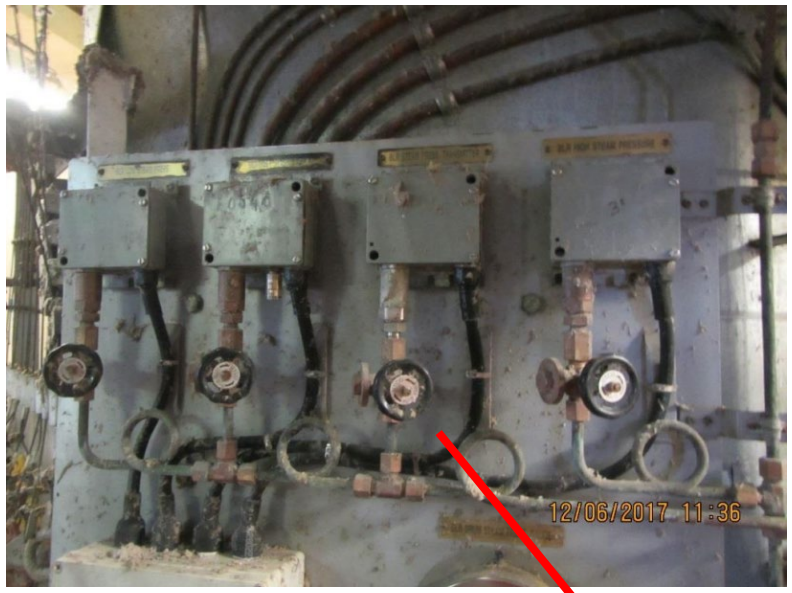
(Rasmussen, 1997)




**No component failure:** None of the physical components failed

**Unsafe Interactions**

- Closing of manual valves (pressure taps)
- Pressure set of PSV above MAWP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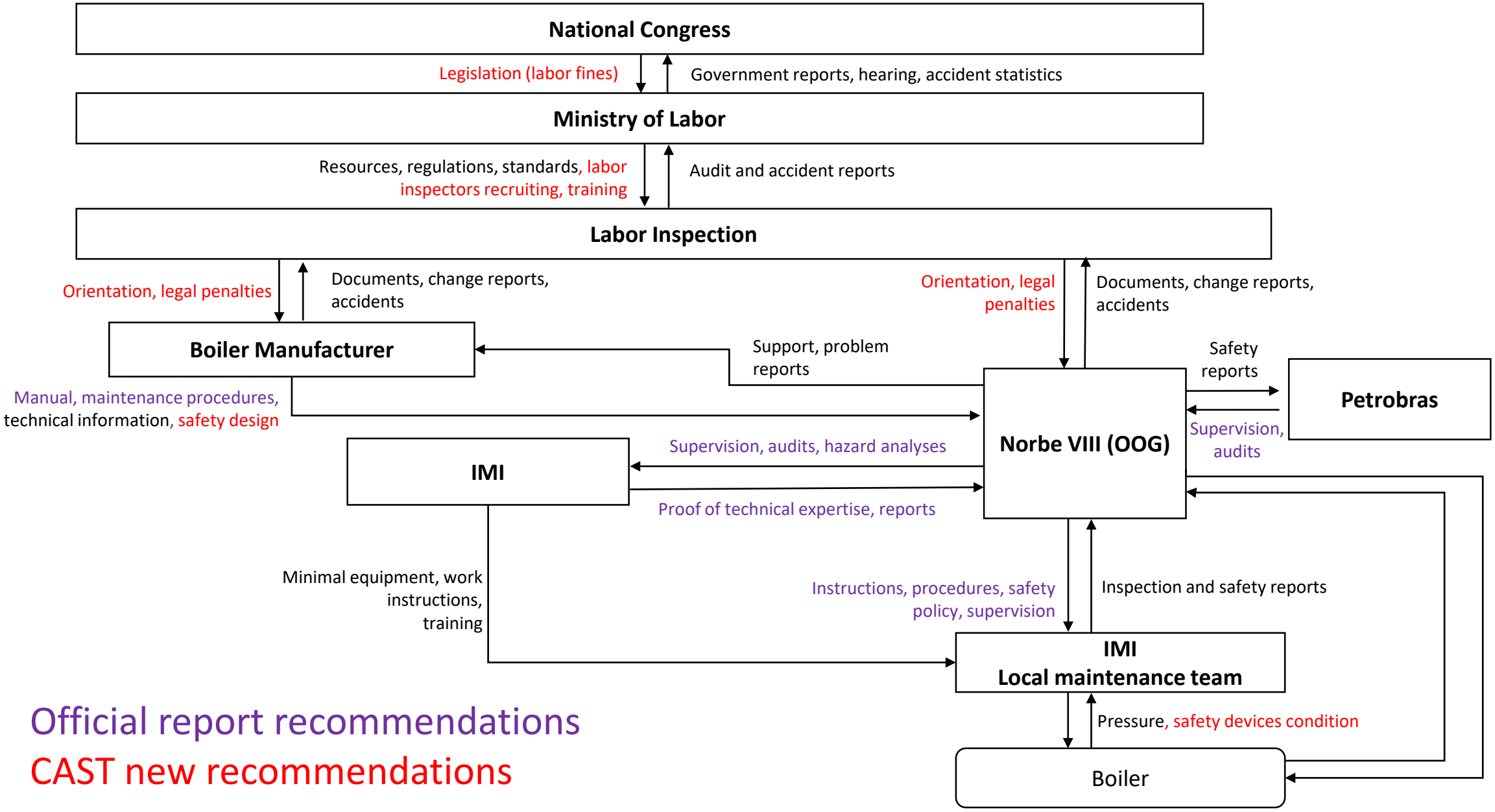


- Official report recommendations
- CAST new recommendations

# CONCLUSION

- New **6** design recommendations (Boiler Manufacturer)
- New **5** recommendations to Government (National Congress, Ministry of Labor, and Labor Inspection)
- **2** other recommendations to Norbe VIII company and Petrobras

# CONCLUSION

- The role or contribution of official agencies (National Petroleum Agency, Ministry of Labor, Brazilian Navy etc.) to the hazardous state were not addressed in their reports.
- Need to reduce the subjectivity in selecting the chaining conditions.

# CONCLUSION

- Defense-in-depth is definitely a good approach. But not enough.
- More important than numbers, the CAST analysis identified systemic causal factors that allow the prevention not only of similar events in the future, but a broader type of accidents that stems from unsafe control actions at higher levels of the safety control structure.

# Thank you!

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## Using systems theory for additional risk detection in boiler explosions in Brazil

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ABSTRACT

Recent technological advances have allowed some human activities, including those related to safety, to be automated. However, these advances increased the complexity of sociotechnical systems, representing exponential growth of interactions between humans, computers, machines, and the environment. Moreover, growing productive and economic pressures demand safer and more reliable products and projects, at lower costs and time than those practised by competitors. To cope with this complexity and set of conflicting objectives, the STAMP (Systems-Theoretic Accident Model and Processes) emerged as a novel approach to analyse processes and accidents. In this study, an overview of boiler accidents in Brazil is presented and a causal analysis based on STAMP (CAST) is conducted to revisit one of the worst boiler accidents in the Brazilian scenario. Even without direct participation in the investigations, additional and more relevant risk factors are evidenced. Furthermore, it was found that government agencies generally refrain from reviewing their own control actions contributing to the hazard, limiting their potential improvements. This suggests a need for companies and government agencies to adopt new paradigms of risk and accident analysis and to work together for a systemic safety improvement approach.

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