Temperature Control Loop Analyzer (TeCLA) Software

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15th European Workshop on Thermal and ECLS Software

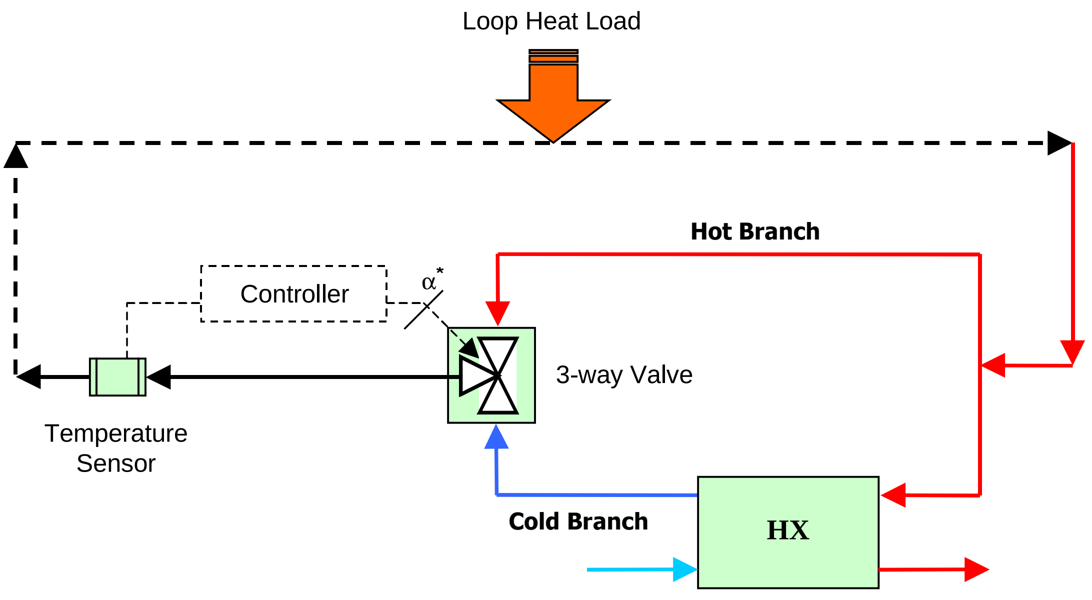
Foreword

A typical feature of an active loop thermal system is to guarantee a tight temperature range to external and/or internal users through a stable and fast control dynamics.

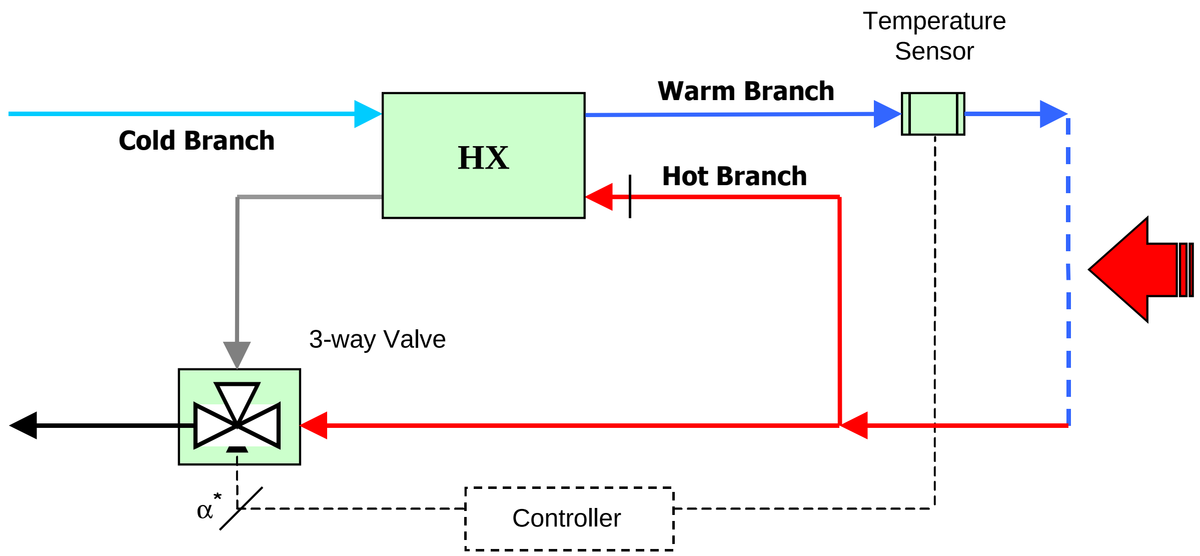
This goal is obtained through a compromise between
- stability (“bullet-proof”, relatively slow system)
- performance (reactive, potentially nervous system)

