Engineering for Mutually Exclusive Requirements

What are they?

When do they happen?

Can failure lead to success?

Mark A. Lobo, P.E.
Lobo Engineering, P.L.C.

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What are mutually exclusive requirements?

Definition of Terms

REQUIREMENT

condition described in quantifiable terms

SPECIFICATION

set of requirements describing an objective

CONFLICT

inability to coexist

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What are
mutually exclusive requirements?

What are mutually exclusive requirements?

- Optimum performance and safety
- Minimum and Maximum
- Consistent performance in complex environments
- Expectation of delivery
- Accuracy over performance range.

What causes mutually exclusive requirements?

Engineering out mutual exclusivity

- Study the specification carefully
- Identify the problem
- Become the authority
- Inquire about requirement priority
- Communicate effectively
- Pursue compromise
- Develop a novel solution

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Case Study:
"We need a control valve . . . "

- Fluid
  - Viscosity, density, vapor pressure
- Range of control – Rangeability
  - pressure, flow rate, temperature
- Accuracy
- Speed
- Reliability

Required Rangeability

- Maximum and Minimum
- Size, temperature, physical properties
- Accuracy
  - Hysteresis
  - Linearity/conformability
  - Repeatability
- Response time

ANSI/ISA-75.11.01-2013
Inherent Flow Characteristic and Rangeability of Control Valves

Inherent Characteristic

- Resistance vs. control range
- Flow Coefficient vs. Control Signal

$$C_V = \frac{Q}{F_P}\sqrt{\frac{\rho_1}{\rho_0(\Delta P)}}$$

C_V = Flow Coefficient

Q = Flow rate, gpm

F_P = Piping geometry factor

ρ_1 = Density of fluid at P & T

ρ_0 = Standard density of fluid

ΔP = differential pressure, psi

Turbulent Flow Only!

Inherent Characteristic

- Static vs. dynamic pressure
- Phase change
- Choked flow
- Valve acts smaller

$$C_V = \frac{Q}{F_{L(P)}}\sqrt{\frac{\rho_1}{\rho_0(P_1 - F_F P_v)}}$$

Severe Service!

C_V = Flow Coefficient

Q = Flow rate, gpm

F_L = Liquid pressure recovery factor

$F_{L(P)} = F_L$ + piping geometry

ρ_1 = Density of fluid at P & T

ρ_0 = Standard density of fluid

P_1 = Upstream pressure, psig

F_F = Pressure drop ratio factor

P_v = Vapor pressure, psig

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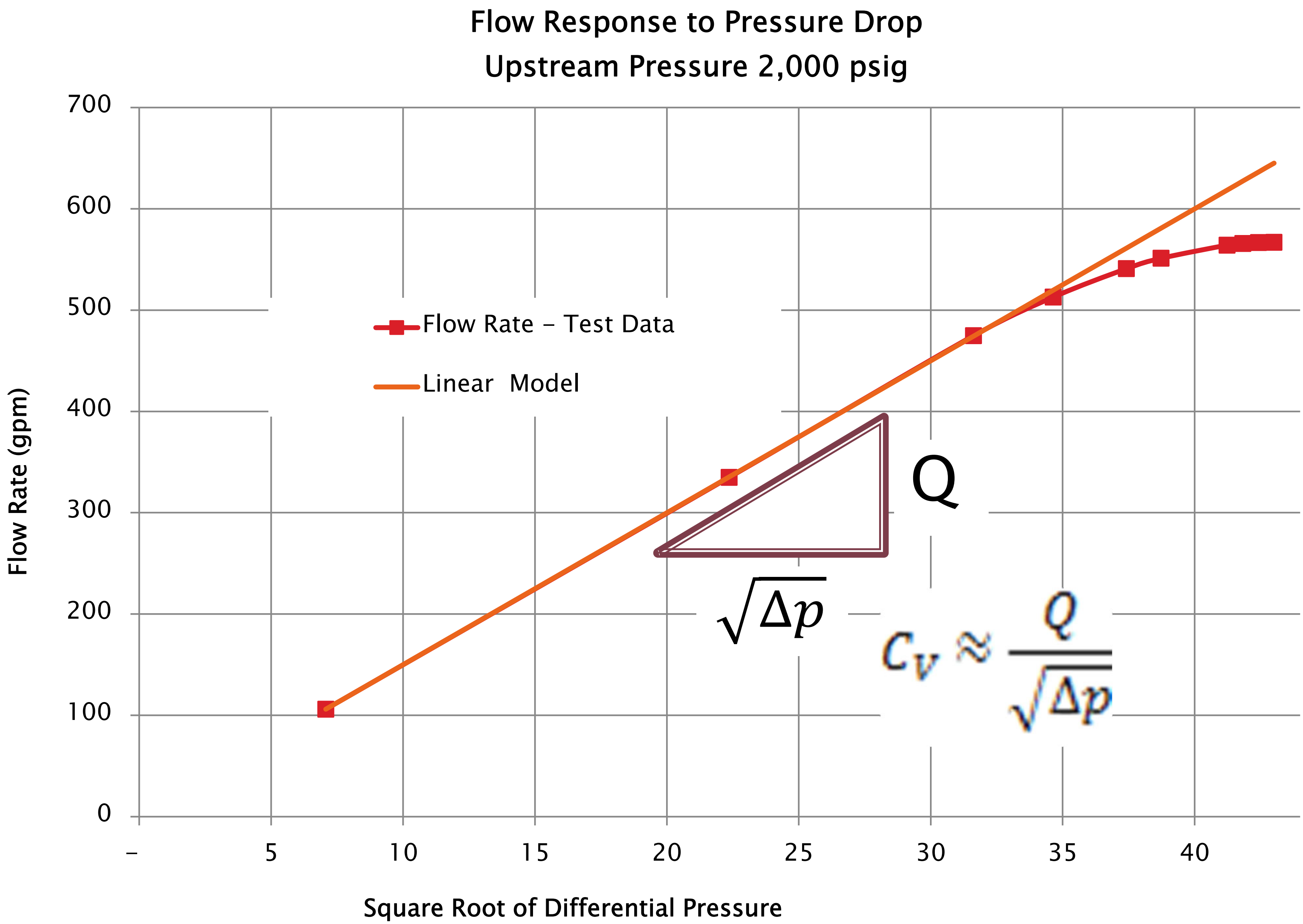
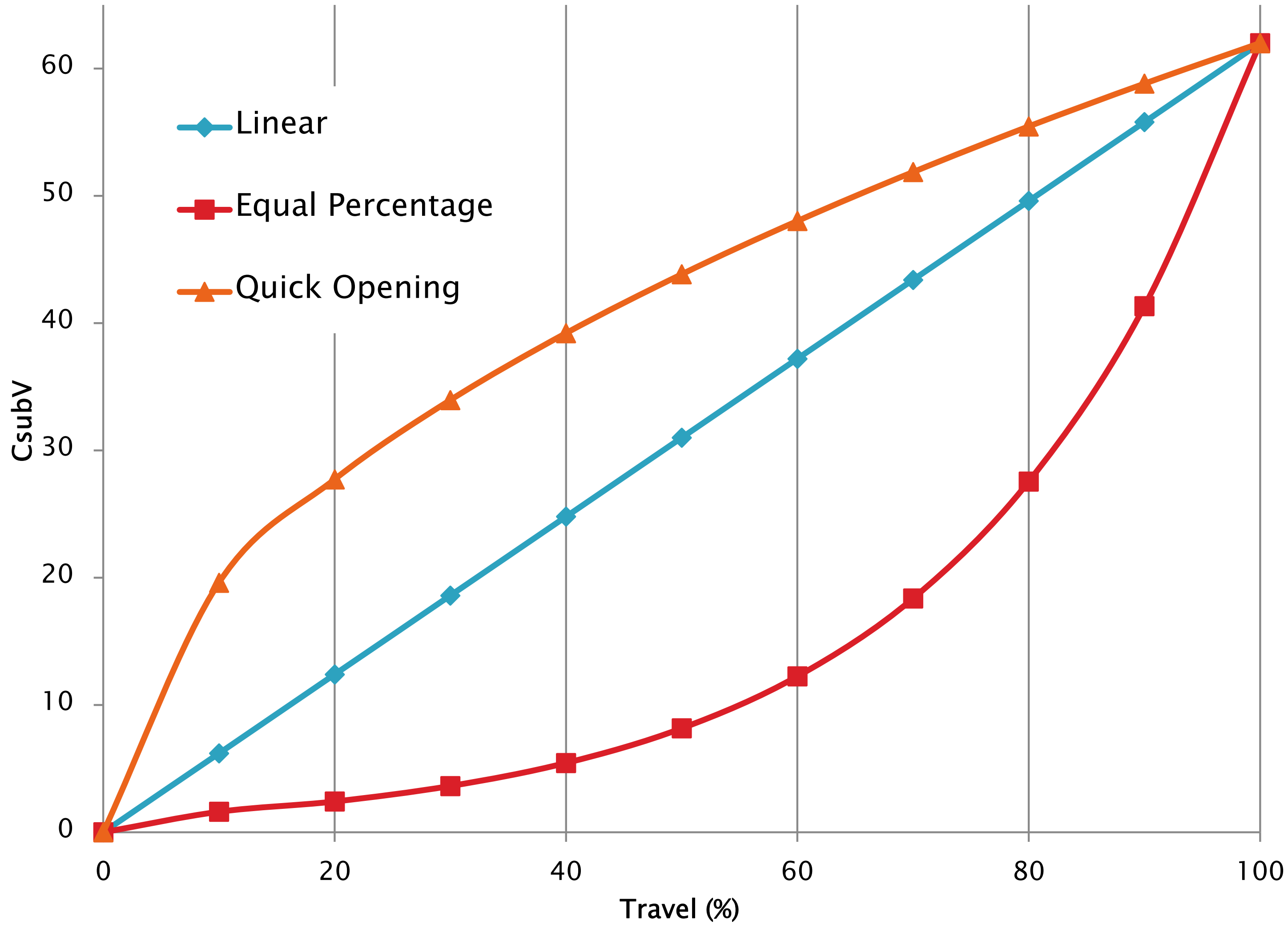

