TITLE 24, PART 6 | 2028 CODE CYCLE

Process Boiler #2: Conductivity-Based Blowdown & Deaerator Settings

Codes and Standards Enhancement (CASE) Proposal

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CALIFORNIA ENERGY CODES & STANDARDS
A STATEWIDE UTILITY PROGRAM

Proposal Description

- Code Change Proposal
- Benefits
- Background Information

Proposed Code Change

- This proposal would add the following requirements for **all newly installed process steam boiler systems with capacities at or above 10 MMBtu/h**:
  - The boilers have an **automatic blowdown controller** that is programmed to be controlled by conductivity, and
  - For systems that use the boiler steam header to pressurize the deaerator, **the deaerator regulator pressure must be set to 5 psig or below** and between 2 and 5 psig for boilers with tubes not rated for oxidizing conditions.

- Exceptions for the automatic blowdown requirement:
  - New construction and addition* boiler systems with condensate return above 90%.
  - Boilers with makeup water treated by an RO system.
  - Boilers employing blowdown heat recovery.

- Exception for the deaerator setpoint requirement:
  - Systems with a design condensate return temperature above 227°F.

See Title24stakeholders.com for proposal description, justification, draft code language, and requested data

*Additions where the boiler systems are contained in the addition.

Benefits of the Proposed Change

Automatic blowdown:

- Automatic blowdown systems use real-time monitoring to **automatically maintain water conductivity** within manufacturer-specified setpoints.
- This eliminates the need for operators to make manual valve adjustments and avoids excessive blowdown, offering the following benefits:
  - **Fuel, water, and chemical savings**, and
  - **Improved conductivity control**, which can **extend boiler useful life** and **slow efficiency degradation.**
- Energy savings are roughly 0.5% to 1% of boiler input energy.

Deaerator pressure:

- Avoiding excessively high deaerator pressurization **saves energy** at no additional cost.

"We recommend automatic blowdown anytime there's a steam system over 100 HP (~3.3 MMBtu/h)."

– Boiler manufacturer

Background Information: Automatic Surface Blowdown

- **High conductivity** in boiler water indicates high mineral content, which **leads to fouling** of the boiler heat exchanger tubes, increased thermal stress, lower boiler efficiency, and ultimately accelerated system wear and tear.
- Boiler water is periodically or continuously discharged or "blown down" to remove suspended and dissolved solids.
- As blowdown discharges hot water, it also results in fuel, water, and chemical losses. **Manual boiler blowdown is typically excessive**, resulting in **unnecessary losses**.
- Automatic surface blowdown systems **avoid excessive blowdown** by monitoring and maintaining water conductivity within manufacturer-specified setpoints.

