Unique Tracking Number Assigned by MORTS _____

RESEARCH TOPIC ACCEPTANCE REQUEST (RTAR) FORM

(2 pages suggested, 3 pages maximum)

TC/TG: 7.9 and 1.4

Title:

Improved Tools for Control Loop Performance Measurement and Evaluation

Applicability to ASHRAE Research Strategic Plan:

This research will help achieve ASHRAE strategic goals in the following areas:

A. Energy and Resources: A6. "Develop integrated, best practice design methods…"

A7. "Develop evaluation methods that will allow reduction in energy…"

Possible Research Projects: Building and Systems Operation – "Continue development of standards and measurement techniques for performance" and "Develop optimized, reliable and practical control and diagnostic techniques."

C. Tools and Applications: C4. "…system to establish the environmental performance…"

Possible Research Projects: Performance Evaluation Tools – "Assess the performance benefits of system and component improvements" and Performance Metrics – "Develop methods to measure performance & verify design ratings."

D. Equipment, Components and Materials

Possible Research Projects:

Sensors and Controls – "Develop specifications for properly selecting sensors and systems based on performance…."

Equipment – "Develop performance rating systems for HVAC&R equipment".

Research Classification: TC/TG Priority:

Applied Research and Advanced Concepts

TC Vote: Reasons for Negative Votes and Abstentions:

TBD (Abstentions)

Estimated Cost: Estimated Duration:

$100,000 24 Months

Other Interested TC/TGs:

TC1.4 is co-sponsor

Possible Co-funding Organizations:

N/A

Application of Results:

- ASHRAE may be able to obtain intellectual property rights for the development of automated performance monitoring methods and license the methodology.
- Improve *ASHRAE® Guideline 11, Field Testing of HVAC Control Components*. Possibly later, establish an ASHRAE® Standard for closed loop control performance.
- The *Fundamentals* Handbook, *Fundamentals of Control* chapter (chapter 15) will benefit considerably from this research. Currently, there is no information on quantitative methods of measuring control performance.

- The *Applications Handbook* will benefit: Chapter 37.16 – *Testing, Adjusting and Balancing – Temperature Control Verification,* and Chapter 42.8 – *New Building Commissioning – Commissioning During Construction – Testing and Verification.* Neither section has any information about control loop tools or quantitative methods of measuring control loop performance.
- This research can help advance HVAC control Fault Detection and Diagnostics by using quantified loop performance data as benchmark information for later determining system deterioration and abnormalities.

State-of-the-Art (Background):

"The HVAC&R industry has frequently approached the problem of tuning control loops informally."[1] It does not have standard methodologies to verify that a control loop is tuned or is performing well. Descriptions of the state of tune of a control loop are often subjective. For example, the May 2007 Public Review Draft of the proposed *ASHRAE® Guideline 11, Field Testing of HVAC Control Components*, under PI Loop Tuning Checkout, suggests the following:

> "Observe the results and note the time between oscillations, the number of oscillations, and the approximate amount of actuator movement with each oscillation." "Continued oscillation, increasing amount of movement with each oscillation, or failure to move at all indicate need for tuning."

Reference 1, *Teaching Improved Methods of Tuning and Adjusting HVAC Control Systems,* reinforces the subjective nature of the tuning data analysis by stating:

- Current analysis is a graphical hand analysis
- Excel or MathCAD for further automation of analysis procedure

Procedures such as these can be highly labor intensive, and subject to human error and subjective interpretation. For example, the "time between oscillations" can be long for space temperature loops, and "continued oscillation" means how many oscillations?

The process control industry employs these common performance methods: ISE~~A~~ (Integral of the Square Error), IAE (Integral of the Absolute Error) and ITAE (Integral of the Absolute Error multiplied by Time). But these have not seen widespread use in the HVAC&R industry.

There are proprietary tools available to tune loops, but each of these tools tunes to its own standard of performance. There is no standard within the HVAC industry to which all of these tools can be compared or specified.

Determining when a control loop needs re-tuning is not always obvious. Small changes in load may result in poor control only for short intervals (during startups or disturbances) but can have a significant cumulative effect. Catching these moments using recorded data can be difficult, as can comparing performance to previous data. Automating standardized performance tools can provide continual monitoring of a loop's state of tune.

Advancement to the State-of-the-Art:

ASHRAE-approved automated performance measuring tools will reduce commissioning time and re-commissioning time by 90% because the user can instantly identify which loops are operating correctly and which are not. Time can be spent more productively, on loops that have problems, not on verifying that good loops are good.

Justification and Value to ASHRAE:
Most commissioning professionals and controls contractors will be impacted. The industry will welcome guidance on closed-loop control. Tools to objectively evaluate control loop performance will be quickly adopted and may result in the actual *specifying* of closed loop

performance. 80% of the professionals involved with closed loop control will be impacted within 5 years. ASHRAE may be able to obtain intellectual property rights for the development of automated performance monitoring methods.

Fair, objective methods to evaluate loop performance will encourage new technologies (auto-tuning, fuzzy logic, model-based, model-free, neural networks and pattern recognition) to come forward and be compared to each other (and to PID) on a level field, rather than by perceptions or prejudices. In this way ASHRAE can help move closed loop control forward without favoring any one technology.

Objective:

The objectives of this project are:

1. Generate a reference list of information on the research subjects through a literature study.
2. Develop or define HVAC closed loop control performance measurement methods that are objective, quantitative and capable of being automated. For example, the methods could output numerical values (e.g.: 1 to 10) that can be compared to established standard values for various levels of performance (~~good, fair, or poor~~poor to excellent).
3. Define objective criteria for evaluating the loop performance measurement data that comes from the EMCS. For example, if the method defines the overshoot on startup, define criteria for good, fair and bad performance (e.g.: good is +/- 10°F for discharge air temperature control; bad is greater than +/- 25°F; fair is between 10°F and 25°F).
4. Define a method for automatic operation of the measurement methods, so that they can run continuously and data can be extracted without interrupting the measurement process. The methods could be described as sequences of operation or flow charts for coding in any language in any programmable controller. Hopefully, the sequences will be short and efficient.
5. Propose how the performance measurement values can be used to diagnose specific loop control problems (both catastrophic and gradual deterioration).
6. Evaluate the performance measurement methods by applying them to a variety of HVAC control loops in existing buildings.
7. Report on how well the performance measurement methods identified well controlled loops and poorly controlled loops. Document how this was determined and if loop problems could be diagnosed by analyzing the performance measurement values. (This information can help propose diagnostic tools for the future.)
8. Recommend in what areas future research on the above subjects is necessary.

Key References:

1. Teaching Improved Methods of Tuning and Adjusting **HVAC** Control Systems
www.**hvac**rcool.org/pdfs_docs/asee_chi.ppt

2. Analysis and auto-tuning of supply air temperature PI control in hot water heating systems
Bin Zheng, *University of Nebraska - Lincoln*
http://digitalcommons.unl.edu/dissertations/AAI3243742/

3. Hittle, D. C. 1997. Dynamic response and tuning. Supplement to *ASHRAE Journal*, Sept.: p. 40

4. Rosandich, R. 1997. Understanding controllers and control terminology. Supplement to *ASHRAE Journal*, Sept.: 22-25.

5. Edgar, Thomas F., 2007, Performance monitoring and tuning controllers, *Control Engineering*, May, p32.

6 Kaya, A, Scheib, T.J.,1988, Tuning of PID of Different Structures, *Control Engineering*, July, p. 62-65.

7. Gerry, John P., 1988, Find out How Good That PID Tuning Really Is, *Control Engineering*, July, p. 69-71