Dynamic Model of an FCCU Gas Plant

Are Dynamic Models A Useful Predictive Tool

John Burgess, P.E. | John Wilkins

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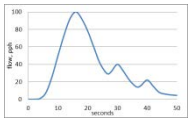
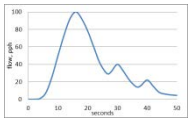


Meetings Agenda

- Introduction to topic
- Review of the Codes on this topic
- Review of a single System
- Review of another single system
- What does this mean
- FCCU Gas Plant
- Questions and Comments



Are Dynamic Models A Useful Predictive Tool?

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Traditional Relief Rate Calculations

$$\dot{m} = \frac{Q}{\Delta h_{l \to v}} = \frac{U_{OA} A \Delta T}{\Delta h_{l \to v}}$$

Where,

A = The surface area of the exchanger (ft^2)

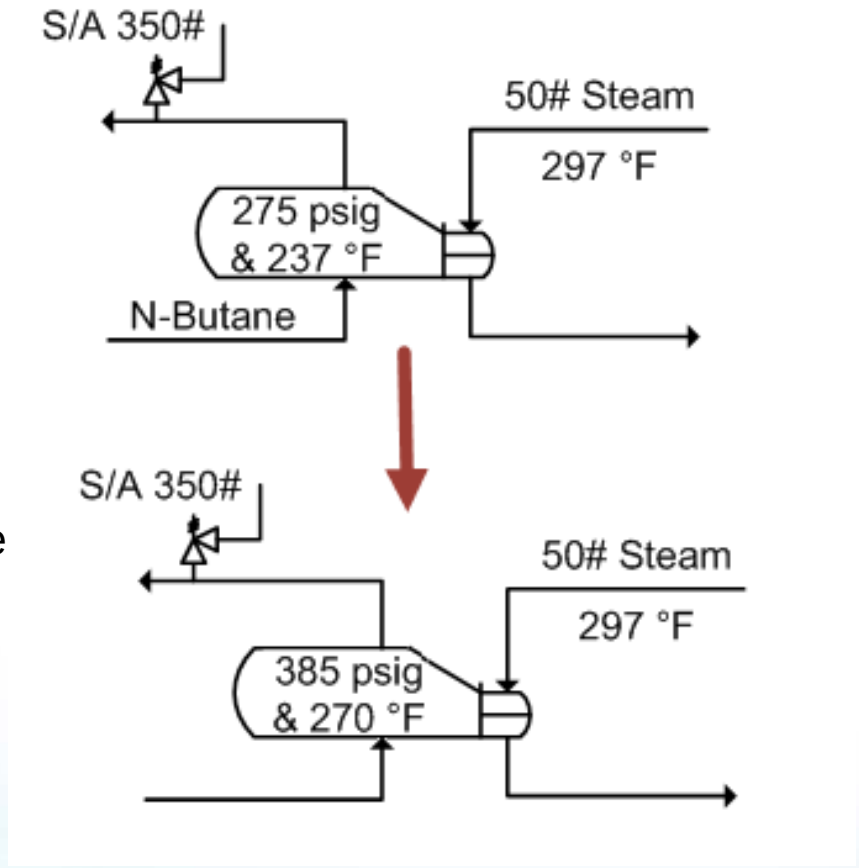
$\dot{m}$ = the required relief rate (lb/hr)

Q = the total heat transfer (btu/hr)

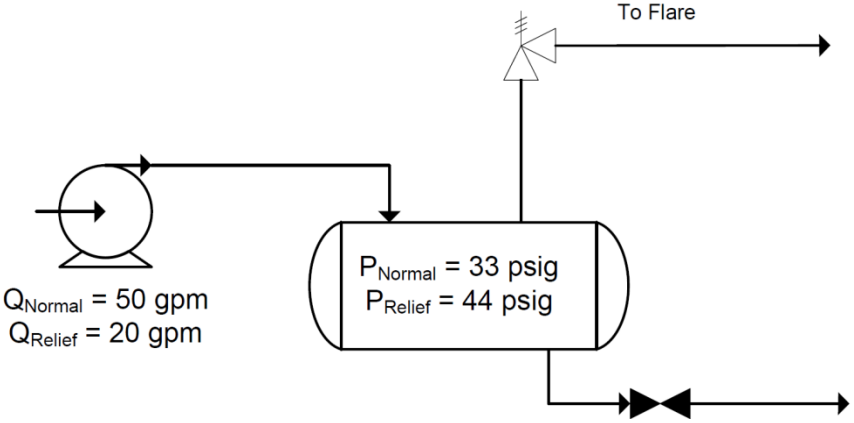
ΔT = the the log mean temperature difference (°F, normal)

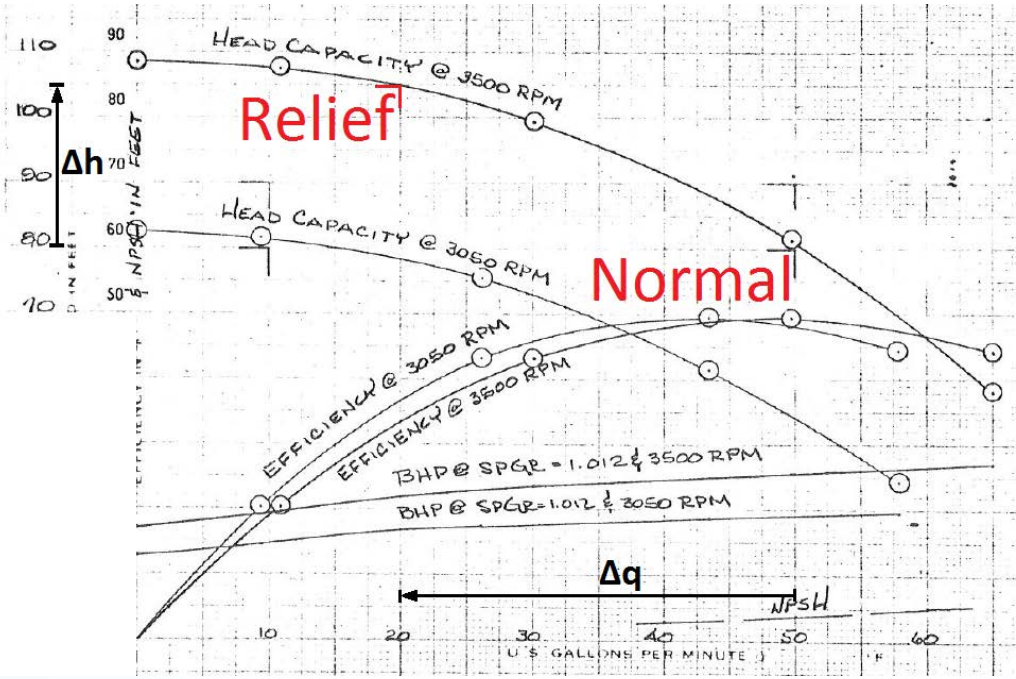
U_{OA} = The overall heat transfer coefficient

λ_{LV} = the latent heat of vaporization of the heating medium (btu / lb)



Traditional Relief Rate Calculations





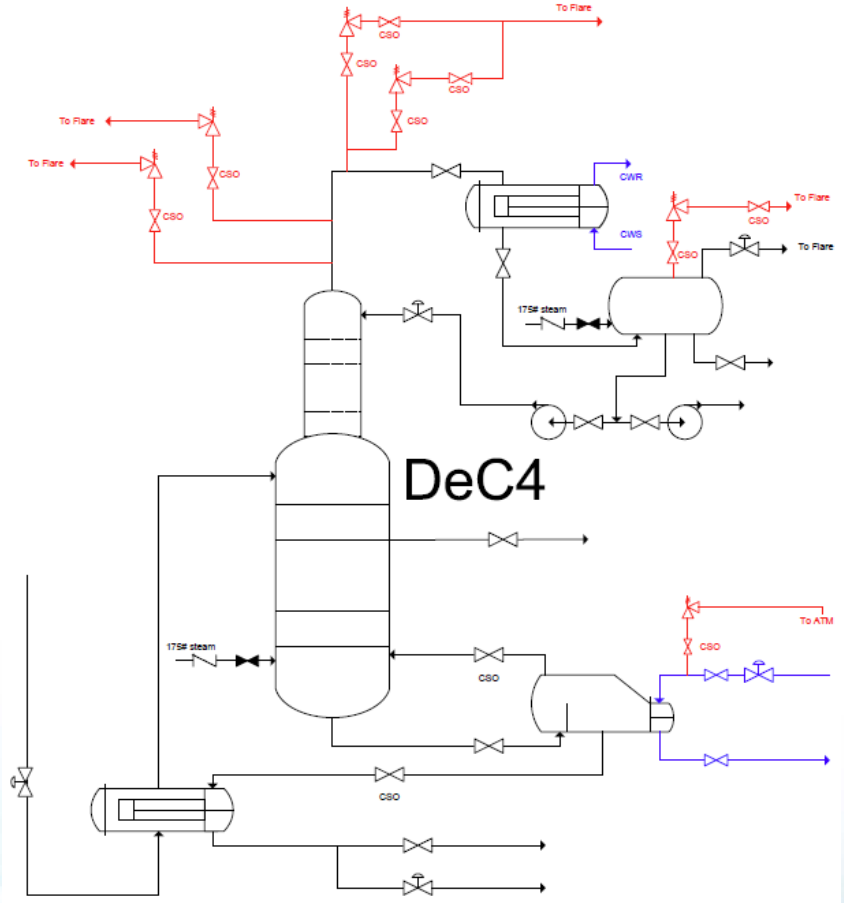
$$\Delta q \propto \Delta P = \frac{\Delta h \rho}{144}$$

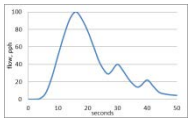
Dynamic Relief Rate Calculations

$$\dot{M}_{relief}\left(t, P_i, T_i, etc\right) = \frac{\dot{Q}_{reb}\left(t, P_i, T_i, etc\right)}{\Delta H_{vap}\left(t, P_i, T_i, etc\right)}$$

Where,

- The relief rate is a function of the initial conditions
- Changes in conditions may affect the relief rate counter intuitively