Blowdown System Diagram

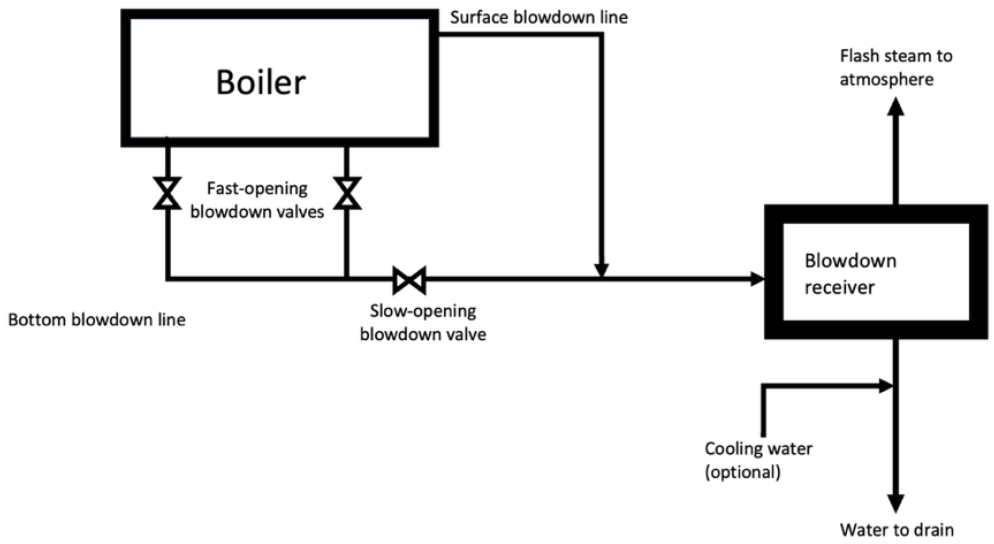

Diagram recreated based on image from: Industrial Steam

Background Information: Deaerator Pressure

- Deaerators **remove dissolved gases** from steam boiler feedwater **to protect the system** from corrosion and ensure high heat transfer rates.
- A deaerator is a pressurized vessel that **heats the feedwater** to temperatures that release the dissolved gases (mainly O_2 and CO_2) from the water.
- At **higher pressures**, water boils at a higher temperature, so higher pressure setpoints heat the feedwater to higher temperatures, **using more energy.**