Flow Response to Pressure Drop
Upstream Pressure 2,000 psig
Flow Rate (gpm)
700
600
500
400
300
200
100
0
–
5
10
15
20
25
30
35
40
Square Root of Differential Pressure
Flow Rate - Test Data
Linear Model
Q
$\sqrt{\Delta p}$
$C_V \approx \frac{Q}{\sqrt{\Delta p}}$

Inherent Characteristic

:



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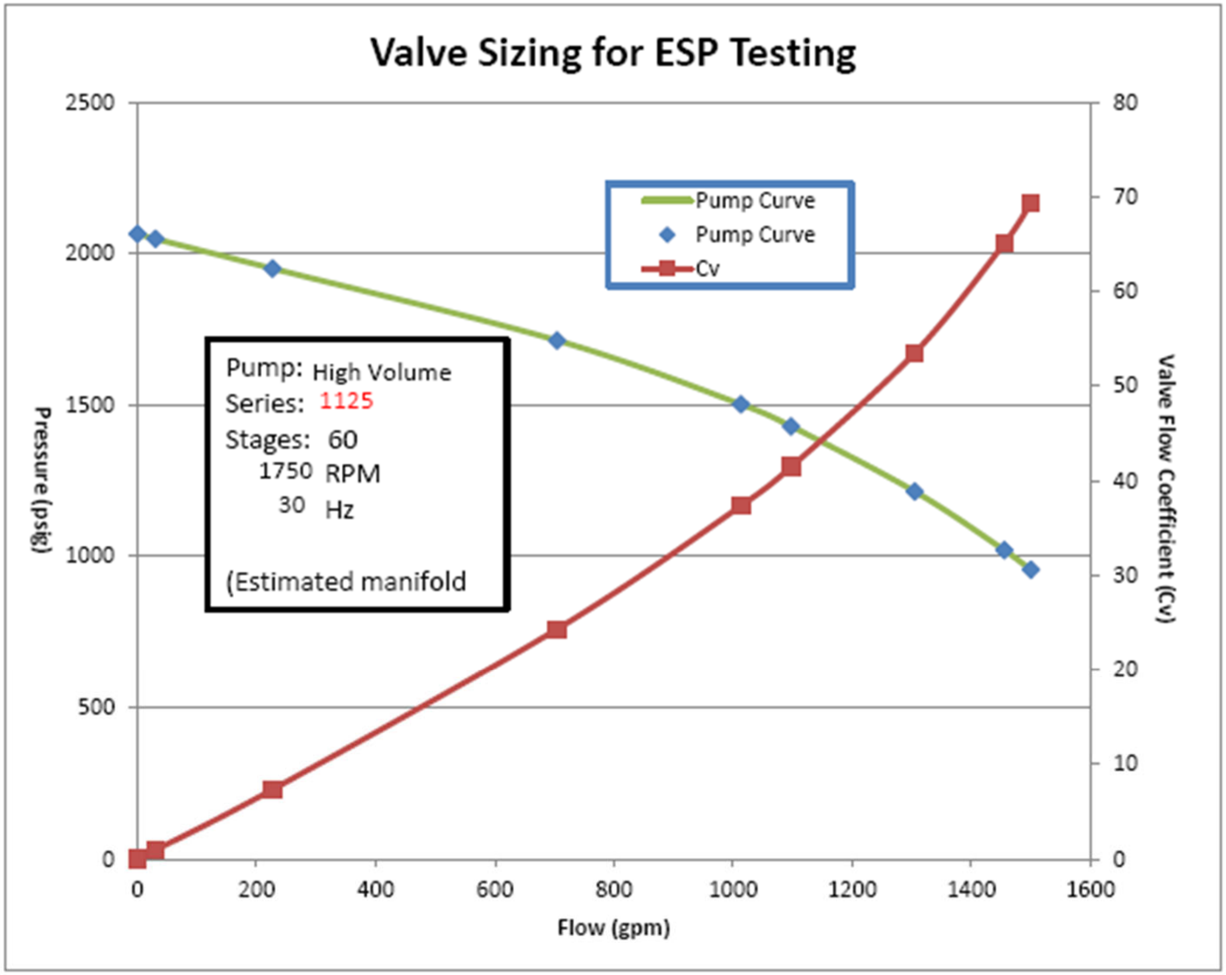
Case Study:
Flow control on ESP test bench

