Study of High-Energy Loads Thermal Performance Under Aircraft Mission Profile Conditions

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Source: https://www.dvidshub.net

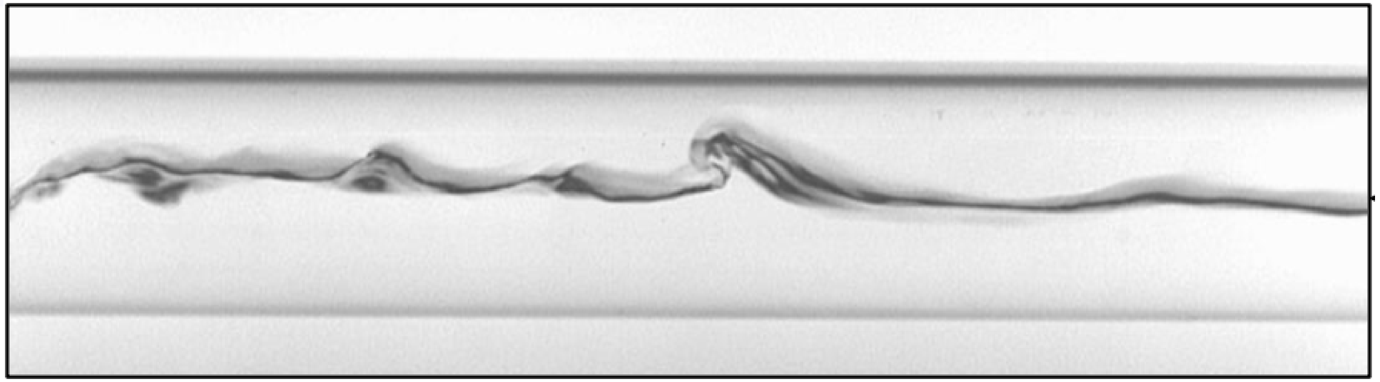
Relevance of Research

- Modern aircraft have seen a dramatic increase in electronics equipment implemented into platforms.
- Power is not added gradually to the aircraft's thermal management system.
- Heat must be dissipated without damaging the aircraft:
  - Thermal instabilities
  - Thermal runaway