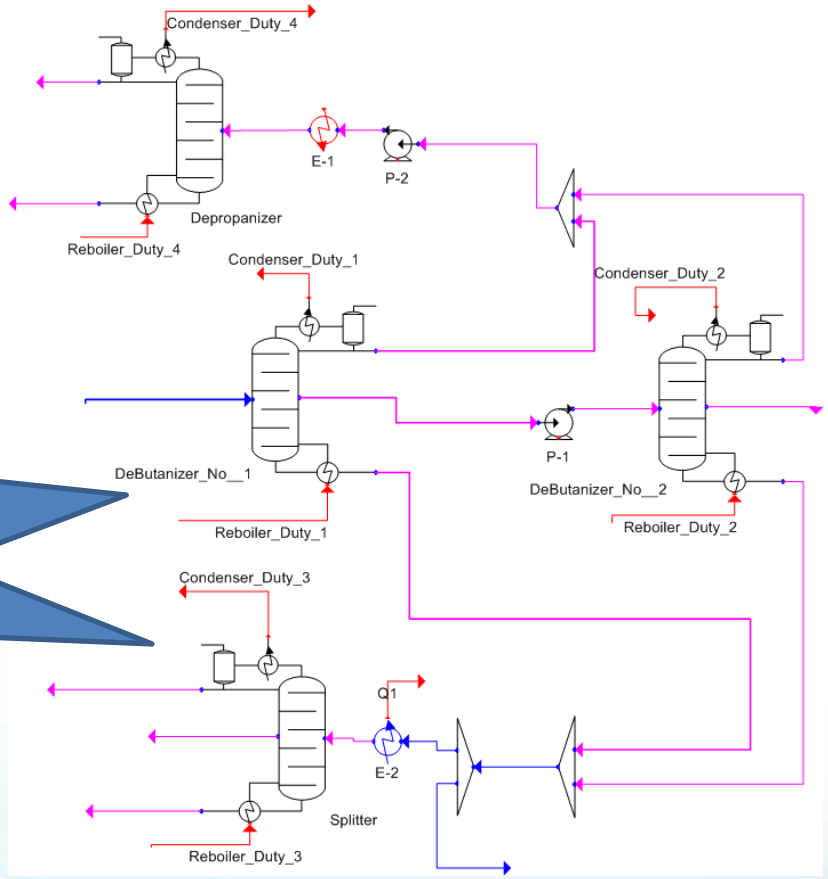


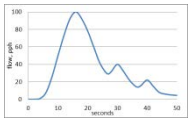


Dynamic Relief Rate Calculations

If the Liquid Level in the first DEC4 increases, will the back pressure on the DEC3 increase (or not)?

Can we even make a conservative assumption?

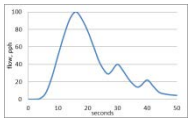




"Code" Acceptance: Dynamic Simulation

From API 521 5th Ed. Sec 5.22:

- "It can be necessary to **perform sensitivity analyses** with respect to control response in order to identify appropriate control response."
- "If dynamic simulation is used for column-relief-system design, it is necessary to **ensure that the model is conservative** with respect to calculating the maximum relief load."
- "These assumptions **shall** be checked by **sensitivity analyses** to assess their impact on the column-relief load."

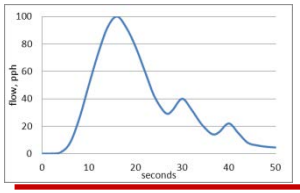


Dynamic Simulation – Single Systems

METHODOLOGY

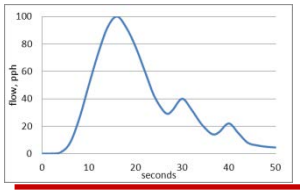
1. Column boilup was selected as the relief basis.

2. Three initial conditions were varied
   - Column liquid level
   - Feed temperature
   - Column pressure



METHODOLOGY [CONT.]

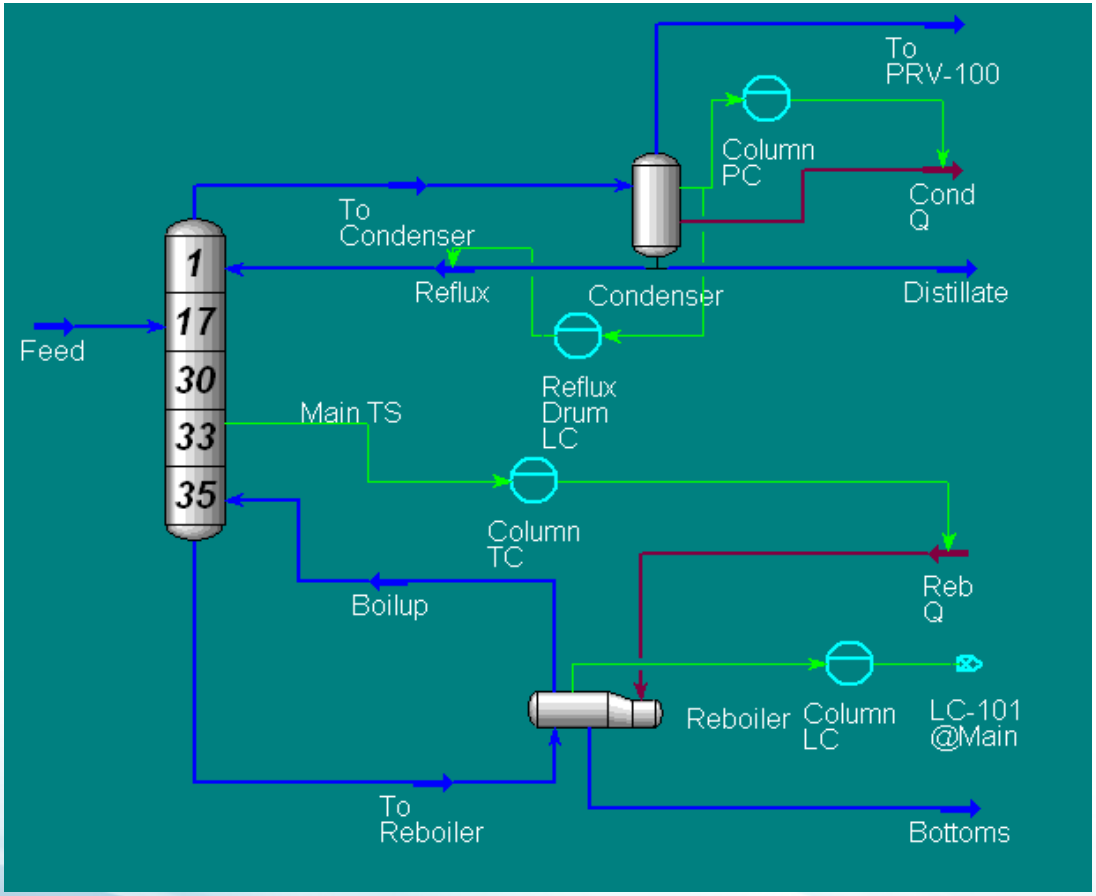
3. Three columns were analyzed
   - Depropanizer (Column temp range: **104-210°F**)
     - (4’ diameter, 21,600 lb/hr feed)
     - (8’ diameter, 32,400 lb/hr feed)
   - Debutanizer (Column temp range: **179-384°F**)
     - (10’ diameter, 623,000 lb/hr feed)



DYNAMIC RELIEF

PROCESS VARIABLES EFFECTS

METHODOLOGY [CONT.]



Column PFD for the depropanizer

4. Steady state columns
5. Dynamic mode was initiated
6. PID controllers were created
   - Column Pressure
   - Column Temperature
   - Reflux Drum Liquid Level
   - Column Liquid Level
   - Distillate Flow Rate

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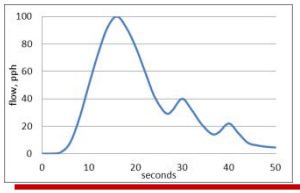

DYNAMIC RELIEF

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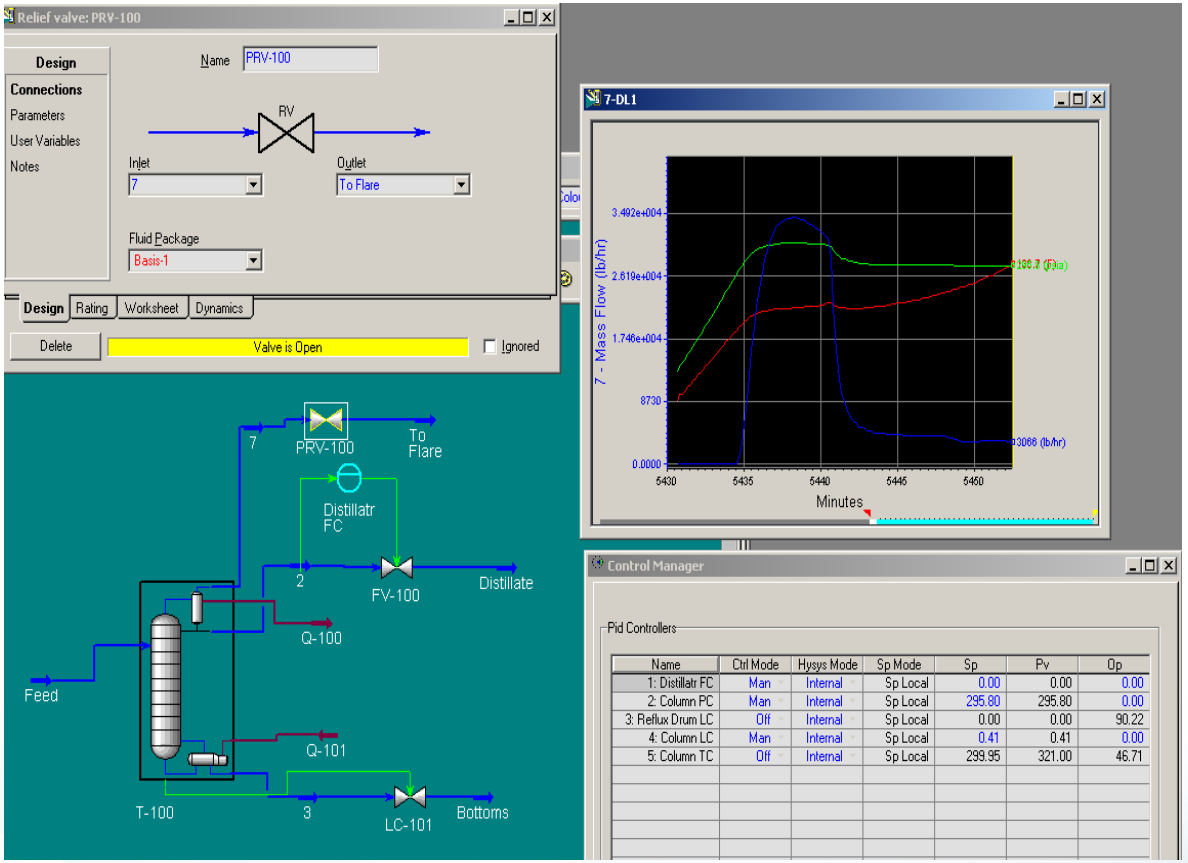
METHODOLOGY [CONT.]