- Fluid: Water, 150F max
- Range of control; extreme
- Accuracy: API Standard 610/ISO 13709
- Speed: Complete test in 5 minutes
- Reliability: better than 2-valve current solution
- Affordable

Range of Control

Flow (gpm)	Pressure (psig)	C_v	Predicted Signal
0	2065	0.00	0.0%
30	2049	0.95	8.2%
226	1951	7.32	23.1%
704	1713	24.31	39.1%
1013	1502	37.34	49.8%
1097	1430	41.46	53.5%
1305	1214	53.50	64.9%
1455	1021	65.06	80.1%
1500	956	69.32	94.8%



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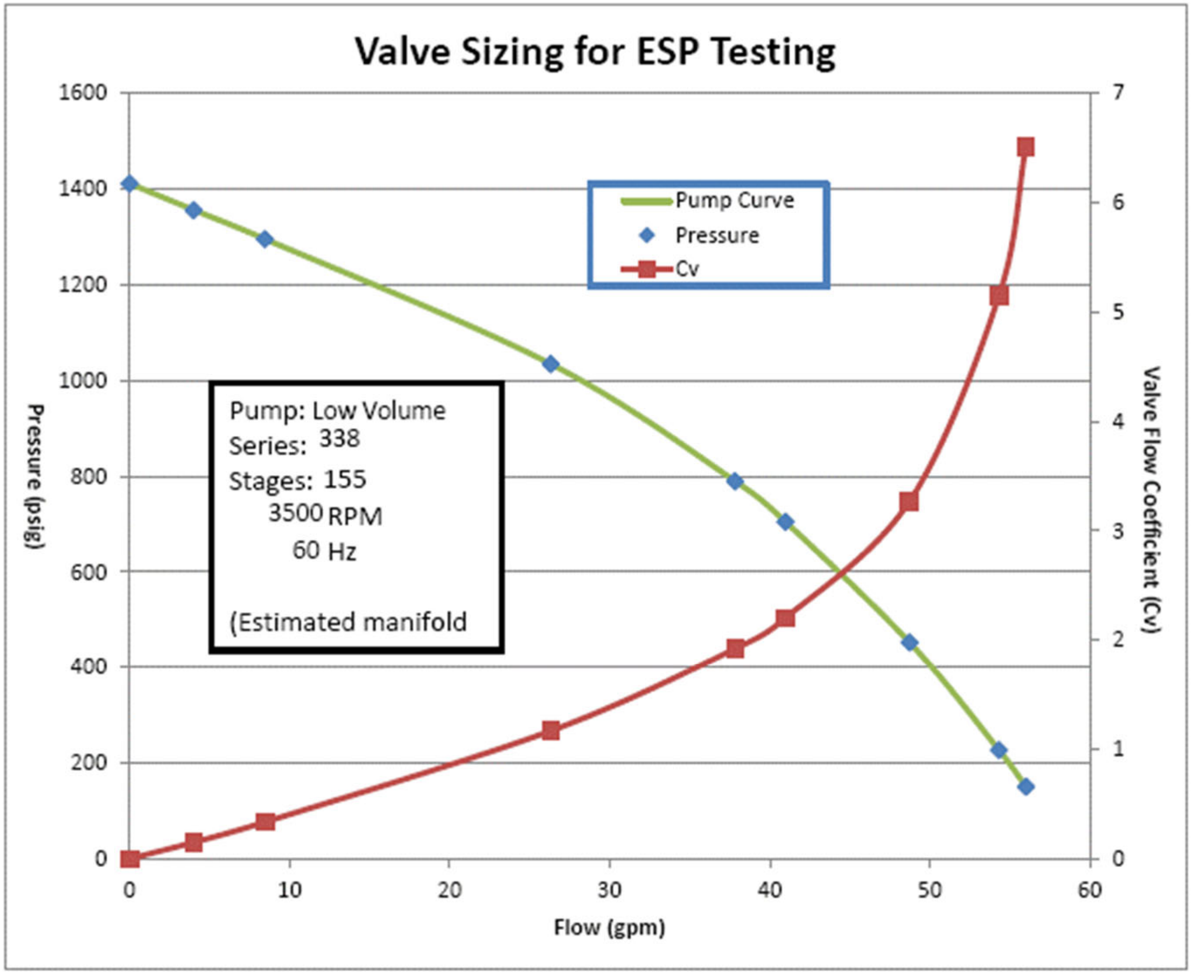
Range of Control

Flow (gpm)	Pressure (psig)	C_V	Predicted Signal
0	1412	0.00	0.0%
4	1357	0.15	1.4%
8	1296	0.34	3.1%
26	1035	1.17	10.0%
38	790	1.92	12.3%
41	705	2.20	13.1%
49	453	3.27	16.2%
54	227	5.15	20.7%
56	151	6.52	22.2%