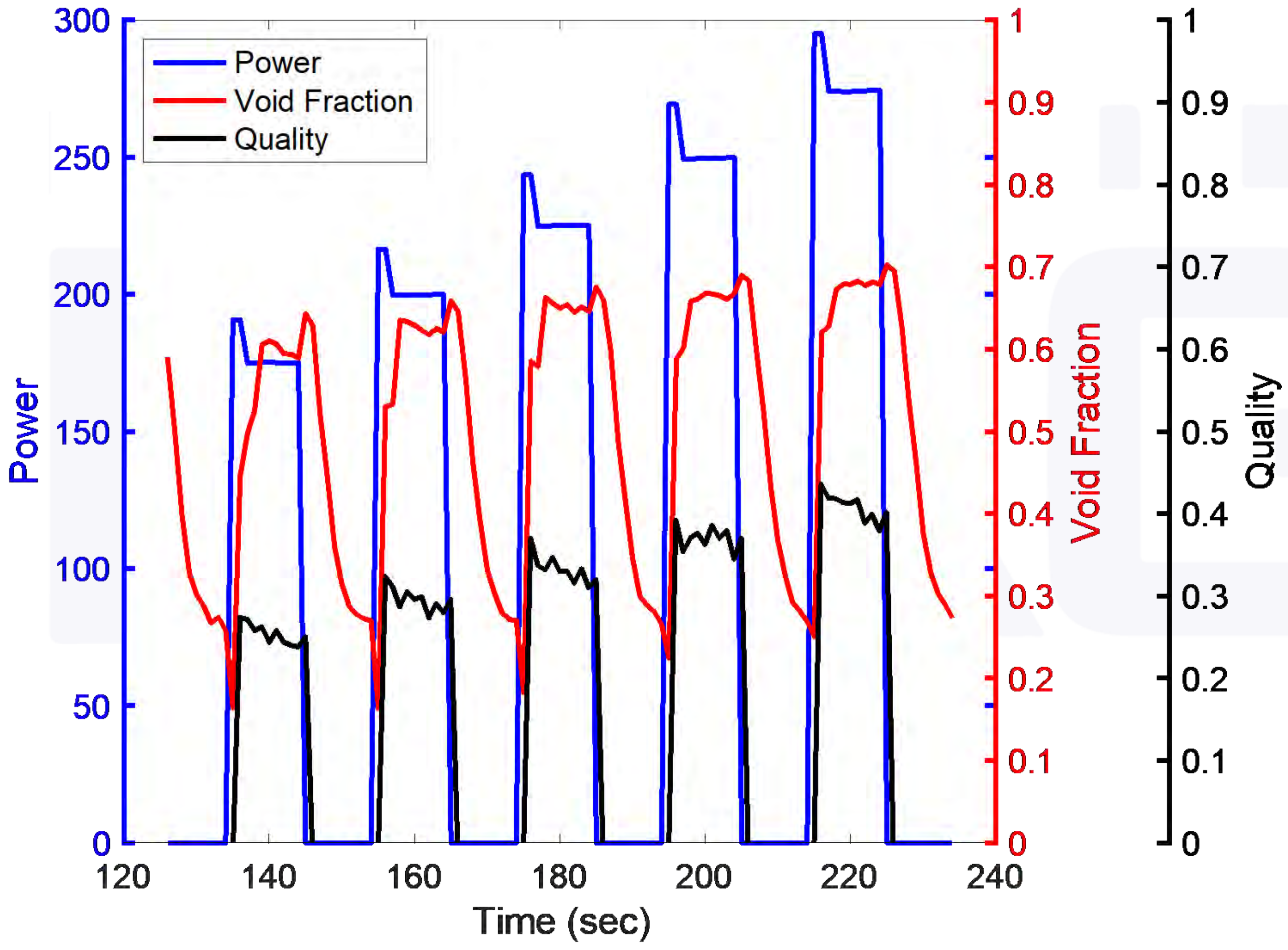
Source: https://www.topgear.com/car-reviews/lockheed-martin/f-35-lightning/interior

Background of Two-Phase Flow

- Two-phase flow is powerful, yet difficult, to achieve in a stable form.
- Liquid and vapor phases exist simultaneously.
- Little control exists over refrigerant in transient two-phase flow.
- Refrigerant flow is impacted by heat addition to the cold plate.
- The ECT sensor quantifies the extent of each state from a volumetric standpoint.