7. Steady state was reached in dynamics mode
8. A PRV was added to the vapor overhead
9. Relief scenario was started
10. Simulation data was recorded



Collecting data for the depropanizer

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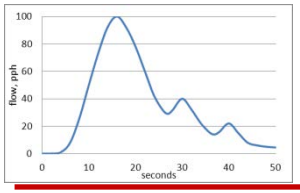

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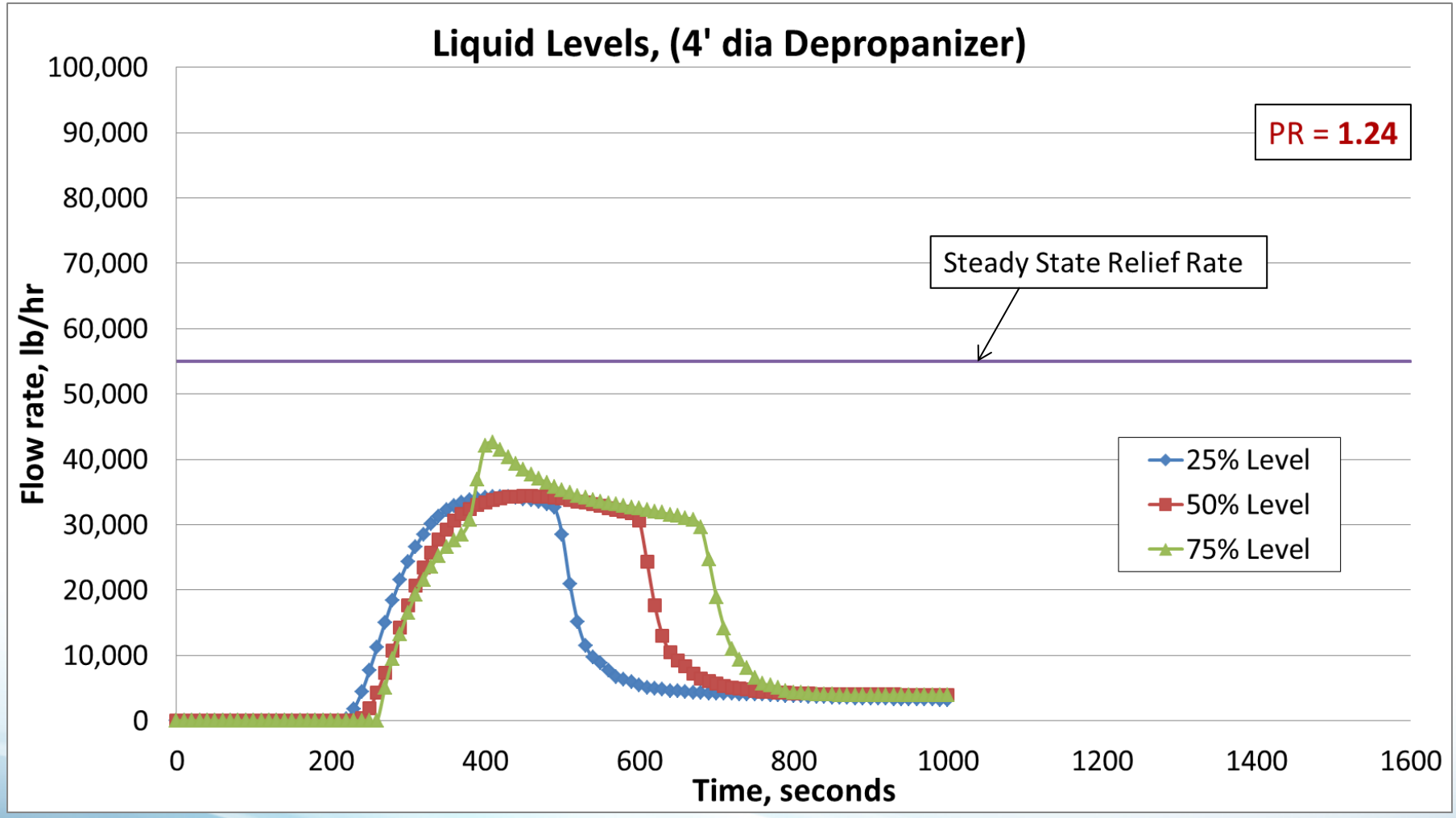

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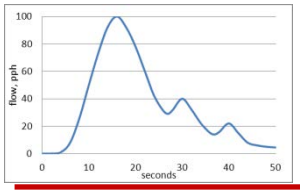

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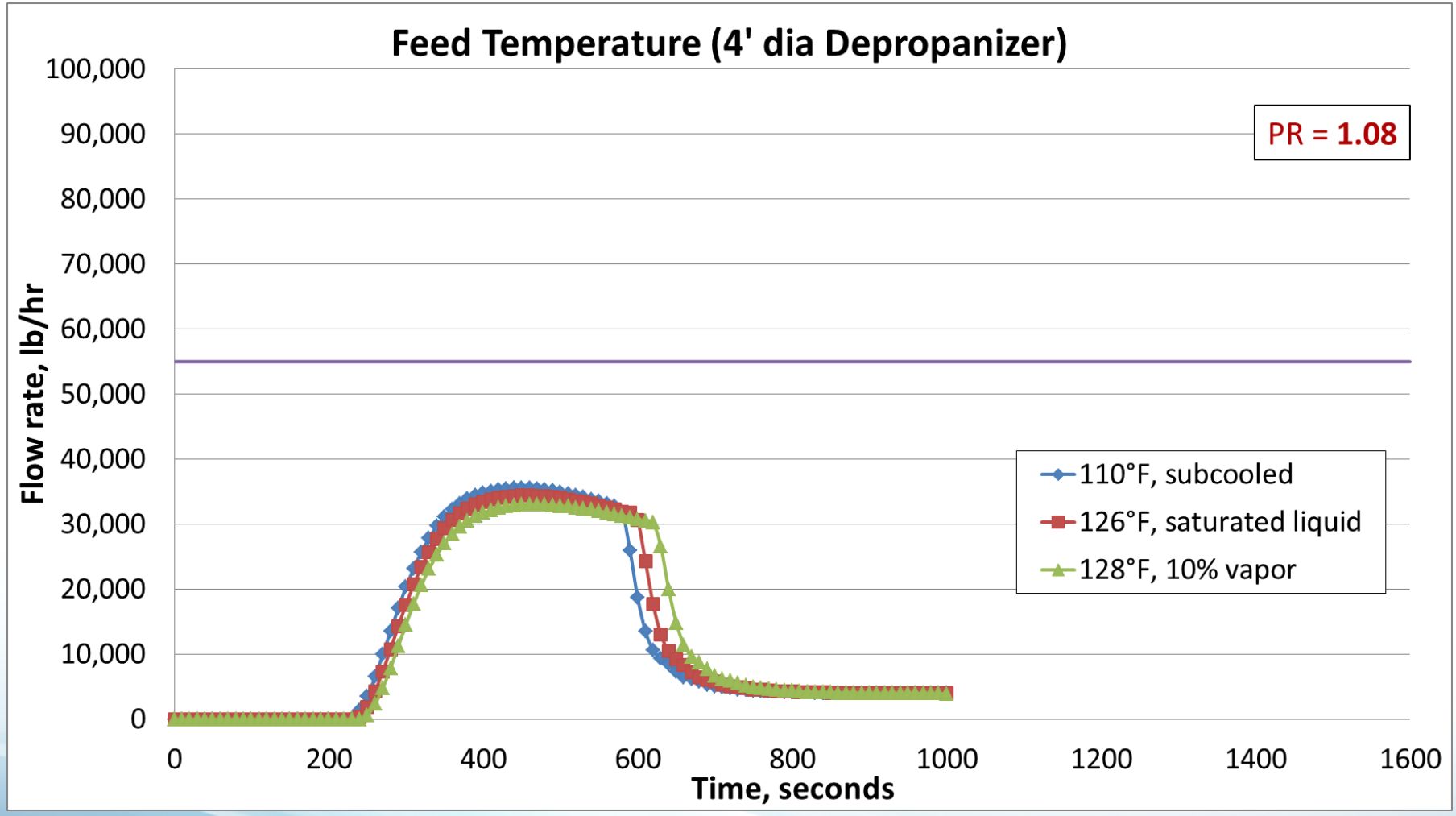

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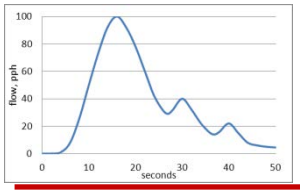