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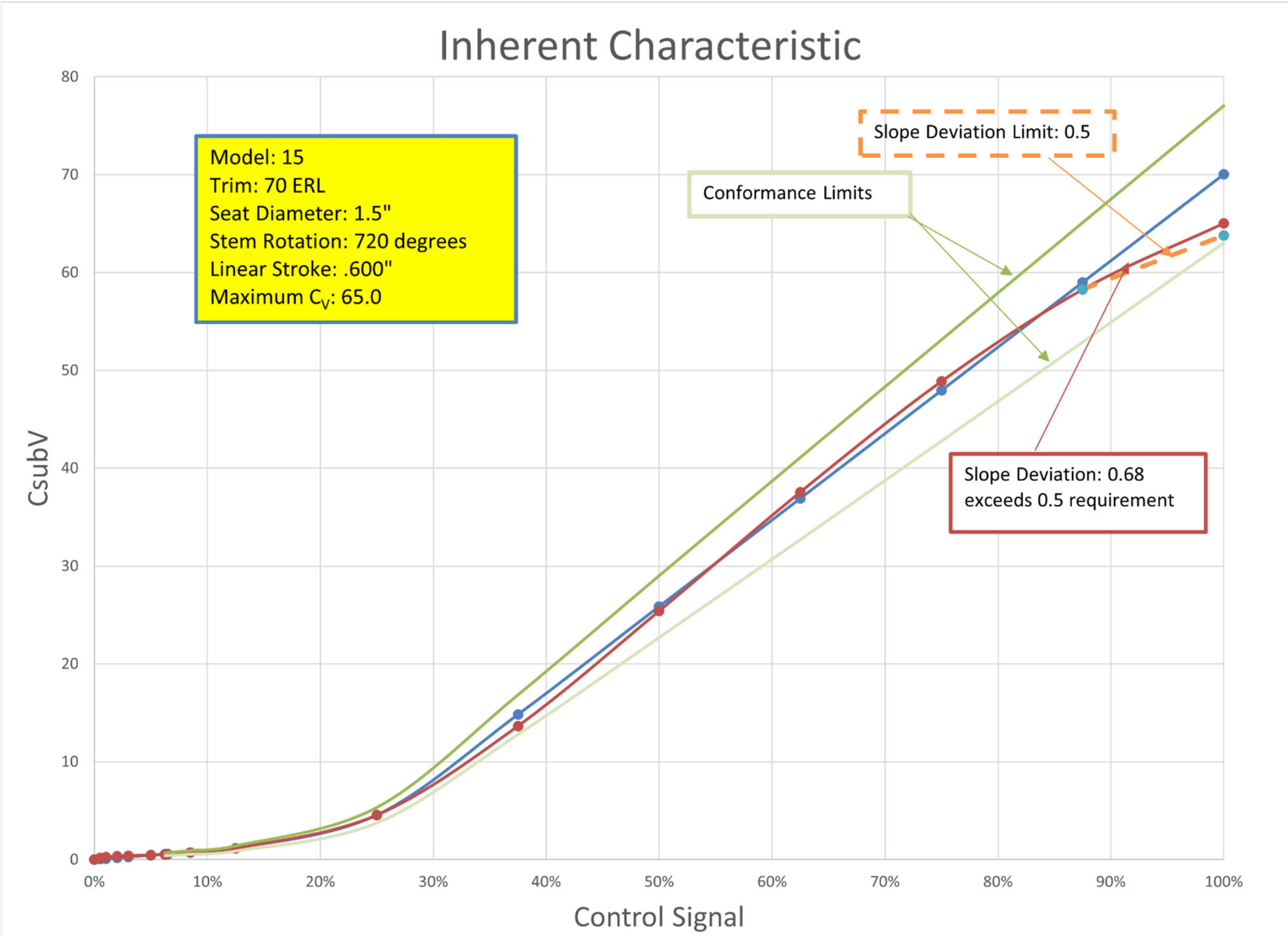

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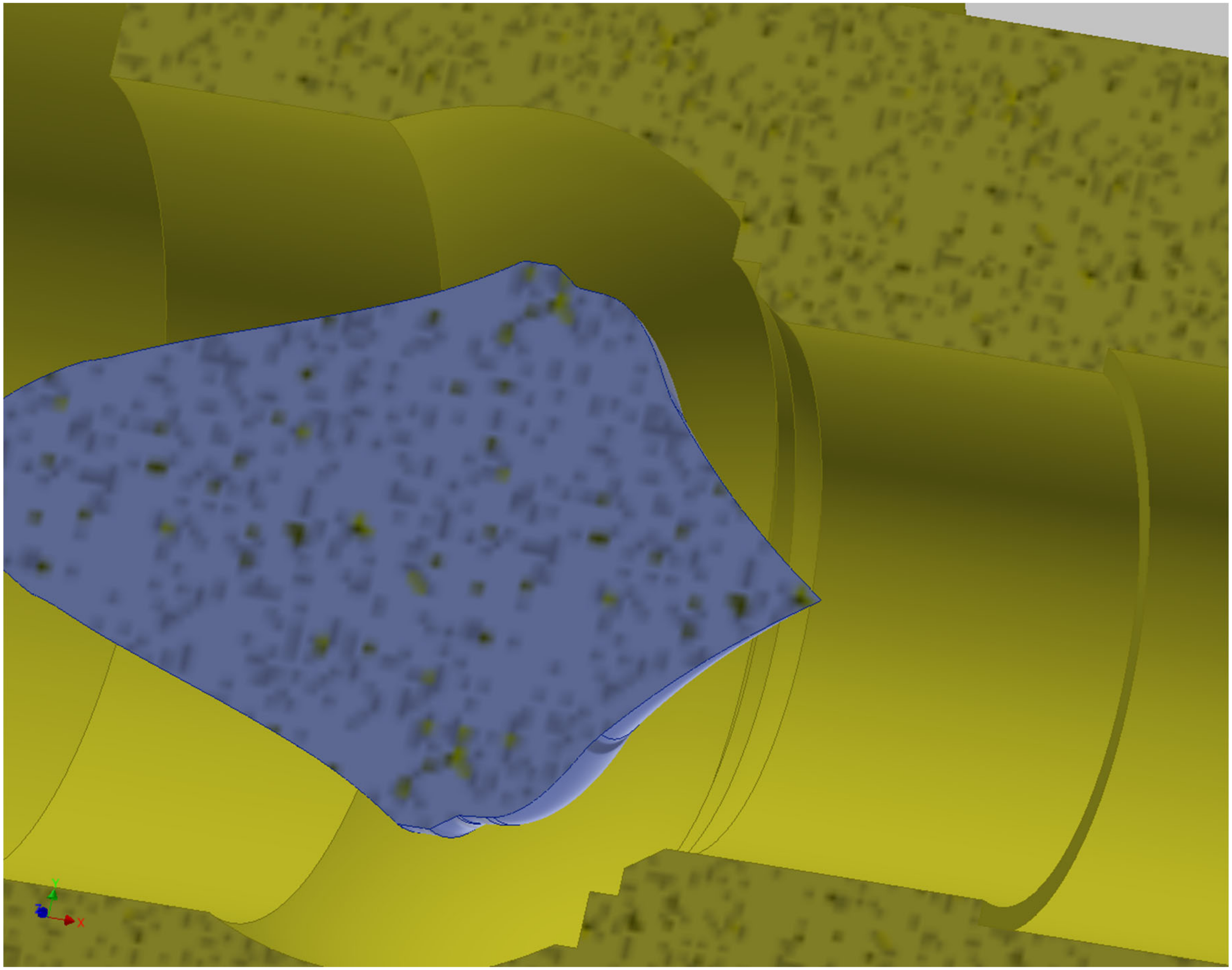