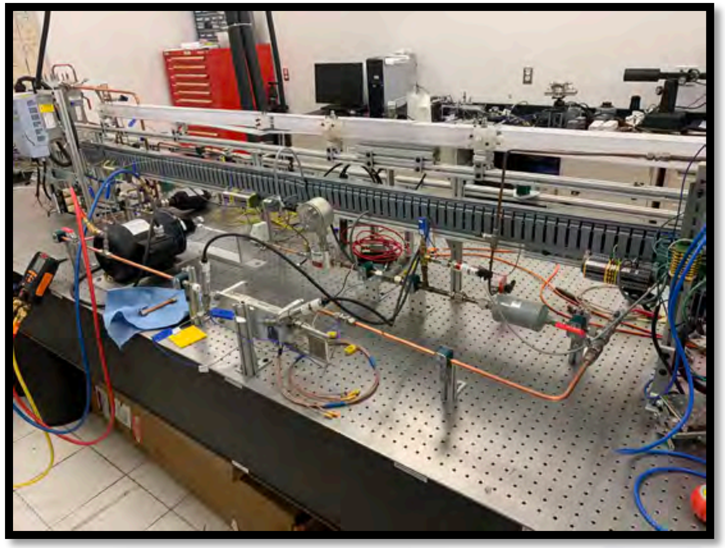


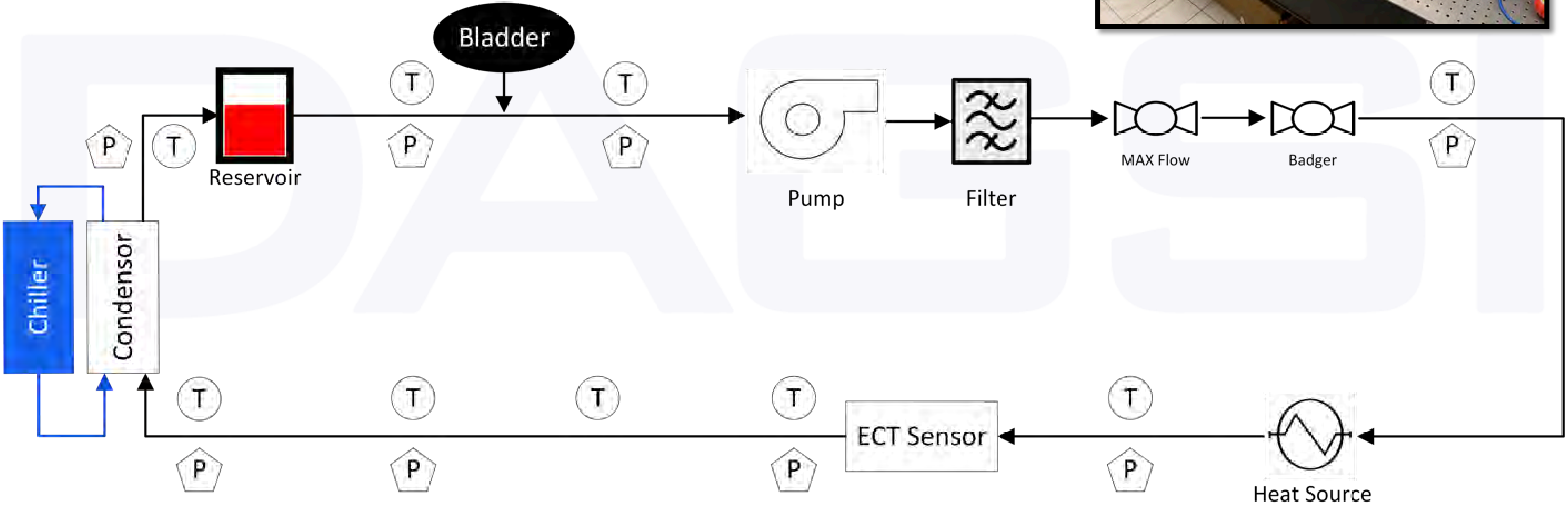
Introduction to Transience



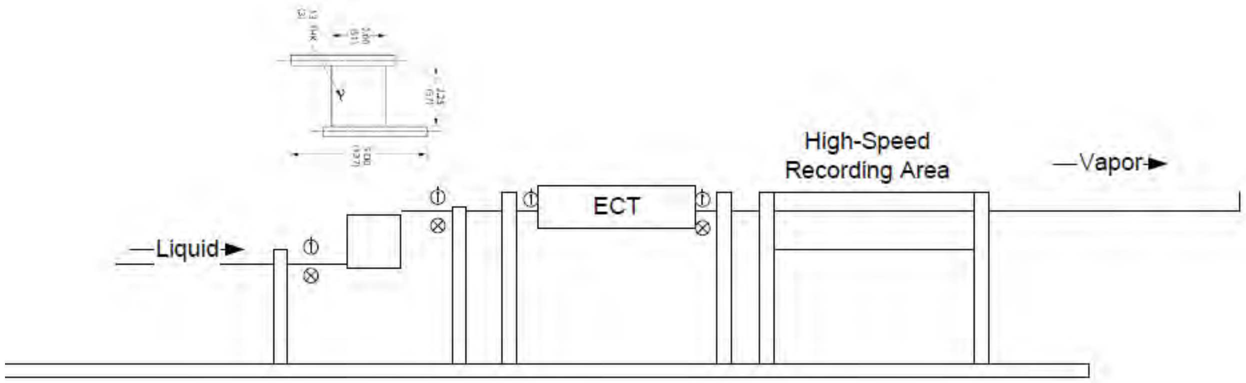
- Quality is calculated through the energy balance equation
- Produces unrealistic results when the power is pulsed off
- Quality should follow a similar profile to that of void fraction
- **Can we use void fraction to predict quality?**

