

Appendix B

Delayed Ignition Testing

Summary

Testing was directed and overseen by Technical Safety BC on June 28, 2023, in accordance with British Columbia's Safety Standards Act. The test setup was prepared, and the testing was conducted, by technicians and representatives from IBC Technologies at its testing facility in the Lower Mainland. The purpose was to test a new boiler under delayed-ignition conditions with a maximum-equivalent-length venting system attached, replicating an expected real-world installation condition.

The investigation testing exceeded the minimum requirements outlined in the CSA 4.9 standard and aimed to evaluate whether attached venting systems using approved materials and maximum equivalent vent lengths would be damaged by the same delayed ignitions used to evaluate boiler damage under the CSA 4.9 standard. In *addition* to the minimum requirements in the standard, the test venting system incorporated lengths of vent pipe and elbows equivalent to the manufacturer's maximum acceptable vent length for installation, to test its resilience to delayed-ignition events.

The boiler manufacturer prepared an SL40-399 G3 boiler taken directly from the production line, with a natural gas supply and a polypropylene venting system complete with the specified boiler connector adaptor fitting. Before testing, a representative of the boiler manufacturer set the gas inlet pressure to approximately 13 inches of water column and the exhaust CO₂ concentration to approximately 10%, in accordance with the manufacturer's recommendations.

The venting was an S636-certified, 4-inch-diameter polypropylene system approved by the boiler manufacturer for use with the appliance and installed to an equivalent length of approximately 200 feet. This was the maximum permitted in the boiler manufacturer's certified manual.

The boiler manufacturer supplied an electronic circuit that allowed ignition to be delayed by a preset interval of 0 to 3 seconds for testing purposes. This was the same circuit configuration used during certification testing. The boiler system was tested at three manually set torque levels 10, 30, and 50 in-lb—on the boiler vent connector gear clamp.

Conclusions

During delayed-ignition testing, detonations occurred intermittently at delay intervals of 1.0, 1.5, and 2.5 seconds.

At each boiler vent connector clamp torque setting 10, 30, and 50 in-lb the vent was displaced upward within the connector by approximately 1 inch or was completely dislodged during individual tests. The venting system's gasketed and clipped connections were also partially or completely dislodged at various locations during delayed-ignition tests. Partially dislodged venting system fittings were compared with reference markings applied before the ignitions.

The gear clamp torque was tested using a large flat-blade screwdriver, a nut driver, and a socket wrench to compare the torque limitations of tools used for field installation. The hand-driven large screwdriver achieved approximately 10 in-lb. The hand-driven nut driver achieved approximately 26 in-lb. Torque settings above 26 in-lb were achieved using a socket wrench, with the values verified using a torque wrench.

Testing configurations

Test equipment details

Torque wrench / 070-212	1502LDIN/1011603338	±4% of reading
Delayed Ignition Apparatus	N/A / 070-3004	N/A



*Nut driver image

Boiler configuration

SL 40-399 G3 Parameters	Parameters for Test	Notes
Inlet gas pressure (in. wc)	13.13	Upper limit of range: 14.0 in. wc
Gas valve CO2 tuning (%)	10.08	Upper limit of range: 10.0%

Venting configuration

The 4-inch-diameter venting system was installed with an equivalent length of approximately 200 feet, including a combination of straight sections and 90-degree elbows.

A 6-inch-diameter test port with 4-inch reducers was added for measurement during testing.

The venting was installed with sufficient horizontal supports to hold the weight of the venting system as required by the venting manufacturer in their certified instructions. The instructions also indicated to use additional supports “as needed” at changes of directions. There were no supplemental supports included for the tests performed.

SL 40-399 G3	
Intake/Exhaust	Maximum Equivalent Length
4-inch rigid pipe	200 ft (each side)
90° elbow	allow 8 ft for each elbow
90° long sweep elbow	allow 5 ft for each elbow
45° elbow	allow 3 ft for each elbow
PP 87-90° elbows	allow 8 ft for each elbow

Images of testing



Image 1 – Venting configuration as installed.



Image 2 – New boiler set up for testing in the manufacturer's laboratory.



Image 3 – Inlet gas pressure measurement.



Image 4 – Boiler internals examined for damage after each test.