This compromise is not always possible.

Standard Temperature Control Configuration



Regenerative Temperature Control Configuration



Approaches to Stability Analysis

Method	Pros	Cons
Experimental Testing	❑ Stability directly assessed for the tested configurations	❑ Usually expensive ❑ Huge number of scenarios to be investigated ❑ Stability not guaranteed in other configurations than the tested ones
Numerical Simulation	❑ No test set-up costs ❑ Utilization of standard simulators	❑ Huge number of scenarios to be investigated ❑ Stability not guaranteed in other configurations than the tested ones ❑ Modeling uncertainties
Theoretical Analysis	❑ Extensive investigation of all the possible loop configurations ❑ Worst case identification (parametric) ❑ Possible use of robustness indicators	❑ Simplified representation of the loop

Approaches to Stability Analysis (cont'd)

A detailed analysis of the loop stability and performance has to consider the following points:

- investigation of stability based on automatic control theory (linear and/or non-linear) ➔ **[theoretical analysis]**
- choice of "optimal" and "robust" control law coefficients ➔ **[numerical simulation and theoretical analysis]**
- identification of operational worst case scenarios ➔ **[theoretical analysis]**
- simulation of transients leading to worst case scenarios (verification of stability regions) ➔ **[numerical simulation]**
- optional testing campaign focused on worst case operational scenarios (verification of stability regions and system performance) ➔ **[experimental testing]**

Node 2/Columbus Testing Experience

Examples of the experimental activity are the testing campaign on Node 2 Breadboard and on Columbus Water Loop Step IV (both carried out in the period July-August 1998) .

Some limits of the trial and error methods were highlighted:

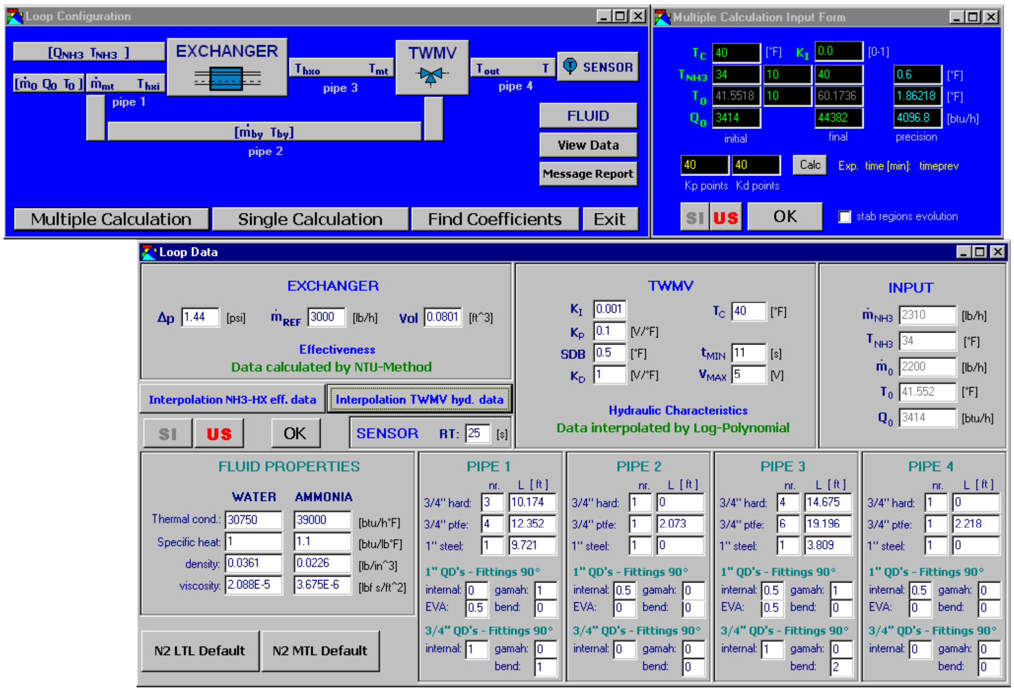
- the stability/instability assessment of the system was limited only to the tested cases;
- various sets of control coefficients were tested to investigate the influence on the system stability;
- evidence about the reliable identification of the worst case scenario was not obtained;