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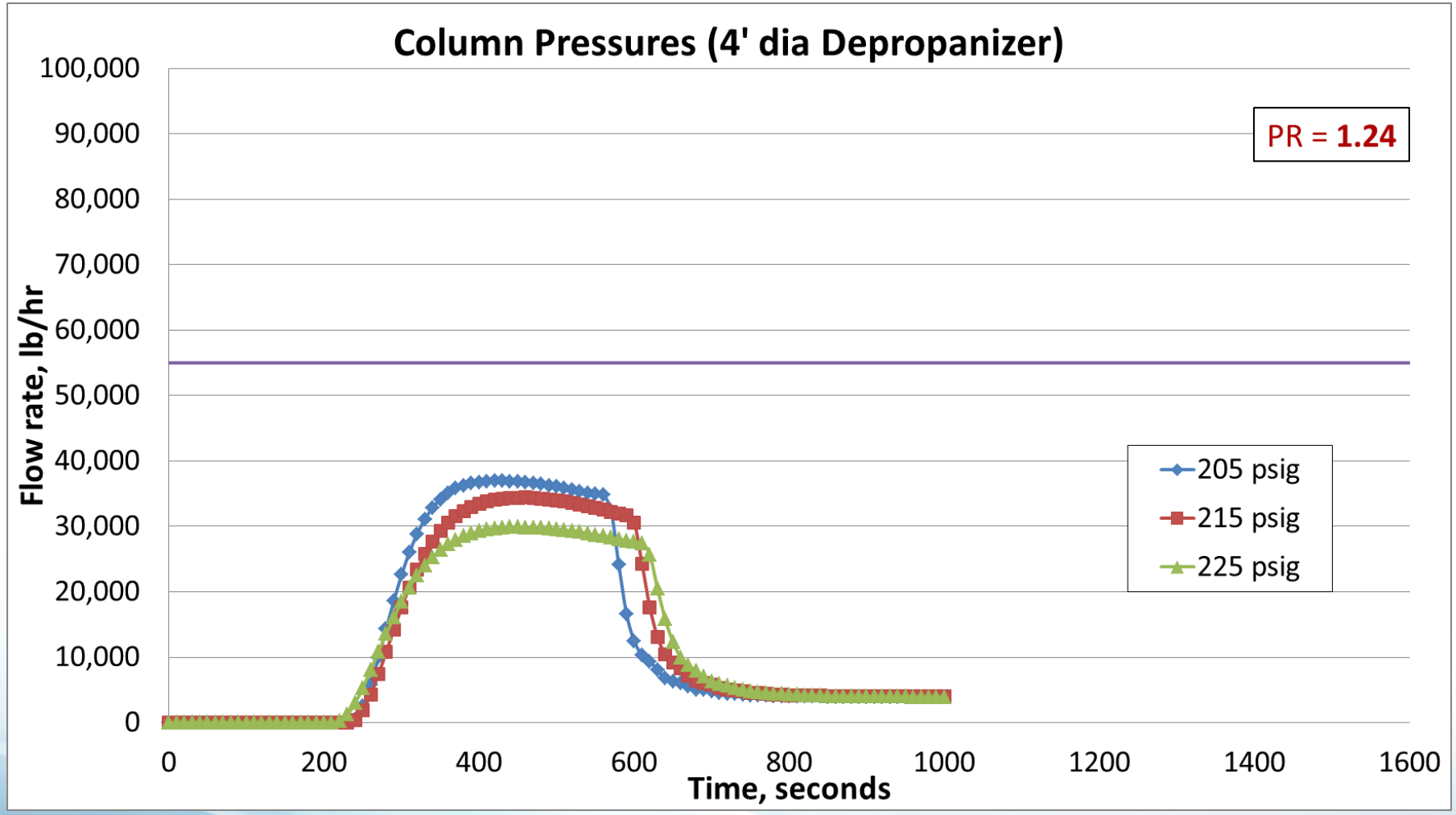

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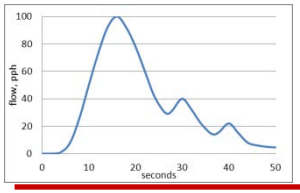

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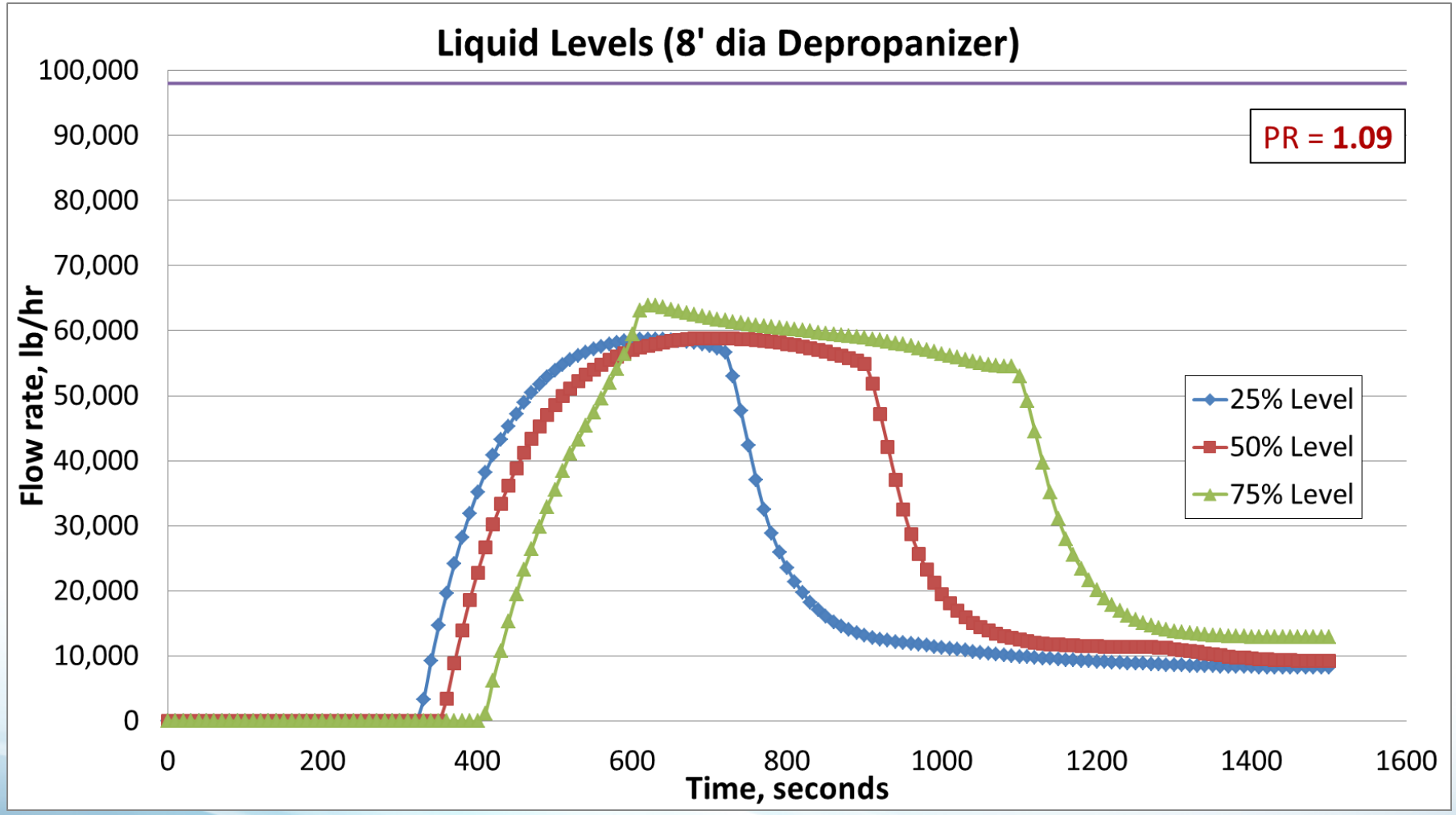

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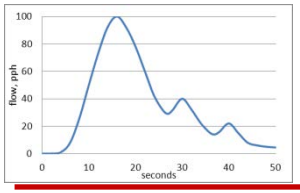

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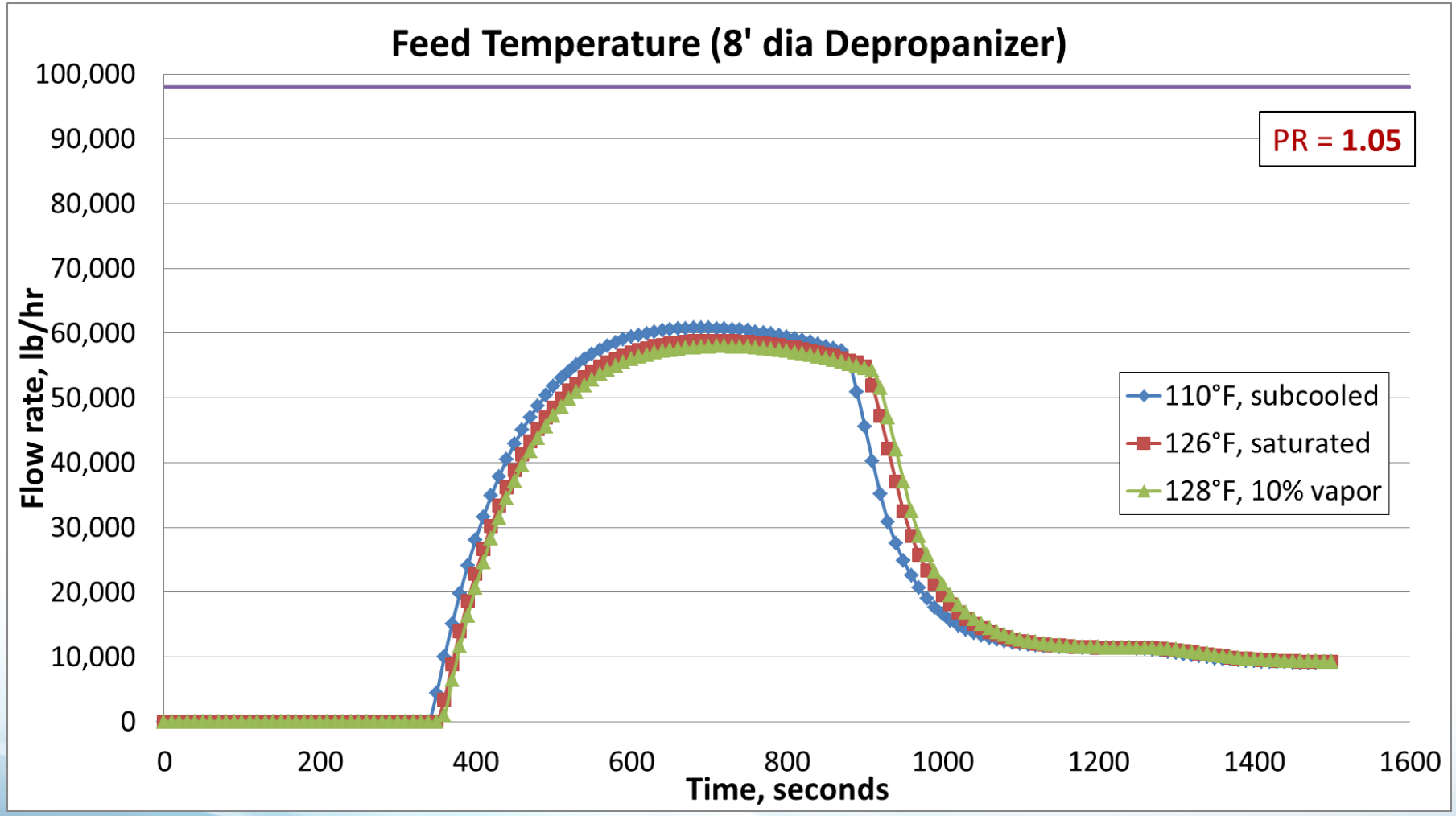