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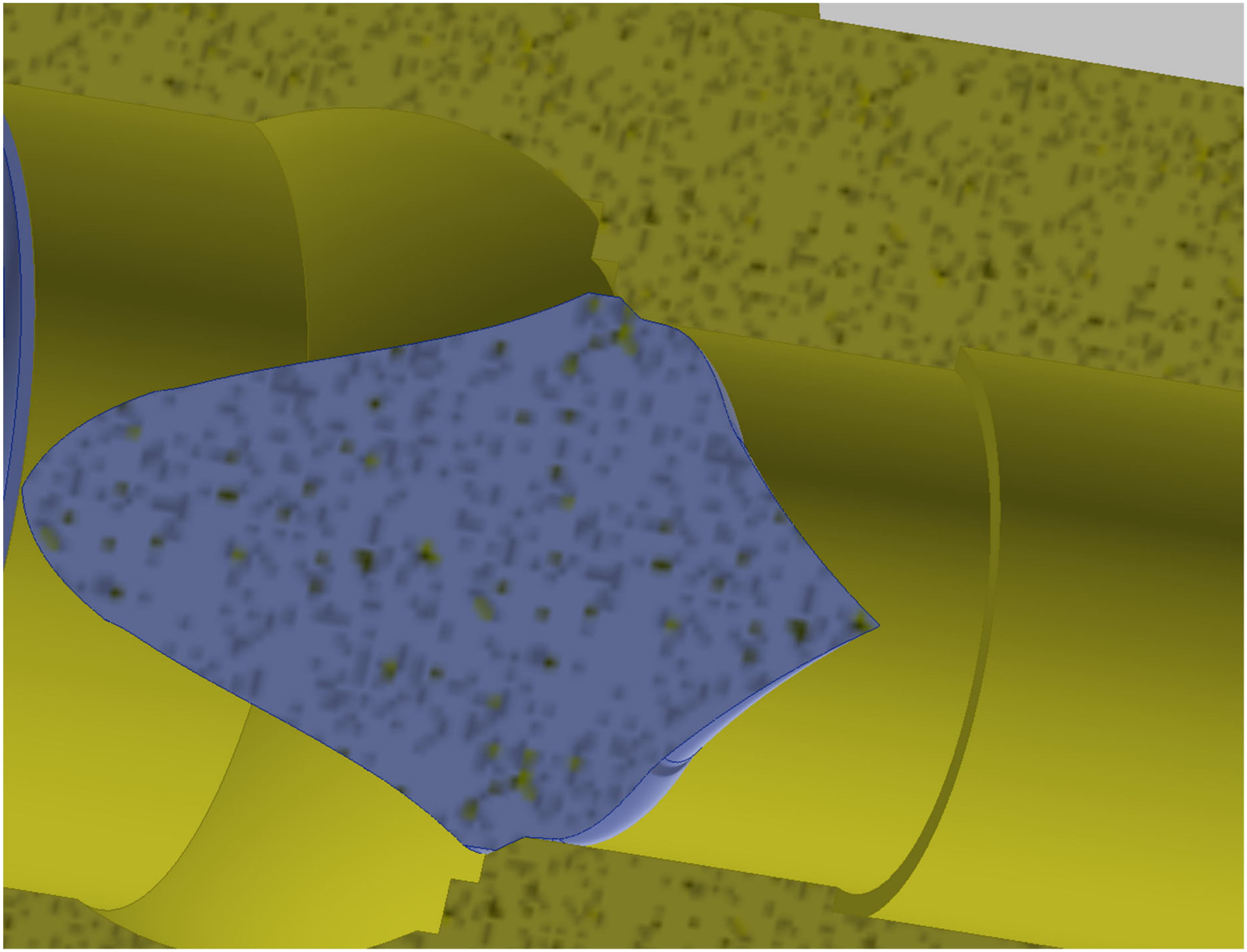

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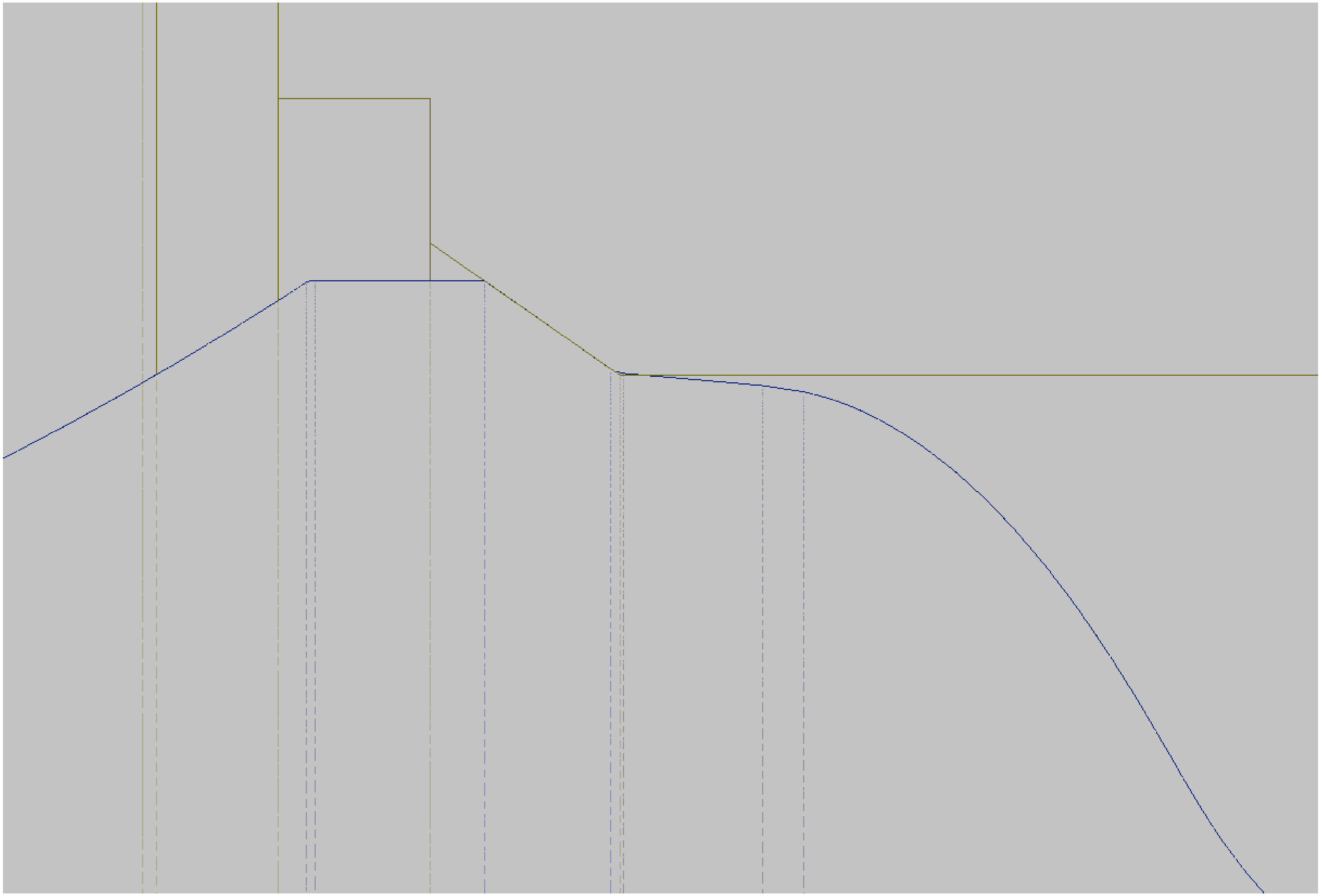