TeCLA Code

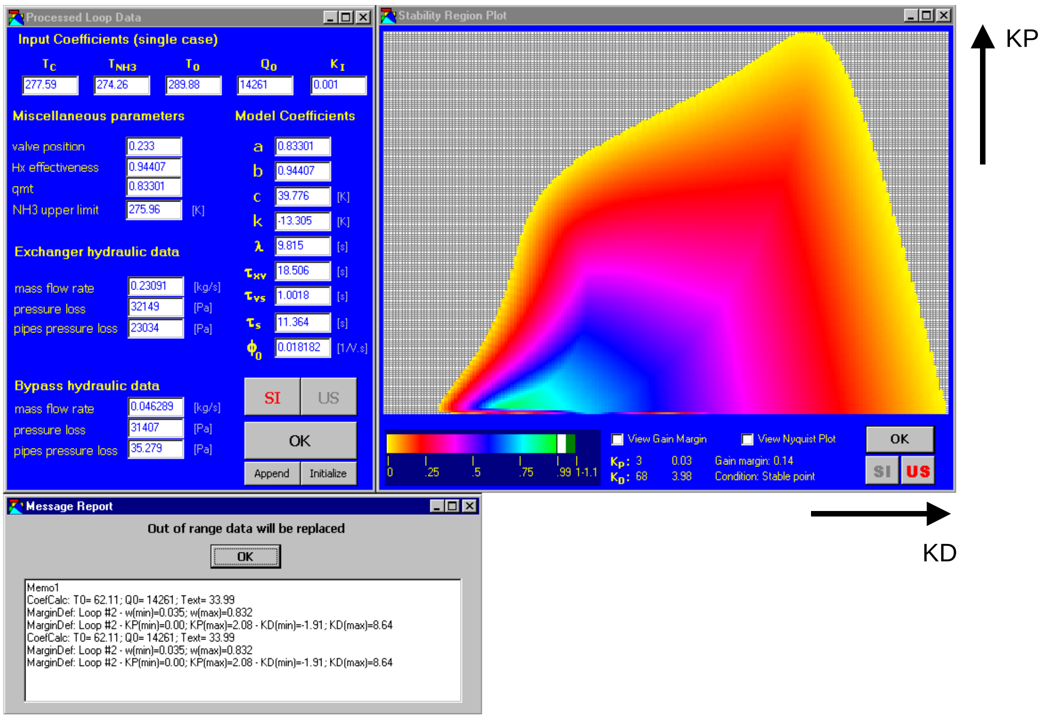
Temperature **C**ontrol **L**oop **A**nalyser (**TeCLA**) was developed by Alenia to perform stability analysis on Node 2 layout and software. The main features of the code are:

- The loop layout can be interactively inserted by the user
- 3-way and heat exchanger hydraulic and thermal data are interpolated by means of neural network
- the worst case scenario is found inside a range of operational parameters given by the user (and derived from requirements)
- stability regions in terms of controller gains are evaluated
- stability regions evaluated on the basis of Nyquist (linear) and circle (non-linear) criteria
- robustness indicators (vector, phase or gain margin) are given for each pair inside the stable zone