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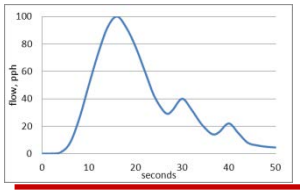

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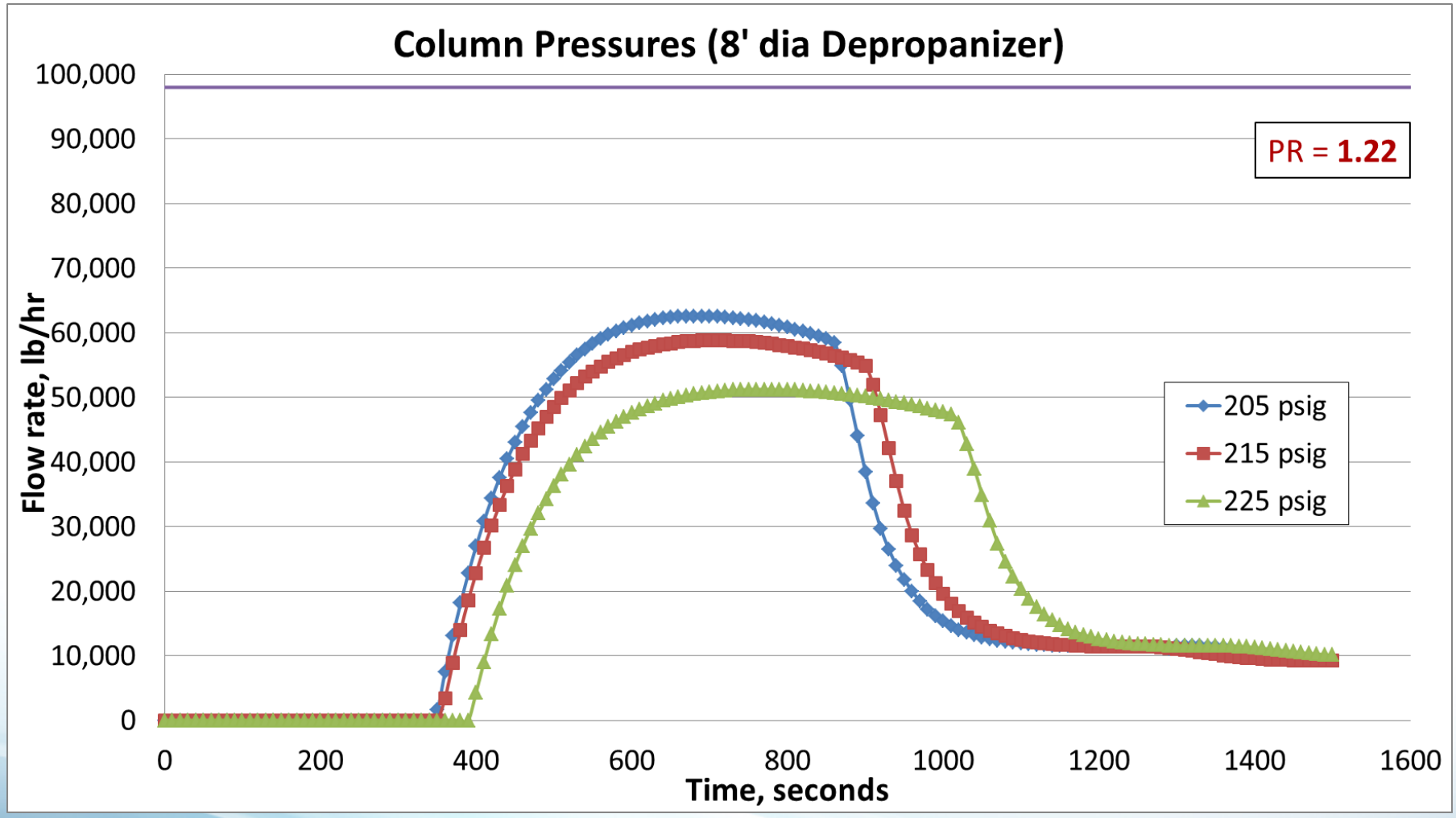

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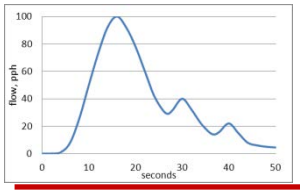

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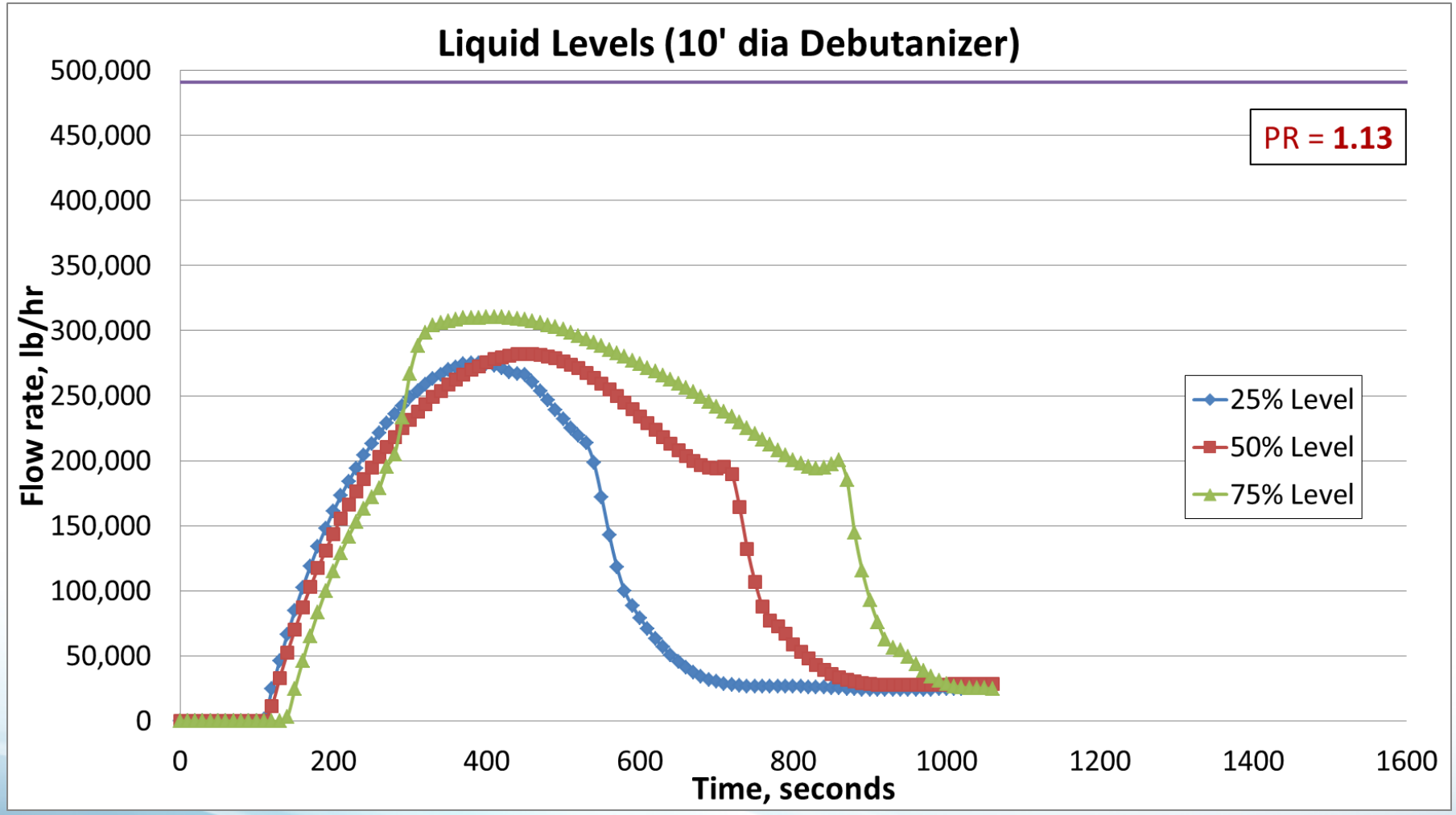

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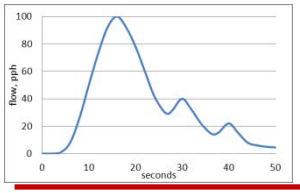

