A Sprinkler's Lag Is Not a Constant of the Part: As the Fire Grows the Gas Moves Faster and the Lag Itself Shrinks

— two links whose RTIs differ by **7.142857** activate at times differing by only **1.742604**, for the time constant is divided by the square root of the ceiling-jet speed and shrinks as the fire grows — the separator is whether the time constant is set by the RTI alone or with the ceiling-jet speed — [Paper 739]

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— *From thinking to syncing.* —

Abstract

A sprinkler link carries a response time index (RTI), a number for how slowly heat gets in. It is a number of the part, but the lag is not set by that number alone.How far a difference in RTI carries into the time and size of the fire at activation is counted.No new theorem or law is claimed. First, a fast link operates at 104.780000 s——RTI 35, with the fire at 514.907990 kW (Section 2). **Second, a slow link operates at 182.590000 s——RTI 250, with the fire at 1563.604170 kW** (Section 2). **Third, and this is the core. The ratio of RTIs does not carry over——a factor of 7.142857 in RTI becomes only 1.742604 in time and 3.036667 in fire size** (Section 2). **Fourth, the lag itself shrinks with the fire——the time constant is RTI over the square root of the ceiling-jet speed, and at activation the ratio is only 5.935707** (Section 3). **Fifth, a no-lag limit is the floor——nothing operates before the ceiling jet reaches activation temperature, at 76.844668 s and 276.949331 kW** (Section 3). **Sixth, the separator is whether the time constant is set by RTI alone or by RTI together with the ceiling-jet speed——comparing the numbers of the parts does not yield the ratio of activations** (Section 4). **Keywords**: sprinkler, response time index, ceiling jet, t^2 fire, activation time, time constant.

> **Scope of this paper (scope note)**: **No new theorem or law is claimed——the thermal response equation of a link, the response time index, the ceiling-jet temperature and velocity correlations, and the t^2 fire are all known (Alpert 1972, Drysdale 1985).No claim for the correlations' values——the ceiling-jet correlations are quasi-steady representative forms, and no value for a real room is claimed.Heat loss is not included——conduction from the link into the pipework is not included.Water is not treated——discharge, cooling and extinguishment are not treated; the account stops at activation.No precision is claimed for representative values——an activation temperature of 68 °C, the growth coefficient, the ceiling height and the radial distance are for comparison.Relation to earlier papers**: **Paper 577 showed that fire grows as the square of time, so the weight of the same minute's delay changes——its scope note stated that the choice, placement and discharge of detectors and sprinklers would not be treated. There the lag was a given quantity. Here the lag itself is set together with the fire and shrinks as the fire grows. The weight of a lag, and the size of a lag.**What is added is **tabulating activation time and fire size against RTI**, **showing the RTI ratio not to carry over**, **putting the ratio of time constants at activation at 5.935707**, **confirming convergence to the no-lag limit**, and **placing the separator on RTI alone against RTI with the ceiling jet**.

1. Notation and the Question

Setting: **the link temperature T_L approaches the ceiling-jet temperature T_g at a rate proportional to the square root of the jet speed u. The fire grows as $Q = \alpha t^2$.**

$$\frac{dT_L}{dt} = \frac{\sqrt{u}}{\mathrm{RTI}}\,(T_g - T_L), \qquad \tau = \frac{\mathrm{RTI}}{\sqrt{u}}, \qquad Q = \alpha t^2$$

Take a 3 m ceiling, 2 m radial distance, 293.15 K ambient, activation at 341.15 K and $\alpha = 0.0469$ kW/s², with T_g and u from Alpert's correlations.

Question: **if RTIs differ sevenfold, does activation come seven times later?**

2. The Ratio of RTIs Does Not Carry Over

Computation 2.1: **for each RTI, the activation time, the fire size then and the time constant then were derived.**

RTI	activation time	fire then	time constant then
35	104.780000 s	514.907990 kW	28.395182 s
50	113.950000 s	608.977857 kW	39.445848 s
100	137.530000 s	887.090092 kW	74.097506 s
250	182.590000 s	1563.604170 kW	168.545470 s

Observation 2.2

this is the core: RTIs differ by 7.142857 and activation times by only 1.742604.Fire size at activation differs by 3.036667——the ratio of the parts does not become the ratio of the outcomes.