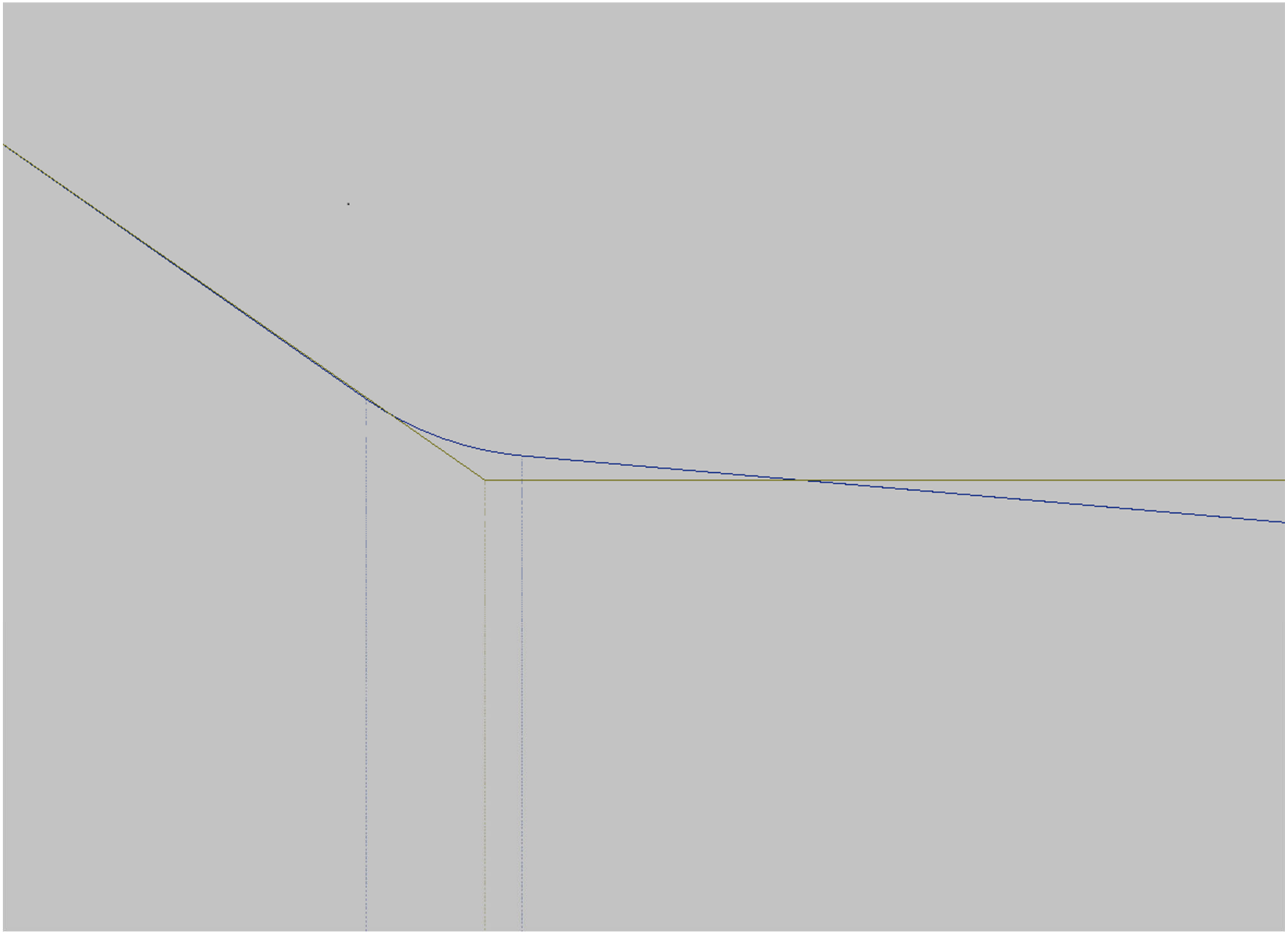

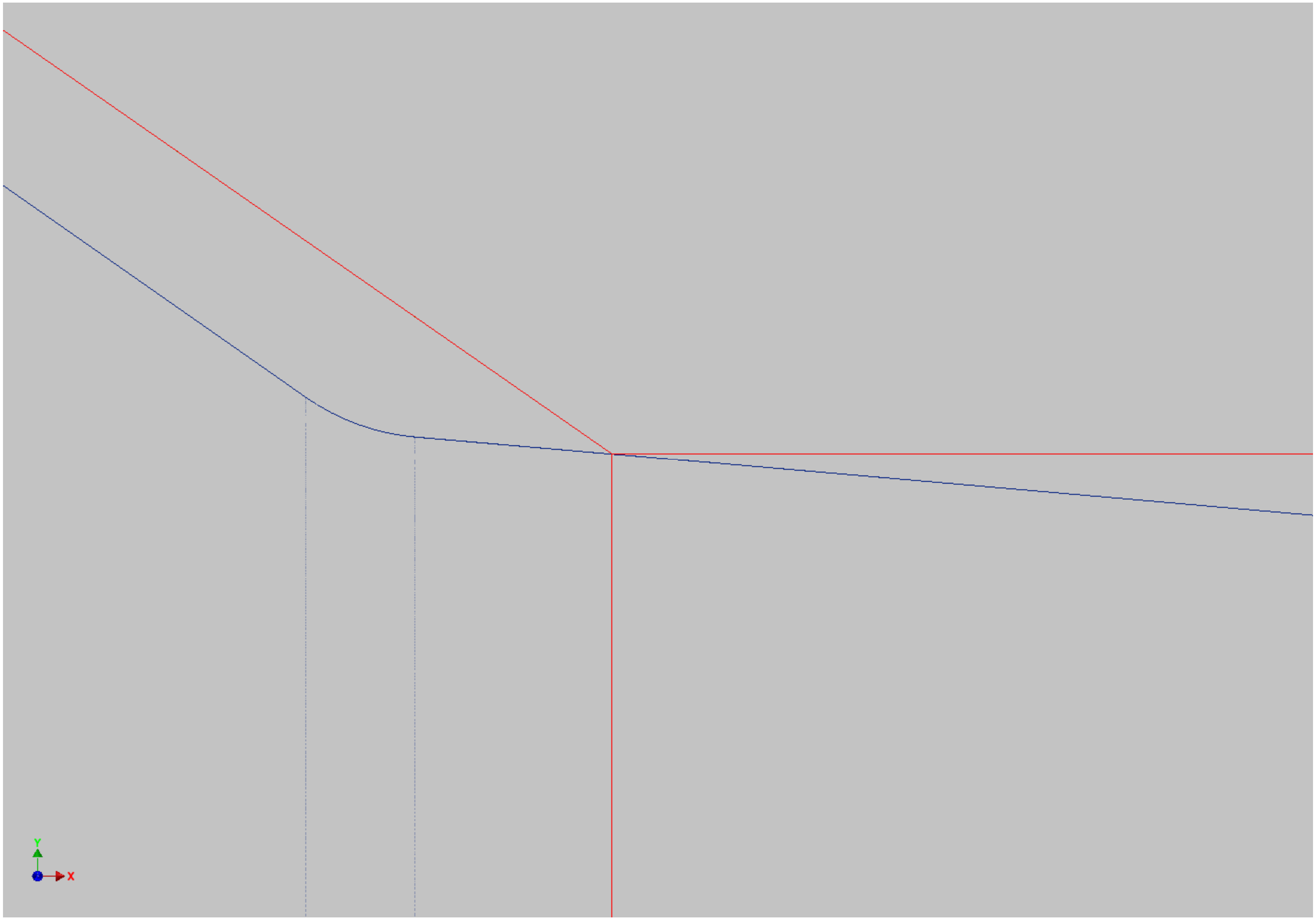