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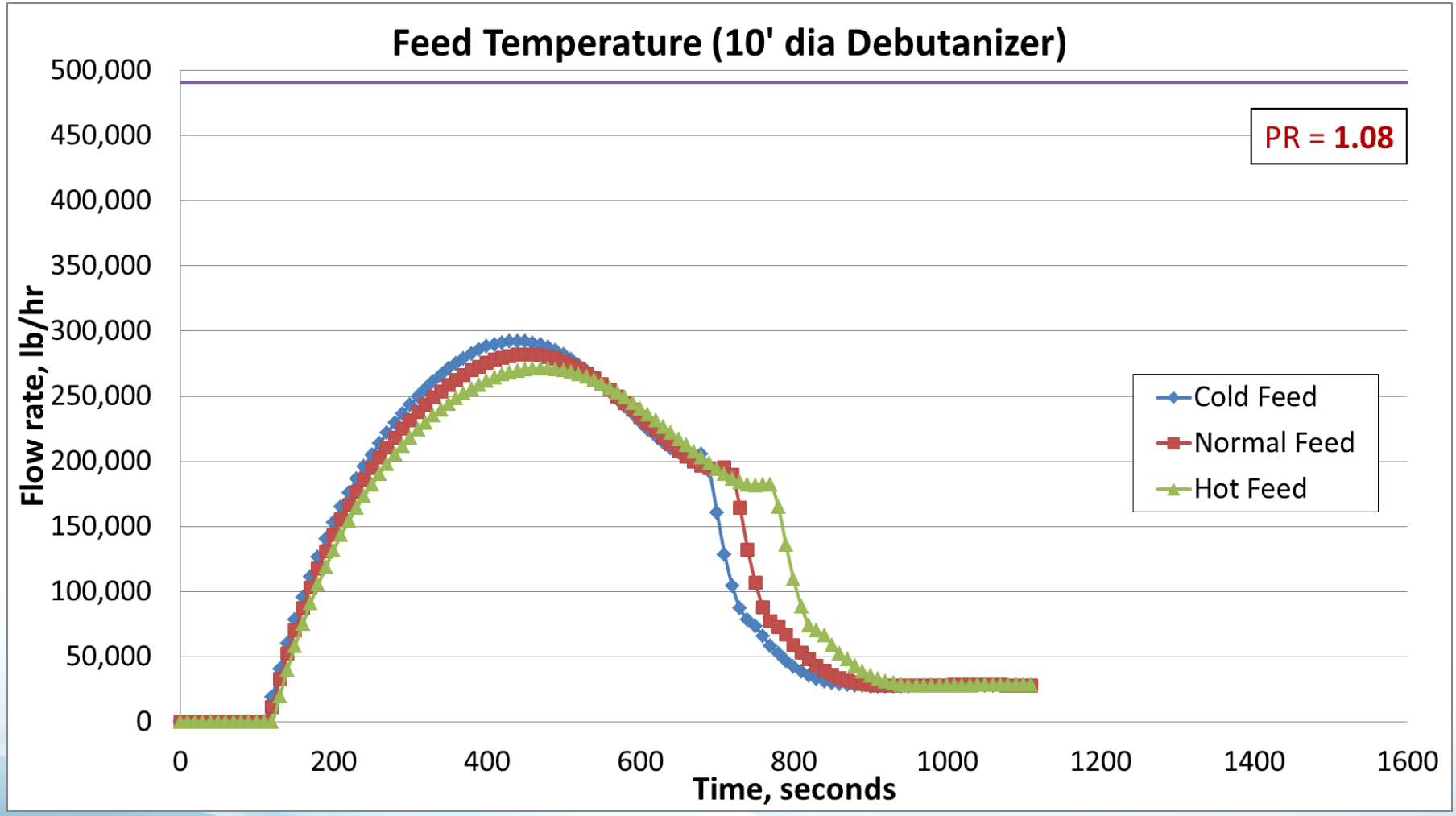

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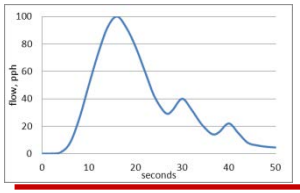

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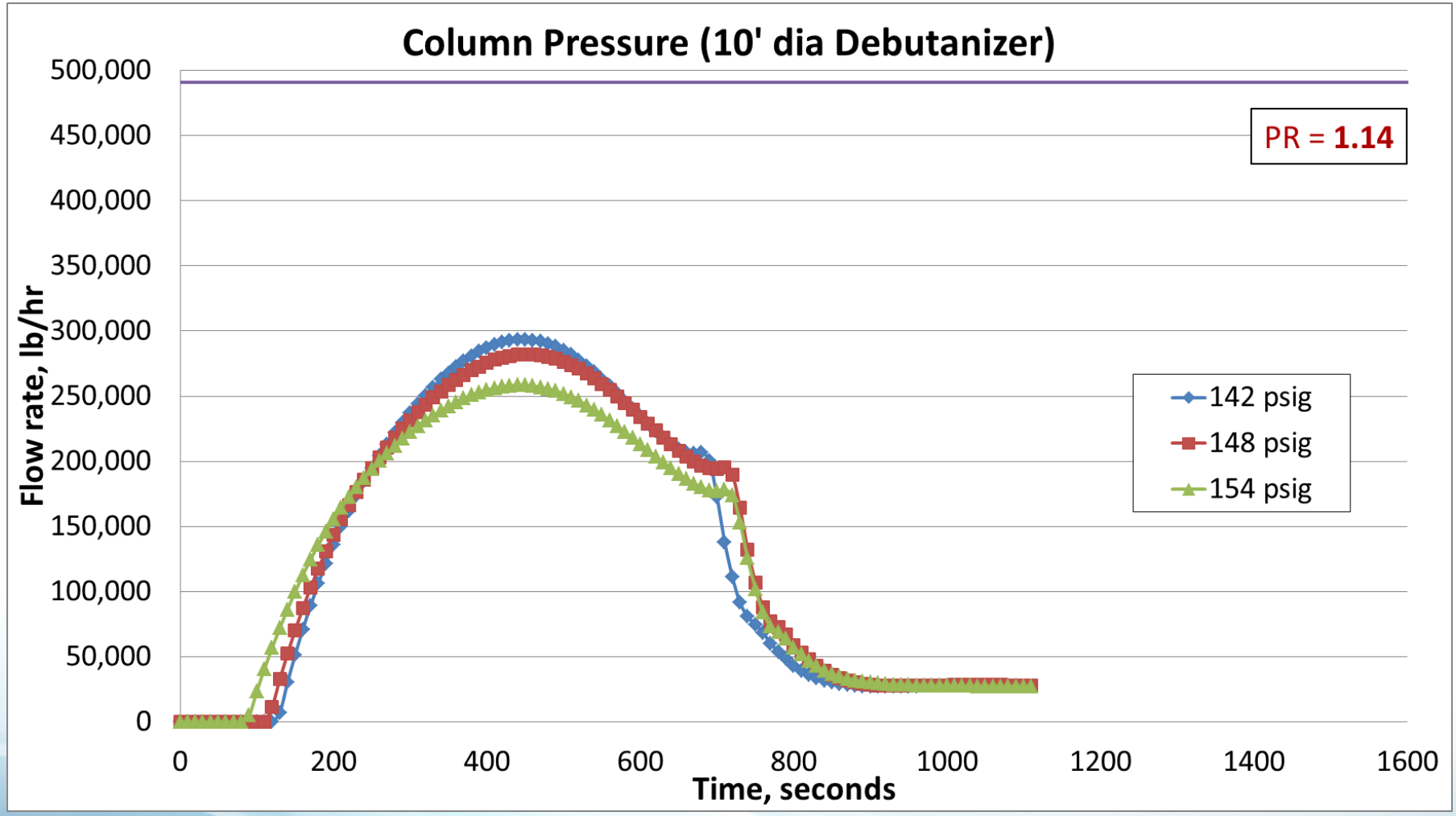

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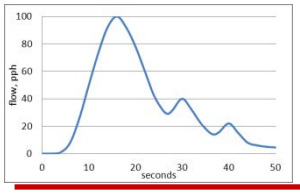
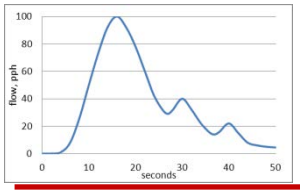


SINGLE SYSTEM CONCLUSIONS

1. Some process variables had more impact on the peak flow rate.
2. Process variables affect
   - Time to initial relief
   - Peak rate
   - Duration
3. Analysis can be time consuming.
4. Cost of analysis vs. savings.



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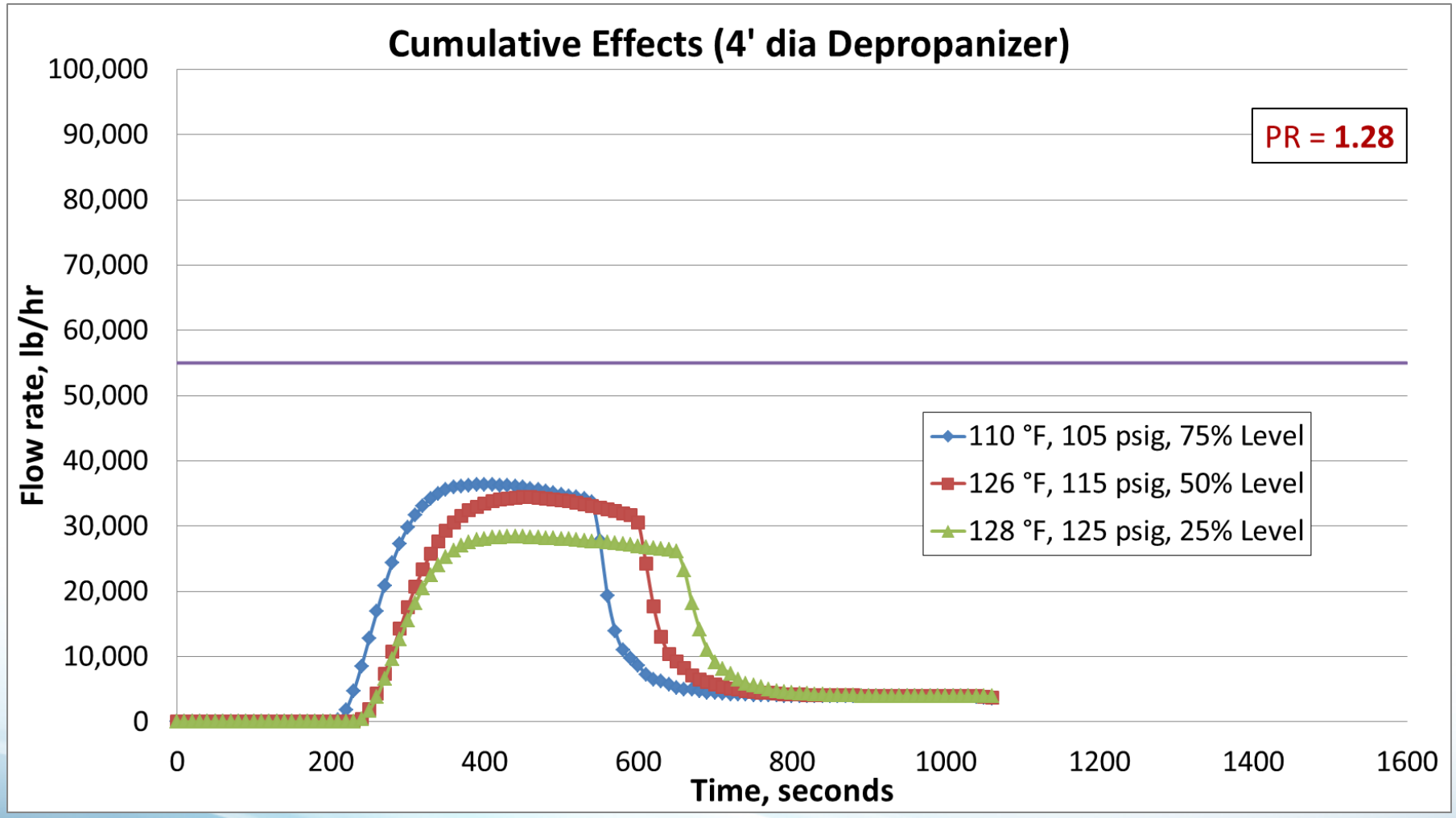

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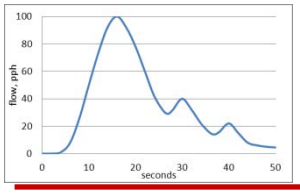
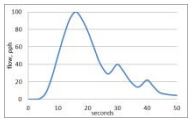


SUMMARY

Table of PR values

Variable\Column	4' dia Depropanizer	8' dia Depropanizer	10' dia Debutanizer
Liquid Level	1.24	1.09	1.13
Temperature	1.08	1.05	1.08
Pressure	1.24	1.22	1.14

1. Sensitivity analyses must be performed for dynamic simulations.
2. Some assumptions impact the peak relief load.
3. Sensitivity analyses can be costly.
4. More work is required to analyze these effects.