Experimental Setup

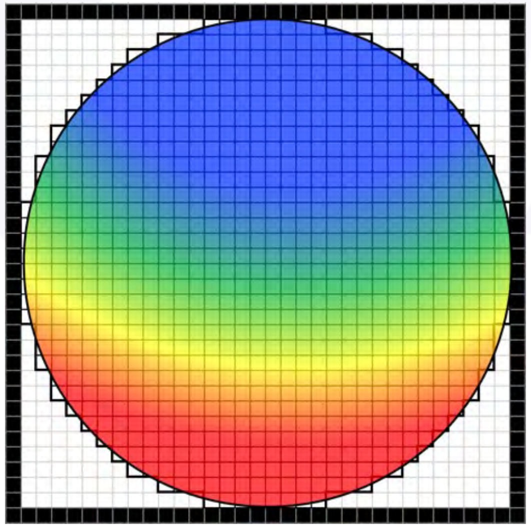




What is an ECT?



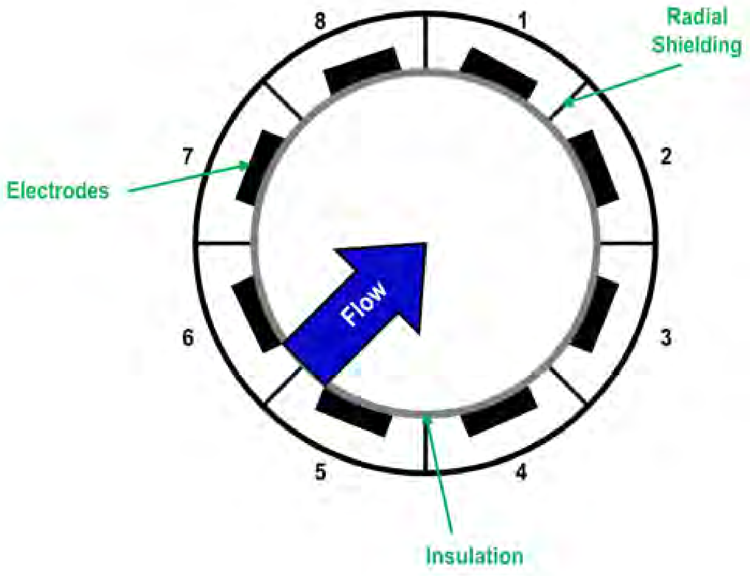
- Electrical Capacitance Tomography (ECT)
- External capacitors used to measure a fluid's permittivity
- Used to find the time-averaged dynamic void fraction



$$\begin{matrix} Void \\ Fraction \end{matrix} = 1 - \bar{\varepsilon}^*(t)$$

or

$$\begin{matrix} Void \\ Fraction \end{matrix} = 1 - \frac{1}{N_p}\sum_{i=1}^{Np} \varepsilon_i^*(\tilde{x}, t)$$