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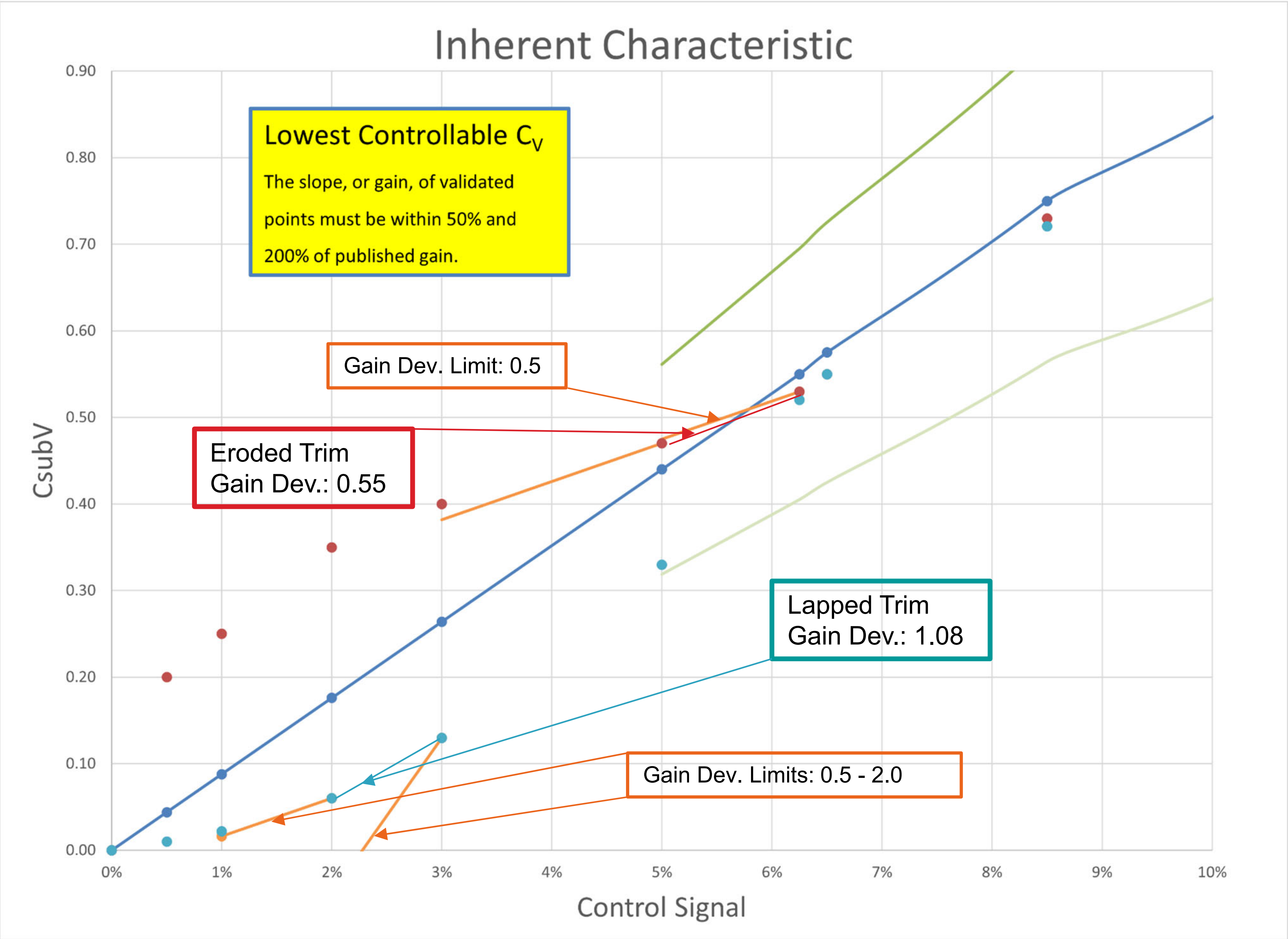