Observation 2.3

the fire ratio is exactly the square of the time ratio.Because growth goes as t^2, the difference is within 4.441×10^{-16}——1.742604 in time widens to 3.036667 in fire.

3. The Lag Itself Shrinks with the Fire

Observation 3.1

the time constant is not a constant of the part.It is RTI over the square root of the jet speed, and it shrinks as a growing fire speeds the jet——at activation the ratio of time constants is 5.935707, below the RTI ratio of 7.142857.

Observation 3.2

a slower link operates in a bigger fire.The bigger fire makes a faster jet and shortens the link's own lag——the grown fire is helping the slow part.

Computation 3.3: the no-lag limit and the approach to it were derived.

condition	activation time
no-lag limit (jet reaches activation temperature)	**76.844668** s (fire **276.949331** kW)
RTI **2**	**78.637000** s (from the limit **1.792332** s)
RTI **0.5**	**77.294000** s (from the limit **0.449332** s)

Observation 3.4

no link, however fast, operates before 76.844668 s.That floor is set not by the part but by the jet temperature——lowering RTI shrinks the gap from 1.792332 s to 0.449332 s.

Observation 3.5

the result does not lean on the step size.Halving the step changes the RTI 35 activation time by a relative 3.770×10^{-13}——the ratios are not artefacts of the numerics.

4. The Separator

Observation 4.1

the separator is whether the time constant is set by RTI alone or by RTI together with the ceiling-jet speed.It is the latter, so comparing the numbers of the parts does not yield the ratio of activations——“seven times the RTI, seven times later” holds only for a steady jet.

Observation 4.2

beside Paper 577.Paper 577 showed that fire grows as the square of time, so the weight of the same minute’s delay changes, and left the choice of sprinklers aside——there the lag was given. Here the lag is set together with the fire. The weight of a lag, and its size.

> **Observation 4.3**
>
> **what is not said.Real correlation values, heat loss to the pipework and discharge are not treated, and four representative values are fixed——what is shown is that the fire sits between the number of the part and the ratio of activation.**

5. Roll Call and Closing

1. **RTI 35 at 104.780000 s** (Computation 2.1): **fire 514.907990 kW.**
2. **RTI 250 at 182.590000 s** (Computation 2.1): **fire 1563.604170 kW.**
3. **RTI ratio 7.142857** (Observation 2.2): **the parts.**
4. **time ratio 1.742604** (Observation 2.2): **the core.**
5. **fire ratio 3.036667** (Observation 2.3): **the square of the time ratio.**
6. **time-constant ratio 5.935707** (Observation 3.1): **the lag shrinks.**
7. **limit 76.844668 s** (Computation 3.3): **the floor is the jet.**
8. **fire then 276.949331 kW** (Computation 3.3): **even with no lag.**
9. **gap 0.449332 s at RTI 0.5** (Computation 3.3): **approaching the limit.**
10. **RTI alone or with the jet** (Observation 4.1): **the separator; Paper 577.**

Closing: **A sprinkler’s lag is not a constant of the part: as the fire grows the gas moves faster and the lag itself shrinks.In a t^2 fire under a 3 m ceiling at 2 m, RTI 35 operates at 104.780000 s with the fire at 514.907990 kW and RTI 250 at 182.590000 s and 1563.604170 kW——a factor of 7.142857 in RTI becomes 1.742604 in time and 3.036667 in fire.The time constant is RTI over the square root of the jet speed, and a growing fire speeds the jet, so the time constants at activation differ by only 5.935707——a slower link operates in a bigger fire, and the bigger fire shortens its lag.No link operates before the jet reaches activation temperature at 76.844668 s and 276.949331 kW, and lowering RTI from 2 to 0.5 shrinks the gap from 1.792332 s to 0.449332 s.Halving the step changes activation by a relative 3.770×10^{-13}, so the ratios are not numerical artefacts.The separator is whether the time constant is set by RTI alone or by RTI together with the ceiling-jet speed——“seven times the RTI, seven times later” holds only for a steady jet.Placed among the earlier papers——Paper 577 weighed a given lag; this counts the lag’s size.To be honest——real correlation values, heat loss to the pipework and discharge are not treated, and representative values are fixed.**

References

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