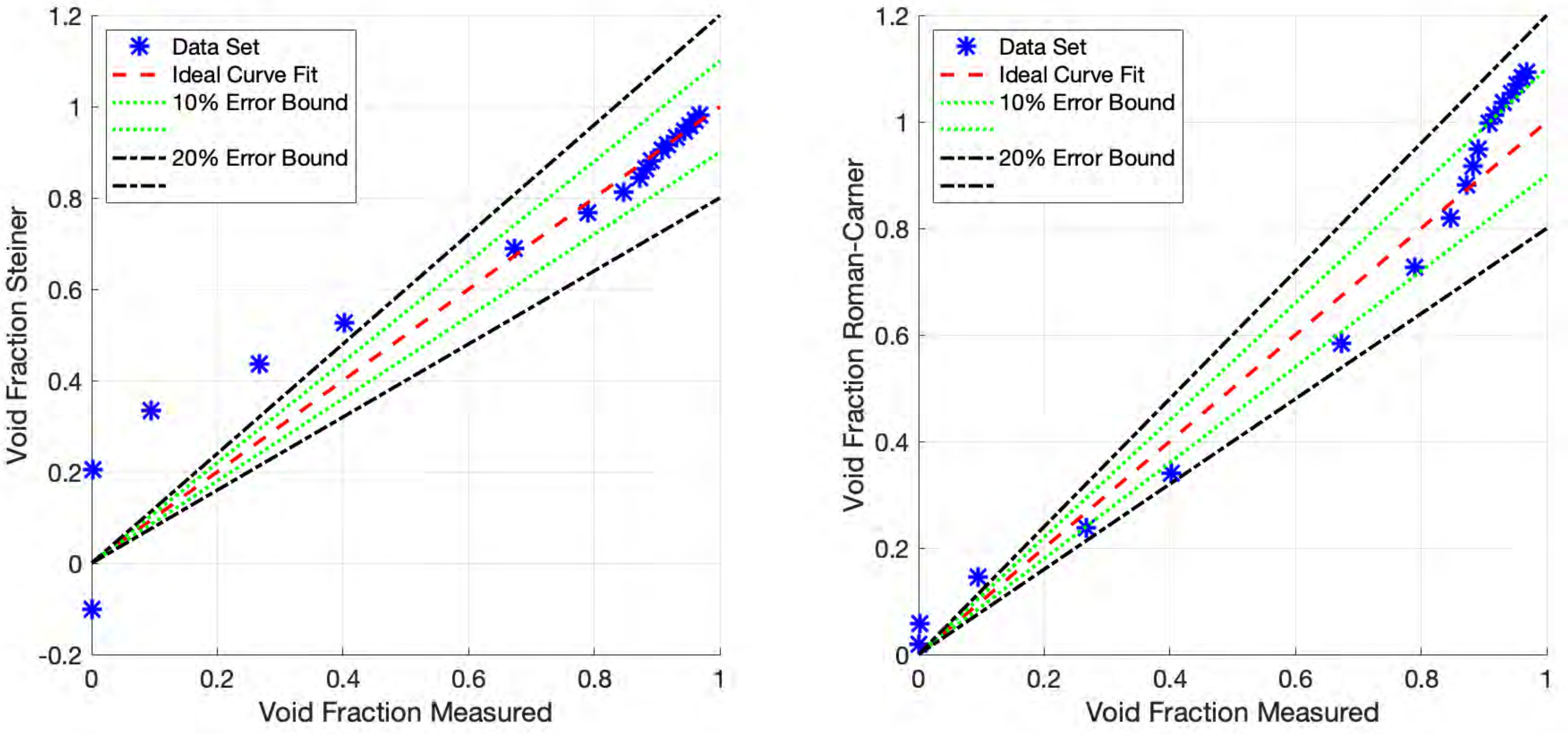


Determining Void Fraction Coefficients

- Generalized void fraction correlation form from literature:

$$\alpha = \frac{1}{1 + A\left(\frac{1-x}{x}\right)^{p}\left(\frac{\rho_G}{\rho_L}\right)^{q}\left(\frac{\mu_L}{\mu_G}\right)^{r}}$$

- Where *A*, *p*, *q*, and *r* are experimentally determined coefficients, α is void fraction, and *x* is quality.
- Steiner correlation is the best fit from existing correlations in literature
  - Left Plot
- Our correlation (Román-Carner) better fits the data
  - Right Plot
  - Fits data to within 20% error