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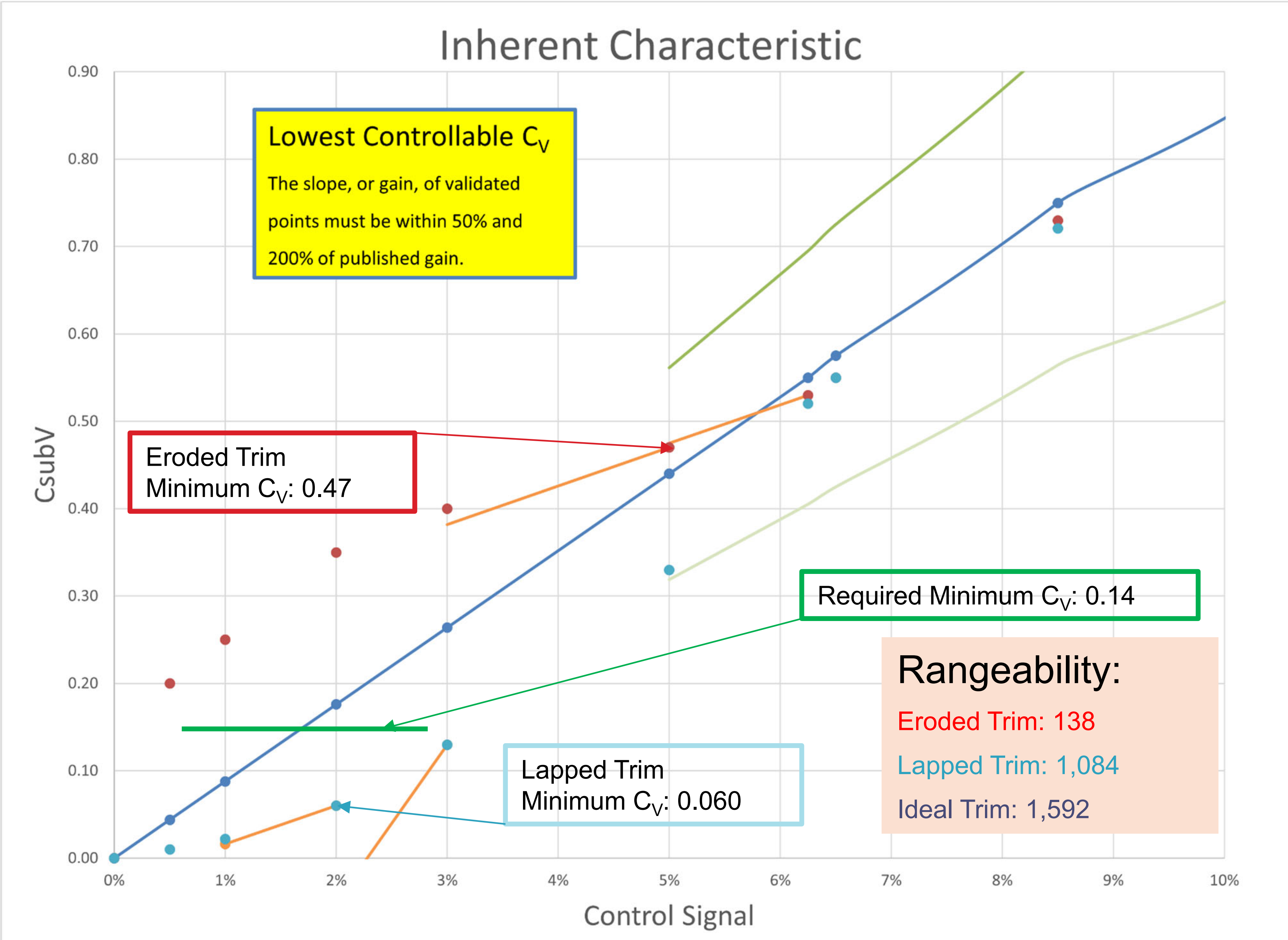

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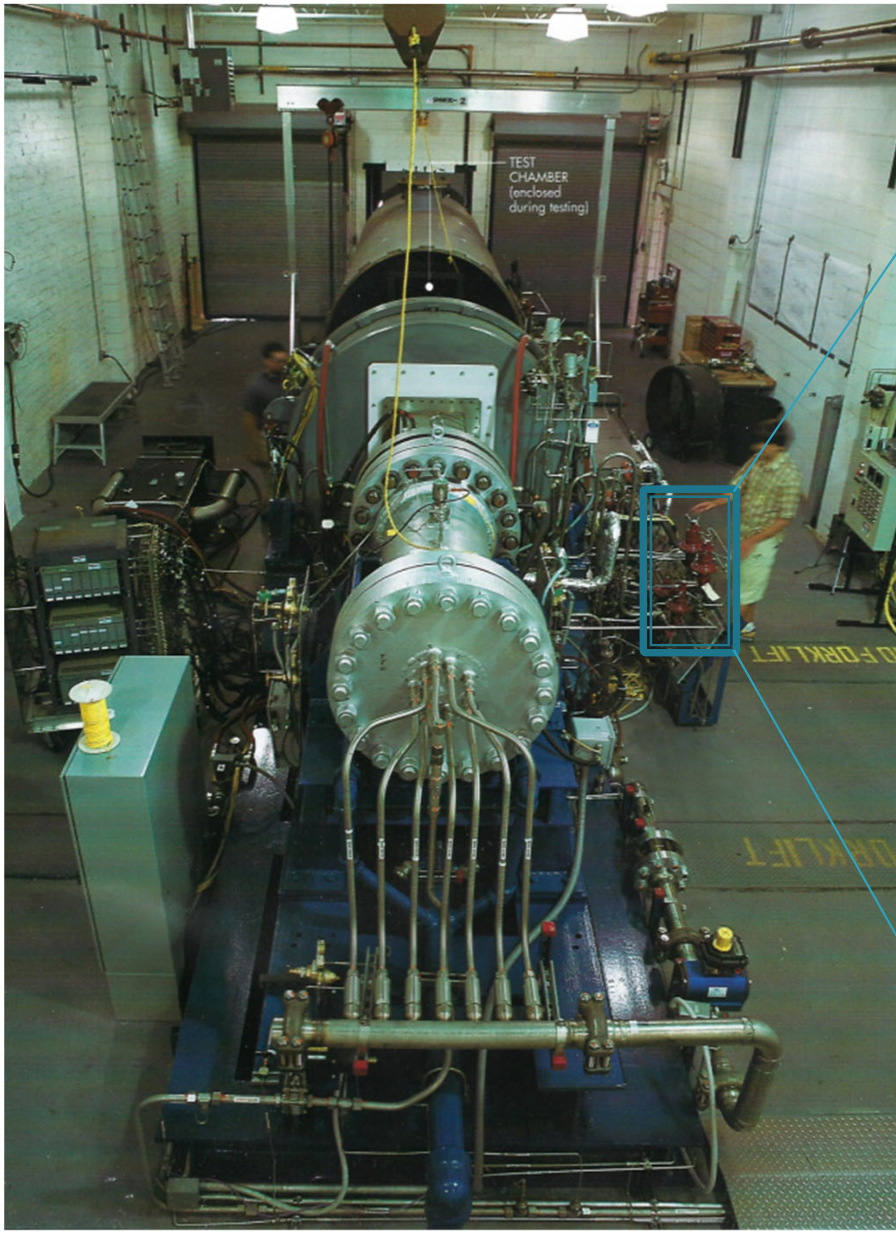

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