Dynamic Simulation – Multiple Systems

- Four distillation column system.
  - 2 DeC4, 1 DeC3, & 1 C4 Splitter
- Cooling water failure was simulated.
- Column liquid levels were varied.
  - Low (20%), Medium (40%), High (60%)

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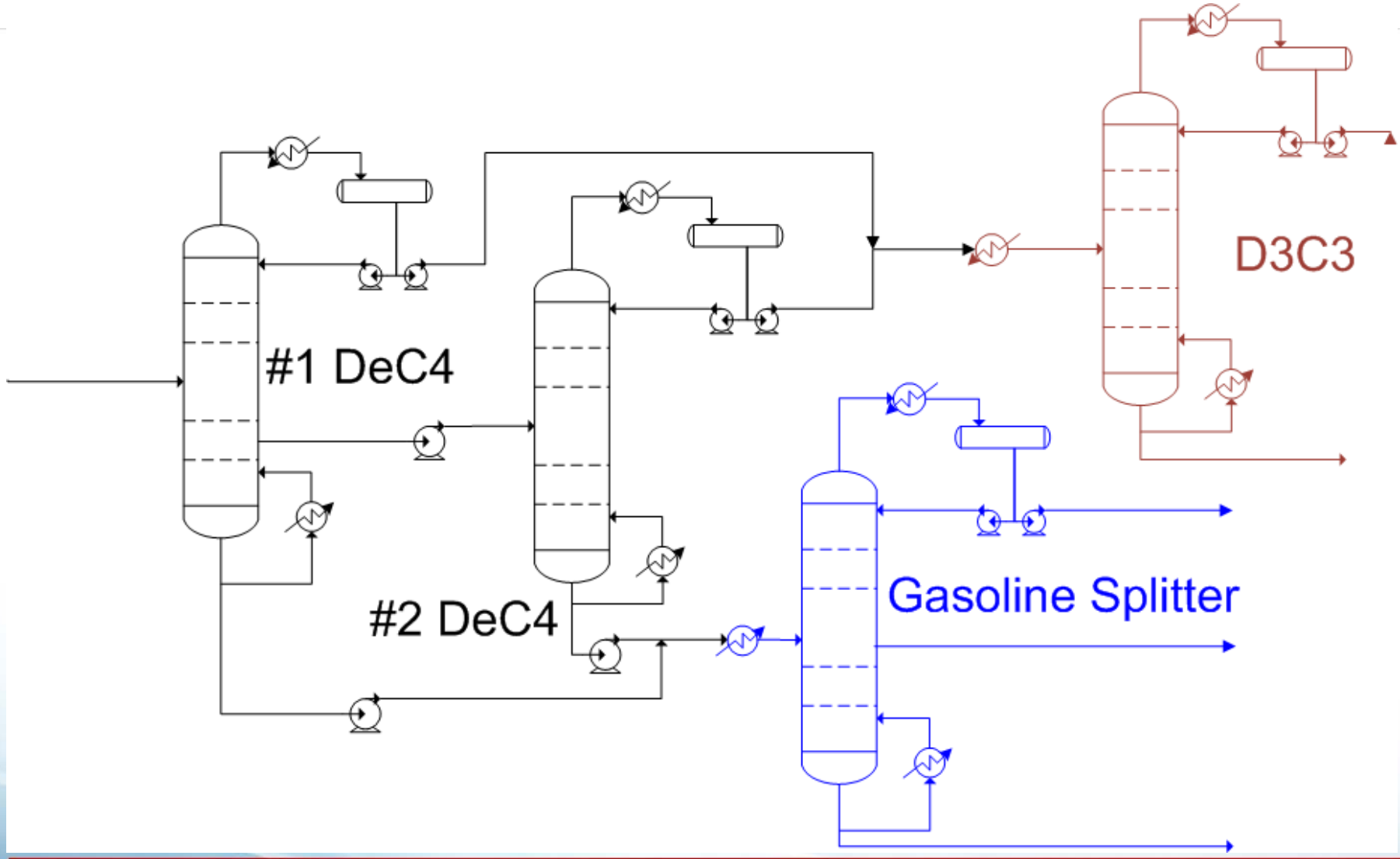

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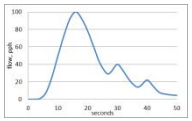

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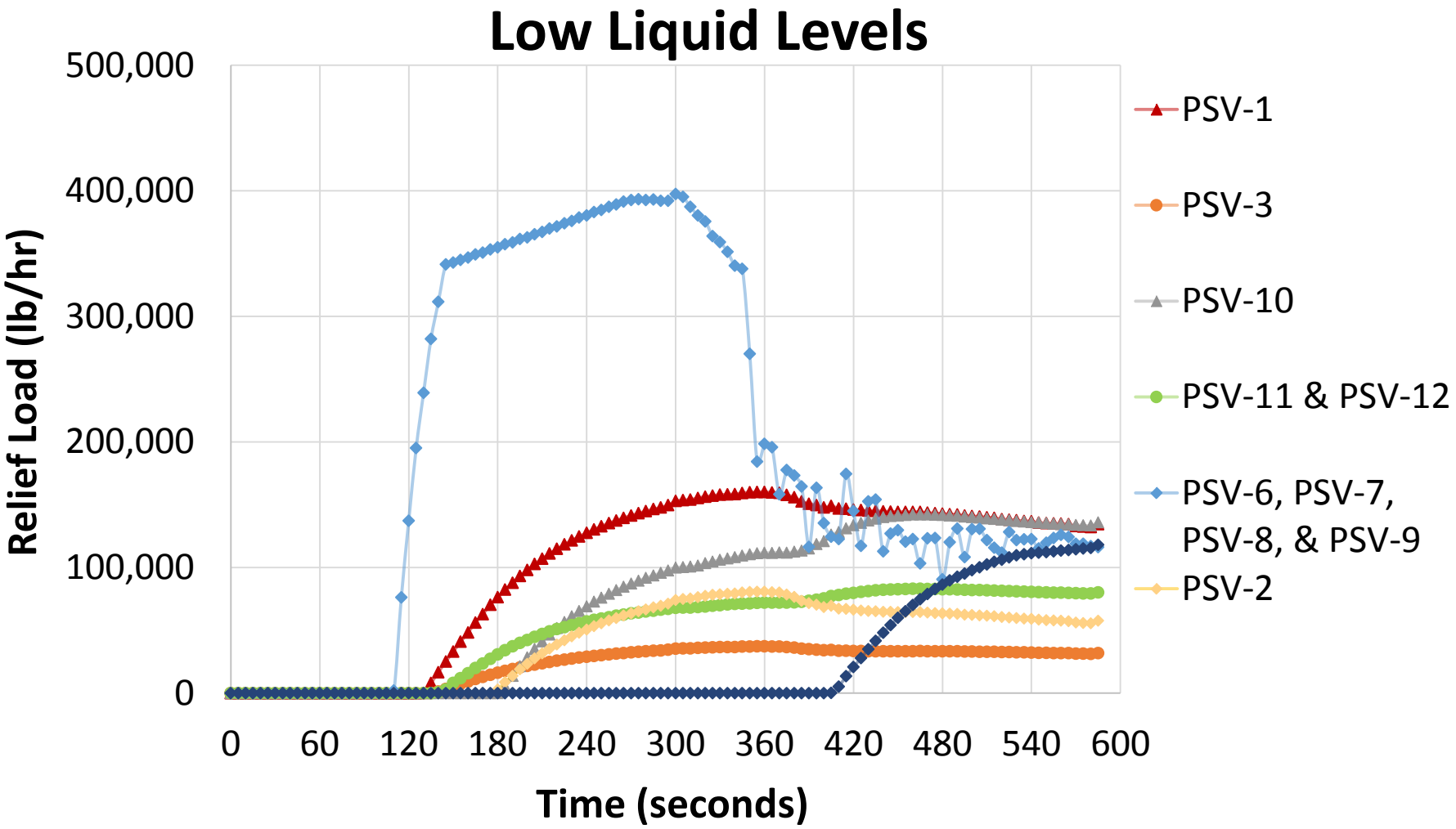

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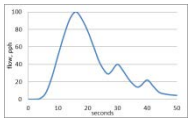