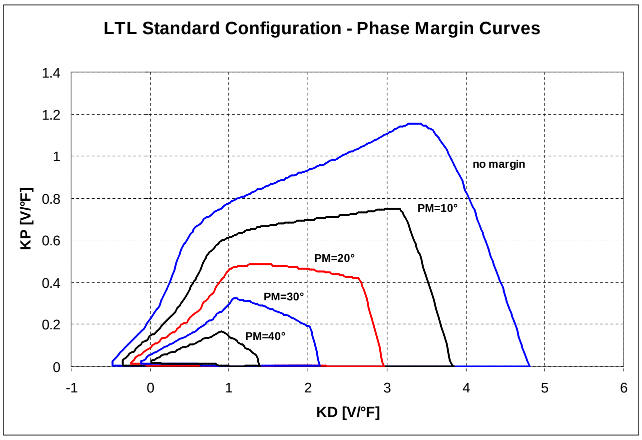
TeCLA Code - graphic user interface

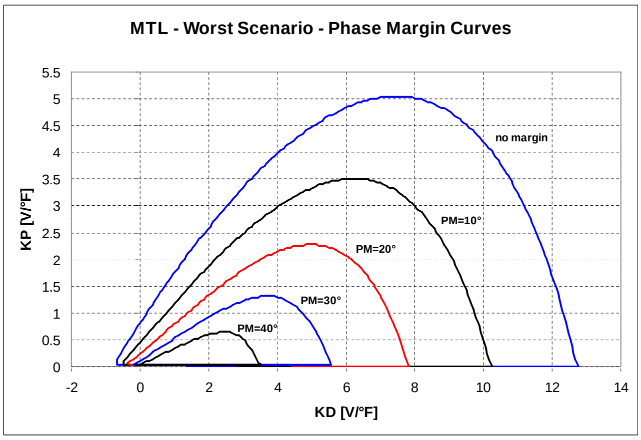


TeCLA Code - stability region screen shot



Application to Node 2 LT and MT loops
(iso-phase margin curves - standard configuration)





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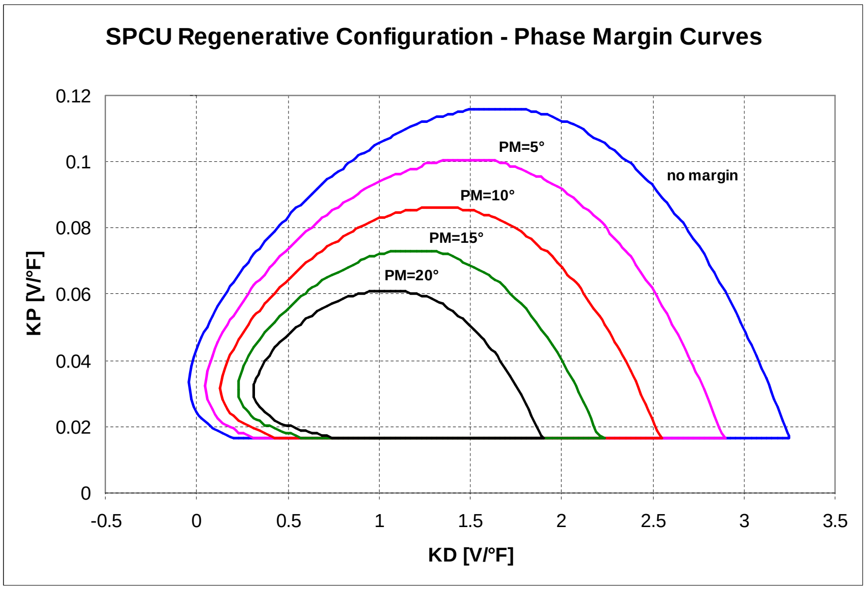
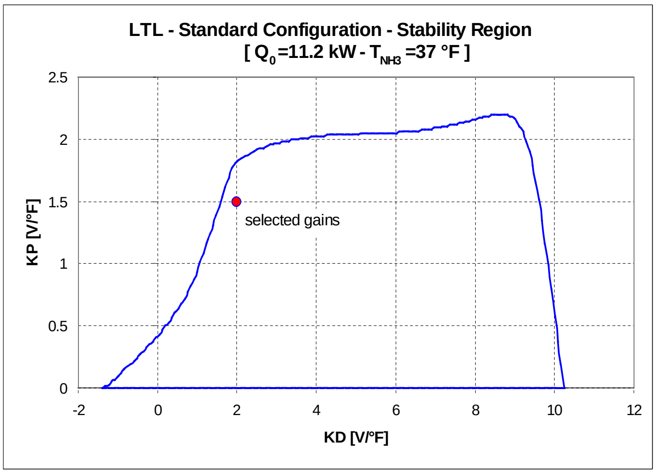
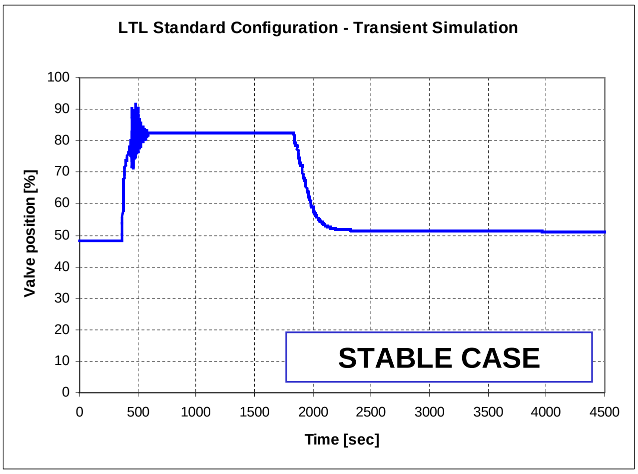
Application to Node 2 LT loop
(iso-phase margin curves - regenerative configuration)