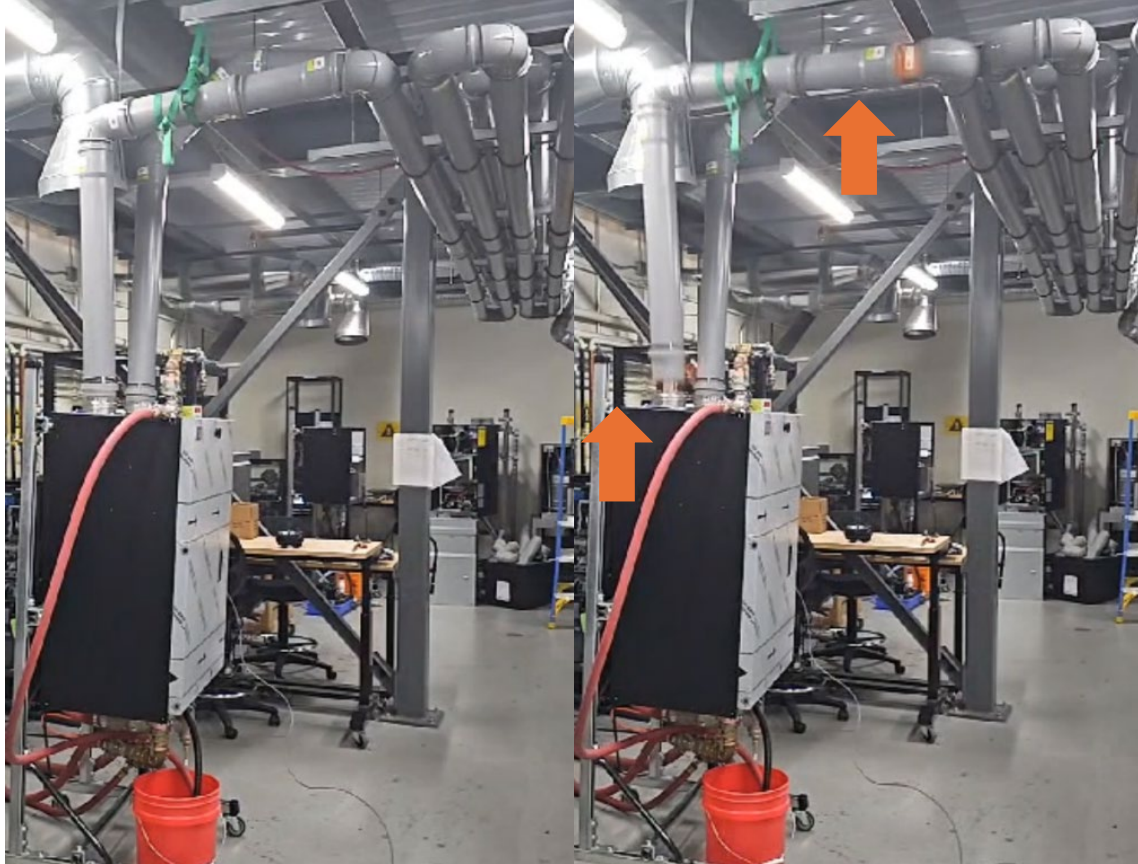


Image 5 – Test 2, showing the vent blown out of the boiler vent connector with 10 in-lb. of torque on the vent connector clamp and a 1.5-second arc-ignition delay.