Deaerator System Diagram

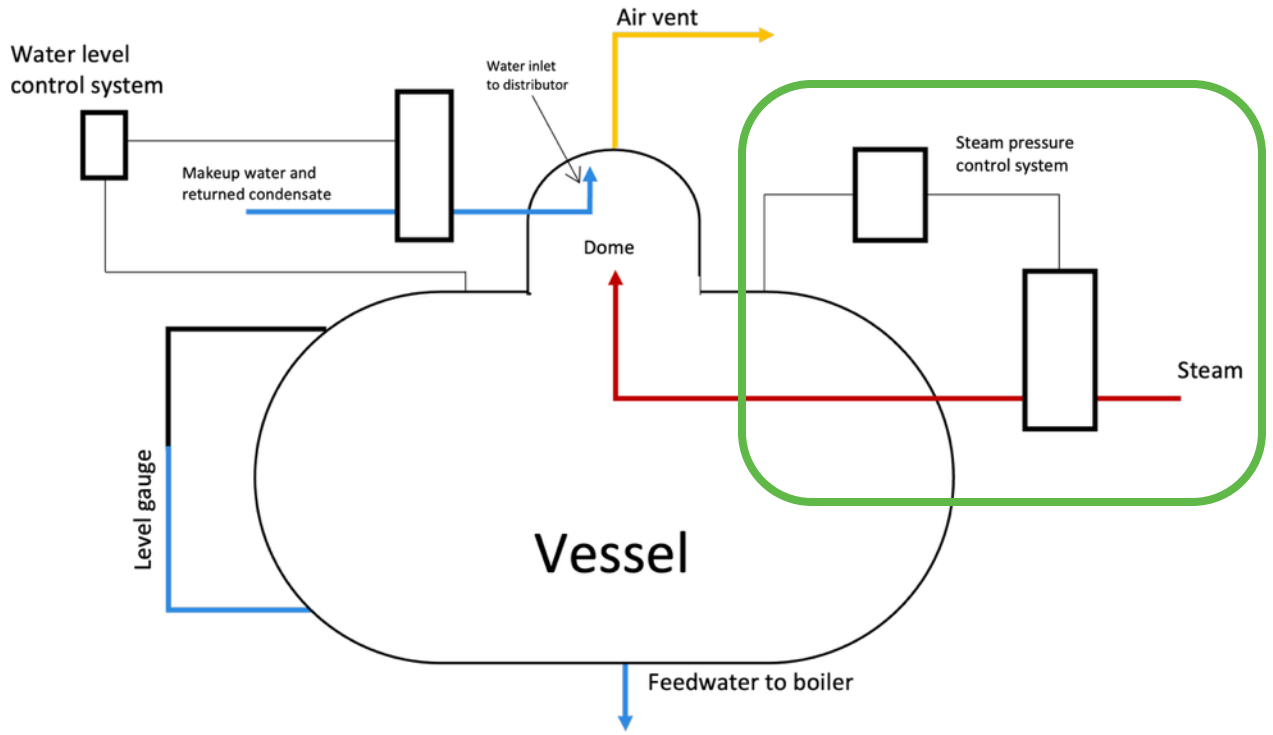

Diagram recreated based on image from: Spirax Sarco

Background Information: Deaerator Pressure

- As pressures increase, more dissolved gases are removed.
- A higher deaerator pressure provides a **greater margin of assurance** for removing dissolved gases but also results in **greater steam losses**.
- Deaerators are installed with steam boiler systems and are sometimes **operated at pressures that are higher than necessary** out of excess caution.
  - Over-pressurization leads to excess steam venting and wasted energy.
  - Under-pressurization can cause insufficient air removal, which can lead to oxygen pitting and corrosion on contact surfaces.

5 psig provides 227°F

Marked-up Code Language

See Title24stakeholders.com for marked-up code language

Title 24, Part 1	Title 24, Part 6	Reference Appendices
▪ No changes	▪ 100.1 (b) Definitions ▪ 120.6 (d) Mandatory requirements for process boilers	▪ Nonresidential Appendix NA7 Installation and Acceptance Requirements for Nonresidential Buildings and Covered Processes ▪ NonRes and Multifamily Compliance Manual, Chapter 10, Section 10.9 Process Boilers

Market and Technical Considerations

- Current Conditions and Trends
- Potential Barriers and Solutions
- Technical feasibility

Current Market Conditions

Automatic blowdown:

- The CASE Team estimates that 20-30% of existing steam boilers in California use automatic blowdown systems. The prevalence of these systems increases with boiler size.
- Automatic boiler blowdown control was patented in the early 1970s. It has been in DOE tip sheets since 2004 and is often recommended in IAC audits.
- Without a code requirement, the CASE team **estimates that the current market share will remain relatively stable**, as boiler operators have had ample time and opportunity to move to automatic blowdown systems.
- The market share may increase slowly as the benefits of automatic blowdown become more widely understood.
- The CASE team is not aware of utility incentive programs for automatic blowdown or deaerator pressure control in California, but programs exist in other states

Deaerator pressure:

- All steam boilers are sold with deaerator systems and a majority are set to 5 psig.

Patent: https://patents.google.com/patent/US3680531. DOE Tip Sheet: https://www.nrel.gov/docs/fy04osti/33474.pdf. Pacific Northern Gas incentive: https://png.ca/smartenergysolutions-2/commercial-efficient-hvac-controls/ Sources: Enesfere analysis of 64 boilers in 32 steam-using industrial plants audited from 2010-2022 as well as interviews with boiler manufacturers.

Market Barriers and Solutions – Automatic Blowdown

Market Barriers	Potential Solutions
1. Lack of general knowledge on the operation and financial benefits of automatic blowdown. 2. The estimated paybacks of up to 4.5 years for some small boilers are longer than most facilities typically consider for investments. 3. Boiler systems with condensate return above 90% require less makeup water and have lower blowdown needs, reducing the savings potential from automated blowdown systems.	1. Include information on automatic blowdown system operation in Compliance Manual or NR Appendix. 2. Support guidelines and market education on automatic blowdown system benefits and payback. 3. Exemption from automatic blowdown requirement for new construction and addition* boiler systems with condensate return above 90%.

*Additions where the boiler systems are contained in the addition.

Market Barriers and Solutions – Deaerator Pressure

Market Barriers

1. Facility operators may prioritize risk minimization over saving energy to a greater extent than is necessary for boiler health, and the potential savings and impacts of different setpoints may be unclear or uncertain, even within a recommended range.
2. Contractors may recommend setpoints outside the 2-5 psig range.

Potential Solutions

1. Ensure code language and required maximum pressure is definitive and vetted by experts. Support guidelines and training on deaerator pressure for boiler operators.
2. Include information on deaerator pressure in Compliance Manual or NR Appendix.