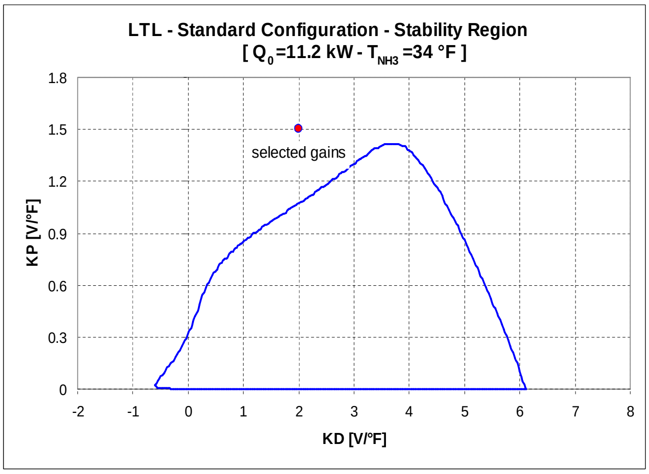
SINDA-Fluint Simulations vs. TeCLA predictions

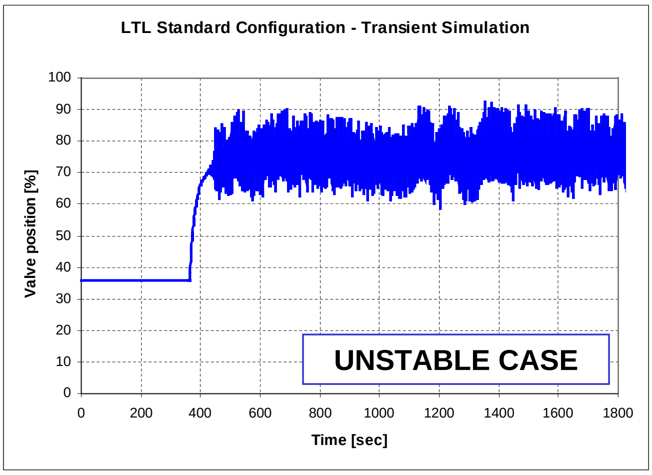




Heat variation: ± 10 kW (max injected power: 11.2 kW)
Ammonia T: 37 °F - KP = 1.5 - KD = 2 - KI = 0.001

SINDA-Fluint Simulations vs. TeCLA predictions (cont’d)