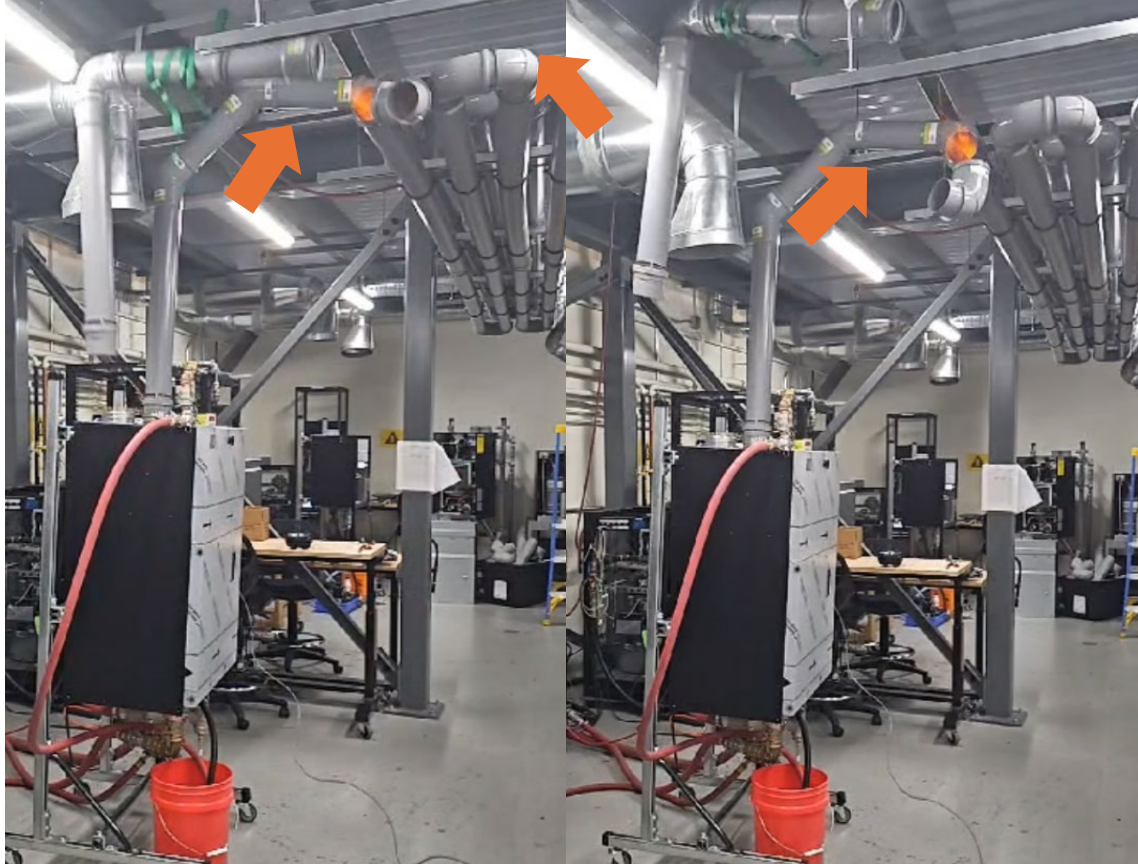


Image 6 – Test 2, showing the vent blown out of the boiler vent connector with 10 in-lb. of torque on the vent connector clamp and a 1.5-second arc-ignition delay.

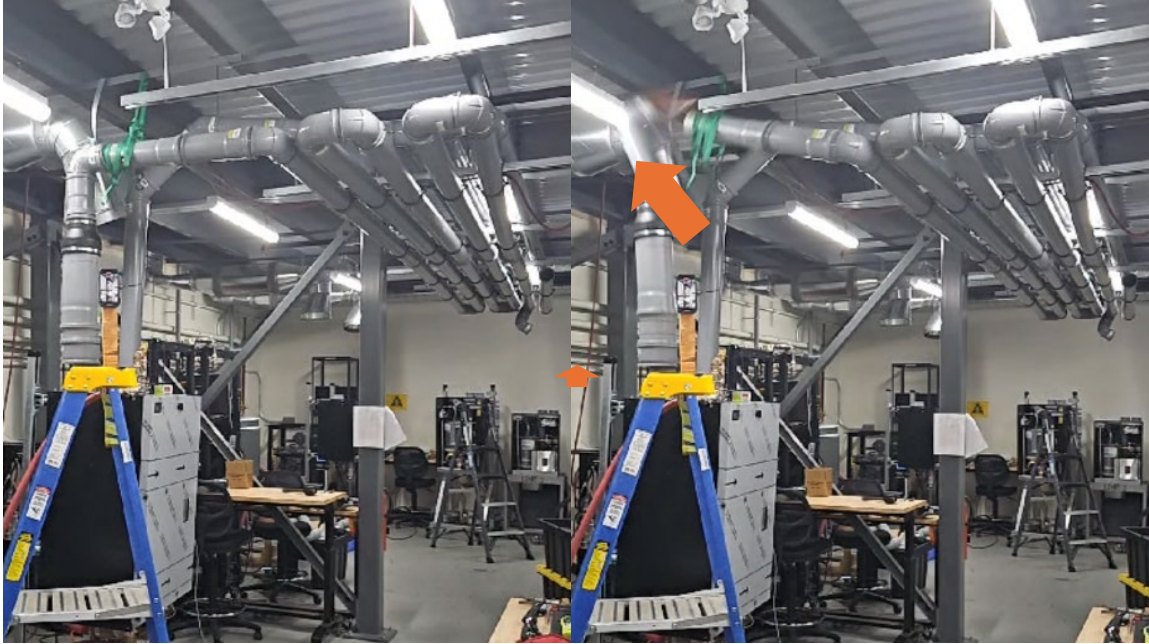


Image 7 – Test 10, showing the first 90-degree vent fitting blown off. The vent moved upward approximately $\frac{3}{8}$ inch with 50 in-lb. of torque on the boiler vent connector clamp and a 2.5-second arc-ignition delay.



Video 1 – Catastrophic venting failure with a 1.0-second ignition delay. Video 2 – Catastrophic venting failure with a 2.5-second ignition delay.

[Video 1](#)



[Video 2](#)



Image 8 – Boiler vent system before (top) and after (below) the 2.5-second delayed-ignition test.



Image 9 – Broken piece of a vent elbow after it was propelled against the laboratory wall during a 2.5-second delayed ignition.

Test sequence — June 28, 2023

Test number	Boiler vent connect or clamp torque (in-lb)	Delayed-ignition time (seconds)	Results
1	10	1.0	Vent moved upward by more than 1 inch in the connector.
2	10	1.5	Vent blown off at connector; vent joints moved approximately 1/8 to 1/4 inch; second 90-degree elbow blown off.
3	30	1.5	Third 90-degree elbow blown off; vent moved upward by more than 1 inch in the connector; vent joints moved approximately 1/8 to 1/2 inch.
4	30	1.5	Vent blown off at the first 90-degree elbow.
5	50	1.5	Third 90-degree elbow twisted.
6	50	0.5	No damage (no ignition)
7	50	1.0	No damage
8	50	1.5	No damage
9	50	2.0	No damage
10	50	2.5	Vent connector moved approximately 3/8 inch; first, third, fourth, fifth, and sixth 90-degree elbows blown off.

Exclusions

Delayed-ignition detonations were not tested at torque settings below the production-line setting for the boiler vessel top-cover gasket because of time limitations.

Exhaust-system pressure measurement devices were installed but could not be actuated, likely because of the short duration of the detonations.