Current Market Share

Market share: percentage of boilers that already use the proposed technology or design practice (at or above the proposed stringency level)

Current Market Share

Sources: Enesfere analysis of 64 boilers in 32 steam-using industrial plants audited from 2010-2022 as well as interviews with boiler manufacturers.

Poll

What is the current market share of automatic blowdown systems for new boilers between 10 to 25 MMBTU/h (10,000 to 25,000 pounds of steam per hour)? That is, what percentage of these new boilers in California currently use automatic blowdown systems?

a. 1% – 10%
b. 11% – 20%
c. 21% – 30%
d. 31% – 40%
e. 41% - 50%
f. 51% - 60%
g. 61% - 70%
h. 71% - 80%
i. 81% - 90%
j. 91% - 100%

Poll

What is the current market share of automatic blowdown systems for new boilers greater than 25 MMBtu/hr (greater than 25,000 lbs of steam per hour)? That is, what percentage of these new boilers in California currently use automatic blowdown systems?

a. 1% – 10%
b. 11% – 20%
c. 21% – 30%
d. 31% – 40%
e. 41% - 50%
f. 51% - 60%
g. 61% - 70%
h. 71% - 80%
i. 81% - 90%
j. 91% - 100%

Poll

What is the current market share of deaerator pressure setpoints at 5 psig or below? That is, what percentage of newly installed boilers in California currently set deaerator pressure to ≤5 psig?

a. 1% – 10%
b. 11% – 20%
c. 21% – 30%
d. 31% – 40%
e. 41% - 50%
f. 51% - 60%
g. 61% - 70%
h. 71% - 80%
i. 81% - 90%
j. 91% - 100%

Technical Considerations – Automatic Blowdown

- An automatic blowdown control system uses high- or low-pressure probes to measure conductivity and compares the measured conductivity with a setpoint value.
- The system **controls a modulating blowdown release valve** to **maintain conductivity close to the setpoint** value.
- The optimum blowdown rate is impacted by boiler type, operating pressure, water treatment, makeup water quality, and the quality and volume of condensate returned to the boiler.
- System benefits vary by how closely the site already controls blowdown with manual practices, but savings will be realized regardless of setpoint due to the variability of manual blowdown.

Technical Considerations (continued)

Deaerator pressure:

- Deaerators are present in nearly all large boiler systems and are **commonly operated at pressures that are higher than necessary.**

Both submeasures (automatic blowdown and deaerator pressure):

- The proposed measures are generally **considered well-established industry best practices** where technical feasibility is not a concern.
- These measures are **agnostic to climate zones**.

Technical Barriers and Solutions

Technical Barriers	Potential Solutions
1. Automatic blowdown systems, including conductivity probes and control valves, can fail.	1. Include cost of replacement in cost-effectiveness calculations.

Poll

What else should we know?

Are there additional market or technical barriers or solutions we should consider?

[Open End]

Per Unit Energy and Cost Impacts

Methodology and Assumptions

- Energy and Energy Cost Savings
- Incremental Costs

Energy and Energy Cost Savings Methodology: Automatic Blowdown

Boiler savings were calculated based on the decreased energy loss when moving from manual blowdown to automatic blowdown.

Savings = annual therm usage with manual blowdown - annual therm usage with automatic blowdown

Annual therm usage = average blowdown energy in Btu/hr * Hours/100,000/Boiler Efficiency), where

$$\boldsymbol{Blowdown\ Energy} \doteq \dot{\boldsymbol{m}}_{\boldsymbol{bdn}} * (\boldsymbol{H}_{\boldsymbol{bw}} - \boldsymbol{H}_{\boldsymbol{mw}})$$