Heat variation: + 10 kW (max injected power: 11.2 kW)
Ammonia T: 34 °F - KP = 1.5 - KD = 2 - KI = 0.001

TeCLA ongoing development

The software is being updated in order to:

- cover a wider range of layout configurations (100% completed, debugging ongoing)
- cover a wider range of control laws (50% completed)
- utilize a wider spectra of stability and robustness indicators (20% completed)

TeCLA will be structured in two separate units:

- the solver (ANSI C) runs on Unix platform
- Intranet/Internet access to graphic pre- and post-processing (Java)

Development schedule:

- mid 2002

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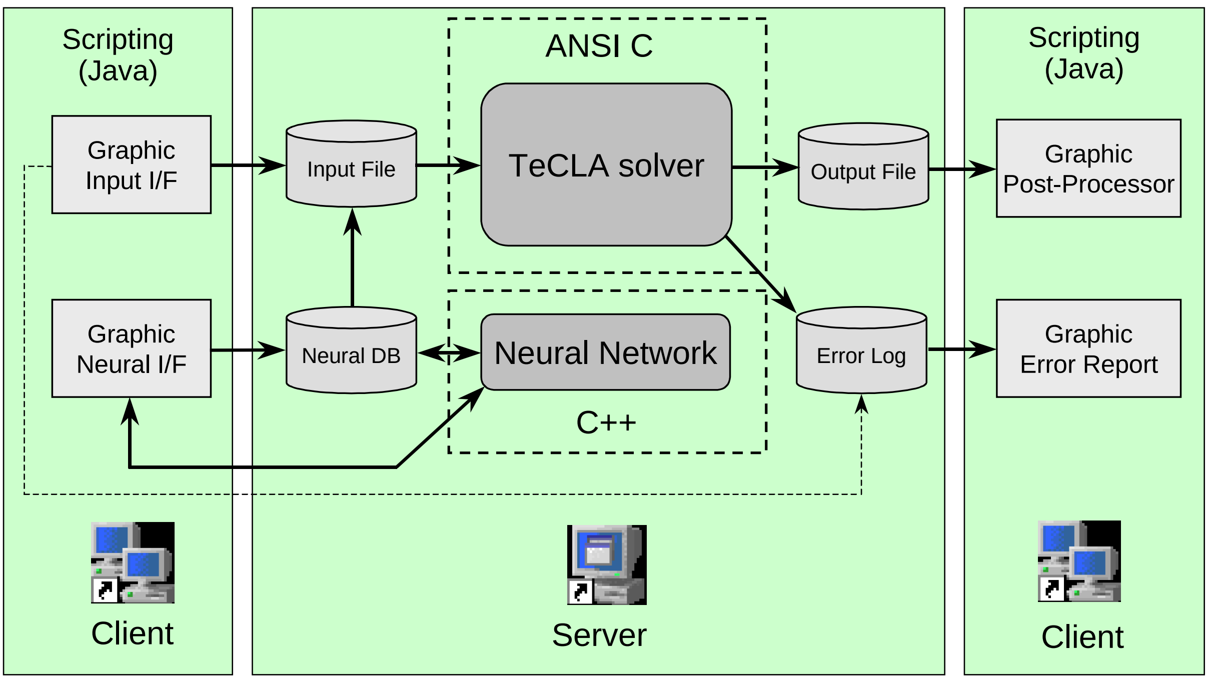
TeCLA Architecture (ongoing development)



Future Work

- Coefficient optimization:
  Insert an inverse Laplace transform routine to provide information on the system performance inside the stable region
- Mission control utilization:
  Link of the software to real-time flight telemetry to analyze off-nominal scenarios and verify the stability of the implemented control law parameters
- Extension to pressure and mass flow rate controls
- Software validation:
  In the framework of Node 2 Testing activity at integration level (if possible)

NOTE: once the Java I/F has been assessed for TeCLA, its use can be extended to develop connection tools between mission control telemetry and simulation software (SINDA-FLUINT, ESATAN-FHTS) to analyze flight transient with considerable time saving.