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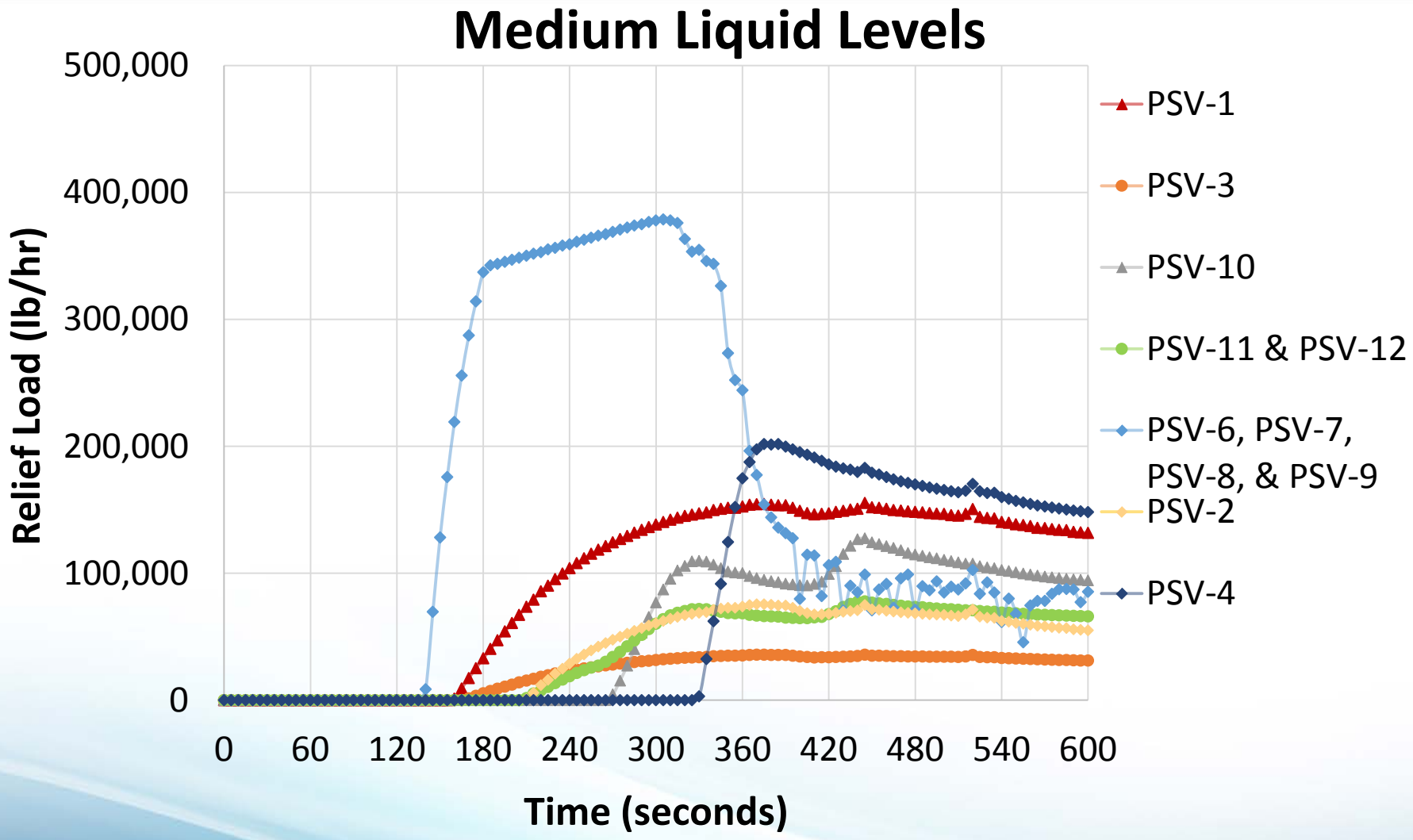

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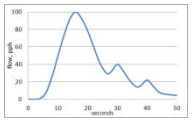

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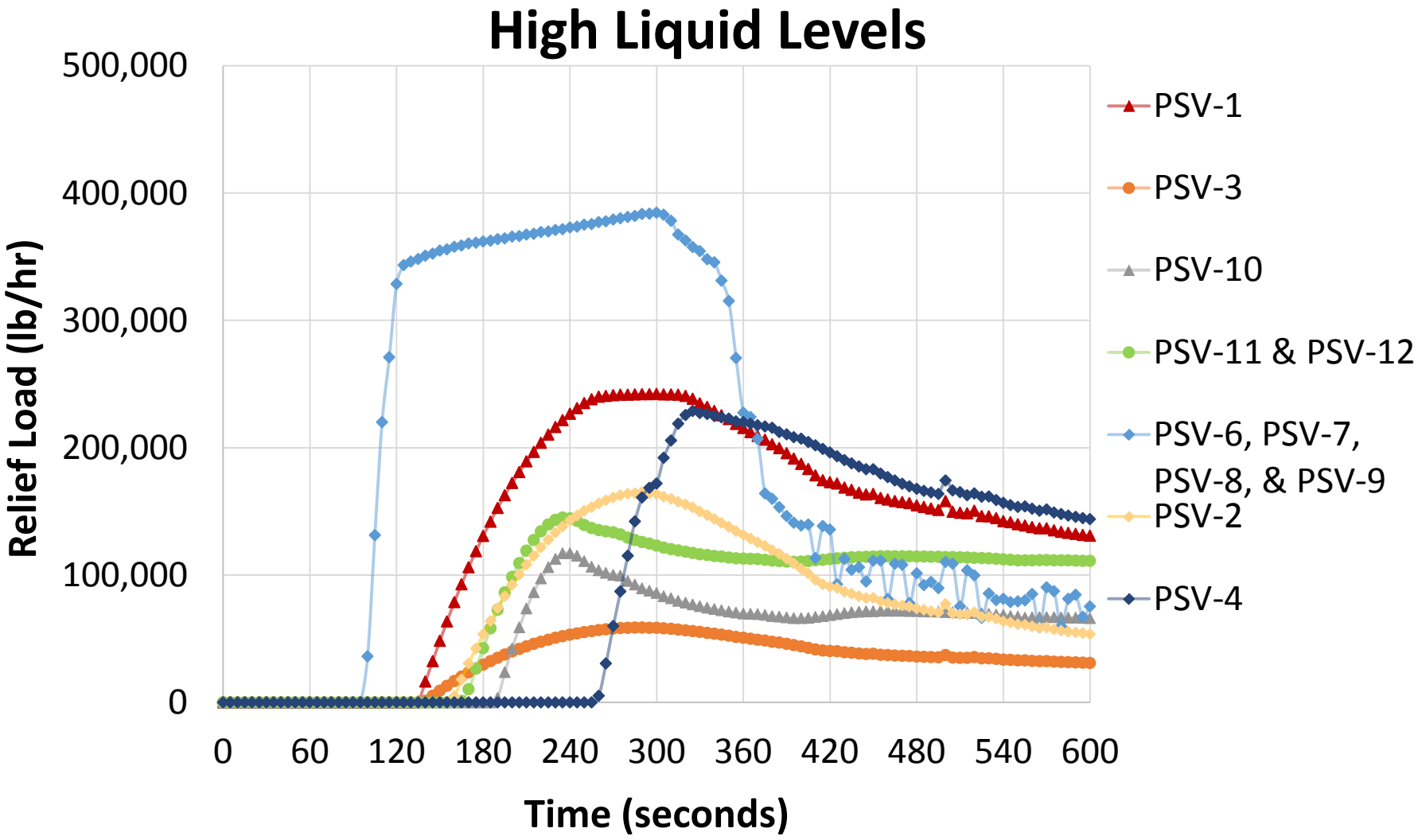

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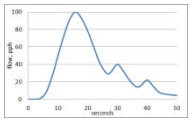

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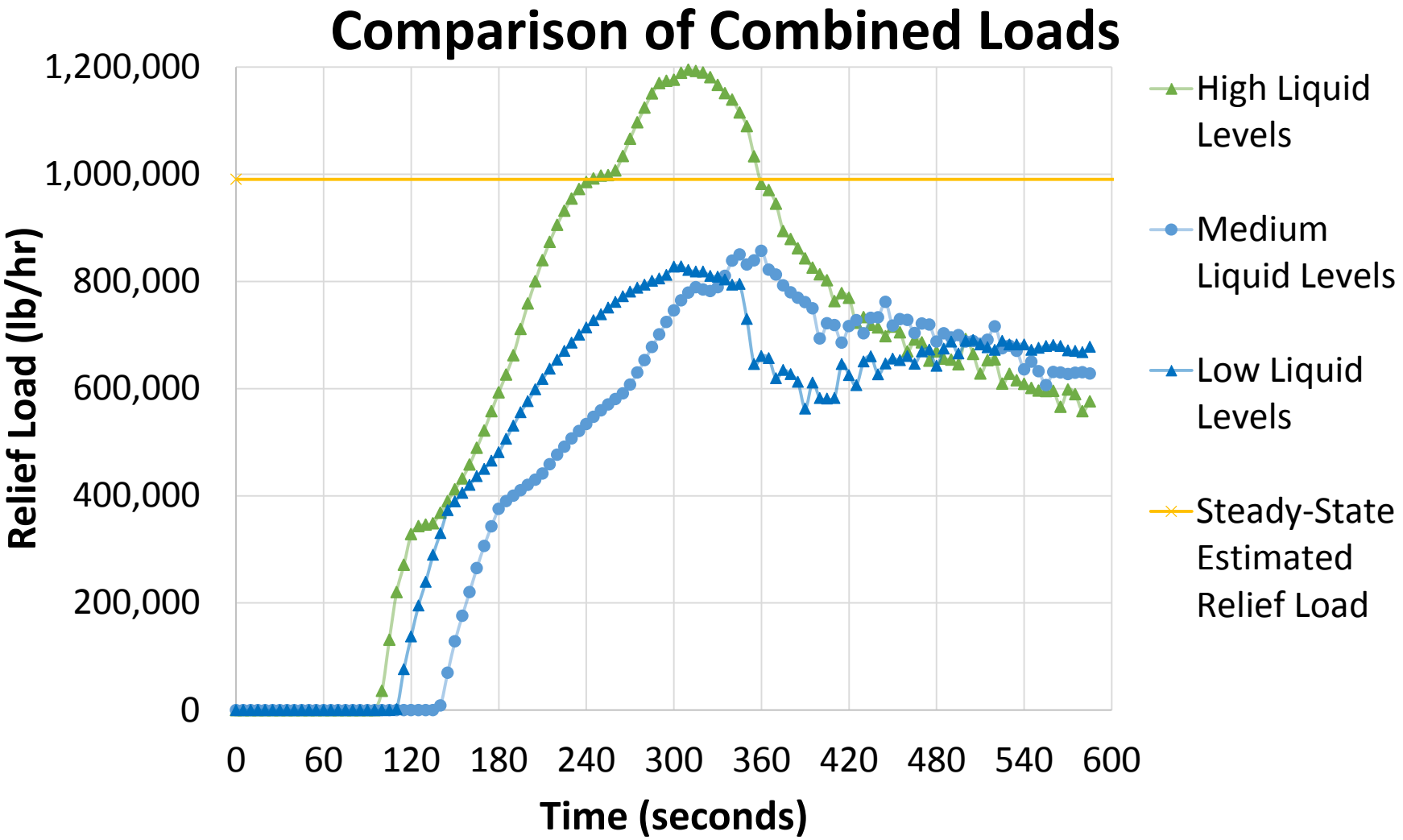

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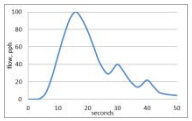

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- Increasing the liquid levels by 50% increased peak load by 43%.

- Initial assumptions can affect:
  - Time to initial relief
  - Time to reach peak flow
  - Magnitude of peak flow

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