$\dot{m}_{bdn} = blowdown\ flow\ rate\ in\ (lbs/hr)$

$H_{bw} = Enthalpy\ of\ boiler\ water$

$H_{mw} = Enthalpy\ of\ makeup\ water$

$$\dot{\boldsymbol{m}}_{\boldsymbol{bdn}} = \frac{\boldsymbol{Steam\ flow}}{(\boldsymbol{COC} - \boldsymbol{1})}$$

$$\boldsymbol{COC} = \frac{\boldsymbol{C_b}}{\boldsymbol{C_{fw}}}$$

$\boldsymbol{COC}$ = Cycles of Concentration

$\boldsymbol{C_b}$ = average conductivity of boiler water

$\boldsymbol{C_{fw}}$ = conductivity of feedwater

Manual vs. Automatic Blowdown:
C_b manual: 2,500 micro-mhos, C_b automatic: 3,000 micro-mhos

Energy Savings Methodology: Deaerator Control

- To estimate the natural gas savings from improved deaerator control, the CASE team will **calculate the mass flow (lbs/hr) of steam lost to over-pressurization** when the deaerator setpoint is greater than 5 psig.

- The CASE team will use a CASE Team tool to:

  1) calculate deaerator steam vent based on deaerator pressure (psig)
     - Baseline: 7-9 psig (average: 8 psig for ~20% of sites)
     - Measure case: 5 psig
  2) calculate the therms required to make up for the volume of excess steam vented

Note: Energy benefits for deaerators inadvertently under 2 psig are not calculated since this is typically a deaerator issue after installation and they are estimated to make up <5% of newly installed boiler systems.

See Appendix slide for detailed calculations.

Key Assumptions

Baseline

Boiler conducting manual blowdown

Proposed

Boiler with automatic blowdown system

Consistent between baseline and measure case:

1. Annual hours of operation: 6,500
2. Condensate conductivity: 20 µΩ
3. Make-up conductivity: 440 µΩ
4. Feed water conductivity: 345 µΩ

Unique to baseline case:

1. Boiler water conductivity setpoint: 2,500 µΩ

Unique to proposed measure case:

1. Boiler water conductivity setpoint: 3,000 µΩ

Incremental Cost Framework

Baseline

Boilers conducting manual blowdown, with deaerator pressure varying by facility

First Cost

1. None

30-Year Maintenance Costs

1. Valve replacement (est. replacement every 9-10 years)

Proposed

Boilers with automatic blowdown systems with deaerator pressure setpoints at or below 5 psig

First Cost

1. Cost of blowdown valve, valve controller, and conductivity probe
2. Installation
3. Additional startup & commissioning (setting conductivity parameters)

30-Year Maintenance Costs

1. Probe replacement
2. More frequent valve replacement (est. replacement every 3-5 years)

Estimated Automatic Blowdown System Costs and Payback

Proposed *Boilers with automatic blowdown systems.*				
Boiler Size (MMBTU/h)	**Automatic Blowdown System First Cost**	**Boiler First Cost (Parts and Labor)**	**Blowdown System Cost as a Percentage of Boiler Cost**	**Estimated Payback (Years)**
12	$10,000.00	$350,000	3%	2.6 – 4.6
19	$10,000.00	$500,000	2%	1.6 – 2.8
33	$10,000.00	$800,000	1%	0.8 – 1.6
71	$10,000.00	$1.2 million	<1%	0.6 – 1.2
143	$10,000.00	$2 million	<1%	0.4 to 0.8
739	$10,000.00	$4 million+	<1%	<0.5

Natural gas cost: $0.90/therm
Boiler size used for calculations is the mean of the estimated installed boilers in CA within the following size ranges: 10-15, 15-25, 25-50, 50-100, 100-200, 200+ MMBtu/h. Blowdown system and boiler first costs are based on correspondence with a boiler manufacturer. Installation costs are estimated to be 10-30% of estimated boiler hardware costs. Deaerator setpoint requirements are anticipated to incur no incremental costs for facilities.