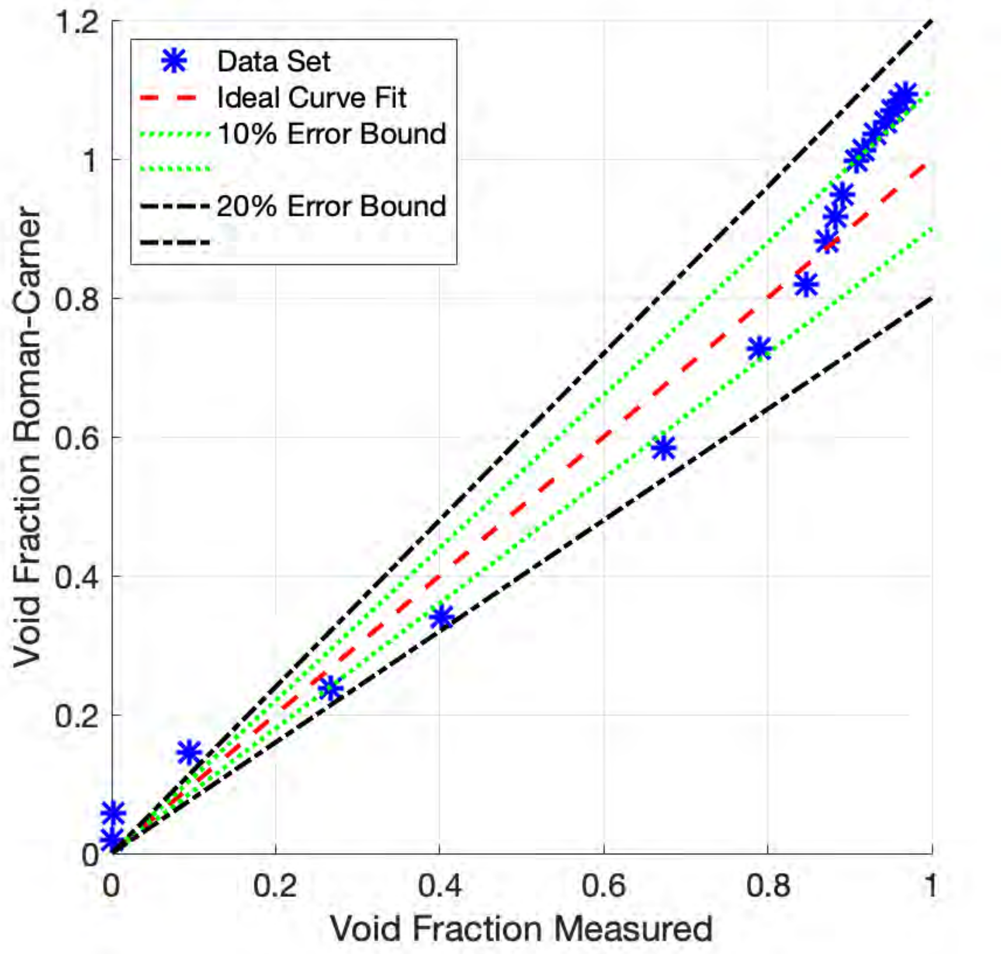


Determining Quality Correlation

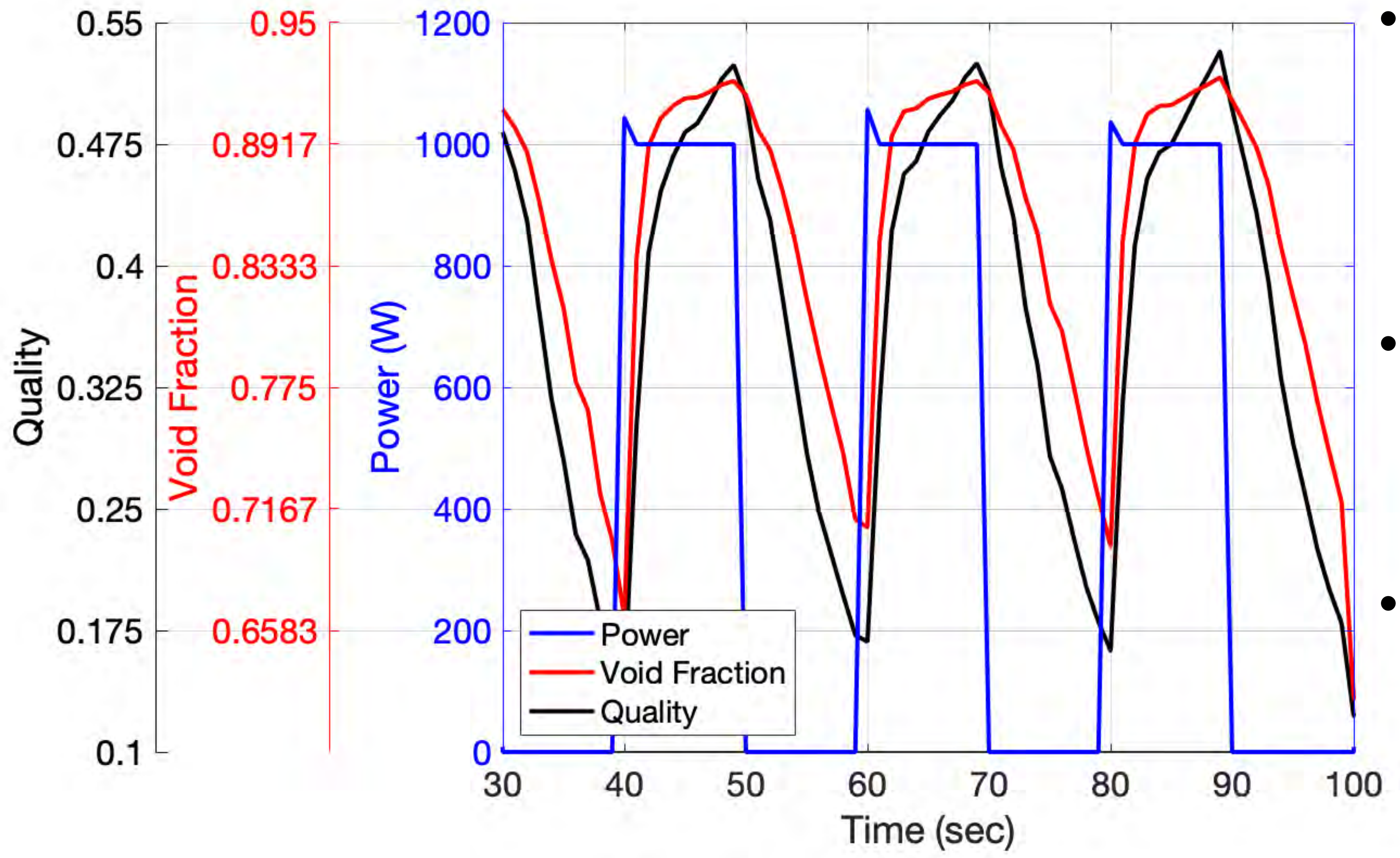
- Using the coefficients developed from adjusting the data to give a one-to-one relation between the measured and calculated void fraction, we can find quality.
- The previous equation given for void fraction can be algebraically solved for quality:

$$x = \frac{1}{1 + \frac{1}{A}\left(\frac{1-\alpha}{\alpha}\right)^{\frac{1}{p}}\left(\frac{\rho_L}{\rho_G}\right)^{\frac{q}{p}}\left(\frac{\mu_G}{\mu_L}\right)^{\frac{r}{p}}}$$

- Using this new equation for quality, we can use the measured value of void fraction, from the ECT, to predict quality while the refrigerant is in transience.



Viewing System Quality In Transience



- Using the new correlation, the value of quality is more realistic while the system is in transience.
- Behavior of quality resembles that of void fraction.
- Important to note: the value of quality does not return to zero in between pulses.

Source: U.S. Air Force Photo Gallery

Conclusion

- Using the energy balance equation to determine quality is insufficient for pulsed profiles.
- An ECT Sensor is capable of measuring void fraction at any point during the pulse profile.
- A correlation exists between void fraction and quality.
- The correlation can be rearranged to find the quality for a given value of void fraction.
- The correlation results in the development of an accurate quality profile while the flow is experiencing transience.