Approach for Gathering Costs

- To gather more data on automated blowdown **incremental first costs**, the CASE Team will:
  - Conduct an updated review of vendor pricing
  - Request pricing, installation, and commissioning cost data from vendors and installers of automated blowdown systems
- Automated blowdown **maintenance costs**, **frequency** of maintenance, and **lifetime** of automated blowdown system components will be determined through:
  - Vendor interviews
  - Interviews with boiler plant operations and maintenance staff
  - Evaluations of lifetime data from the CPUC DEER database
- The proposed deaerator pressure setpoint requirement has no incremental costs.

Poll

What do you think most industrial sites pay per therm for natural gas that feeds their boilers?
[results will not be shown or shared.]

a. Less than $0.30/therm
b. $0.30-$0.60/therm
c. $0.60-$0.90/therm
d. $0.90-$1.20/therm
e. $1.20-$1.50/therm
f. $1.50-$1.80/therm
g. Greater than $1.80/therm

Approach for Gathering Costs: Cost Data Needed

The CASE team is looking for information on the **first costs**, **installation costs**, and **annual maintenance costs** for:

- Automatic blowdown control systems
- Blowdown heat recovery (including flash recovery)
- Conductivity probe (standalone)

Compliance Verification

- Key Aspects of Compliance Verification
- Barriers and Solutions
- Revisions to Compliance Software

Key Aspects of Compliance Verification

New compliance verification steps for this measure will consist of the following:

- **Design document review** to verify:
  - planned installation of a blowdown valve, valve controller, and conductivity probe (automated blowdown system).
  - planned installation of blowdown heat recovery equipment, RO system, or adequate condensate return infrastructure if the boiler is pursuing an exception.
- **Acceptance testing performed by a field technician** on all qualifying boilers to ensure that:
  - automatic blowdown is programmed to be controlled by conductivity.
  - deaerator pressure setpoint is at or under 5 psig and within 2 to 5 psig for boilers with tubes that are not rated for oxidizing conditions.
  - blowdown heat recovery equipment or RO system is operational if the boiler is pursuing the associated exception.

Updates to compliance forms:

- Update Certificate of Compliance form (NRCC-PRC-E) and the Process System Certificate of Installation (NRCI-PRC) form to include automatic blowdown system installation and verification of exceptions as applicable.
- Add blowdown system and deaerator pressure requirements to a new Nonresidential Certificate of Acceptance form (NRCA-PRC-18).

Compliance Barriers and Solutions

Compliance Verification Barriers	Potential Solutions
1. AHJ plan checkers must be comfortable checking for an automated blowdown control system in design documents and field technicians must be comfortable evaluating blowdown controls and the deaerator pressure setpoint.	1. The CASE Team will support comprehensive AHJ training on automated blowdown control and deaerator pressure and add supporting information to the Nonresidential Compliance Manual (10.9).

Compliance Software Updates

No software updates required. CBECC currently does not cover boiler measures.

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More information on
CEC's 2028 proceeding website.

We want to hear from you!

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Energy Savings Calculation: Deaerator Control

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$$\frac{(p_1-p_2)}{p_1} < F_\gamma * x_T \rightarrow m_s = 63.3 * C_v * \left(1 - \frac{\frac{p_1 - p_2}{p_1}}{3 * F_\gamma * x_T}\right) * \sqrt{(p_1-p_2) * \rho}$$

$$\frac{(p_1-p_2)}{p_1} \geq F_\gamma * x_T \rightarrow m_s = 0.66 * 63.3 * C_v * \sqrt{F_\gamma * x_T * p_1 * \rho}$$

p_1: Primary Pressure (psia)

p_2: Secondary Pressure (psia)

C_v: Secondary Valve Cv Value (Cv (US))

$\mathrm{m_s}$: Secondary Steam Flow Rate (lb/h)

ρ: Density of steam (lb/ft^3)

F_γ: Specific heat ratio factor (=Specific heat ratio/1.4)

x_T: Pressure differential ratio factor (=0.72)

Note on Thermal Fluid Heaters

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Thermal fluid heaters, defined by AQMD.gov as a natural gas fired process heater in which a process stream is heated indirectly by a heated fluid other than water, are excluded from all 2028 covered process boiler measures.