AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.
1791 Tullie Circle, N.E./Atlanta, GA 30329
404-636-8400

TC/TG/MTG/TRG MINUTES COVER SHEET

(Minutes of all Meetings are to be distributed to all persons listed below within 60 days following the meeting.)

TC~~/TG/MTG/TRG~~ No. 6.1 DATE August 8, 2016

TC~~/TG/MTG/TRG~~ TITLE Hydronic and Steam Equipment and Systems
DATE OF MEETING June 28, 2016 LOCATION St. Louis, MO

MEMBERS PRESENT	YEAR APPTD	MEMBERS ABSENT	YEAR APPTD	EX-OFFICIO MEMBERS AND ADDITIONAL ATTENDANCE
Niels Bidstrup (non-quorum)	2015			
Scott Fisher	2015			
Larry Konopacz	2015			
David Lee	2015			
Frank Myers	2013			
Thomas Neill	2014			
Donald Prather	2013			
Rex Scare	2015			
Steve Tredinnick	2015			
Robert Walker	2015			

DISTRIBUTION

All Members of TC/TG/MTG/TRG plus the following:	
TAC Section Head:	Mark C. Hegberg
TAC Chair:	Dr. Thomas M. Lawrence
All Committee Liaisons As Shown On TC/TG/MTG/TRG Rosters:	ALI/PDC – Cameron R. Labunski Chapter Tech. Transfer – Maggie Moninski Research – Harvey M. Sachs Special Pubs - Standard – Cyrus H. Nasseri 2016 HB Systems - Forrest S. Yount 2017 HB Fundamentals – Van D. Baxter
Manager Of Standards Manager Of Research & Technical Services	Stephanie Reiniche Mike Vaughn

1. **Call to Order:**
   Chair Scare called the meeting to order at 1:00pm. Chair Scare welcomed all in attendance and self-introductions were made. An attendance sheet was passed and signed by those in attendance. A roll call of voting members was conducted and a quorum was present with 9 of 10 voting members. One additional voting member arrived at 1:08pm. One voting member left the meeting at 1:19pm.

   Technical Committee 6.1 is concerned with all aspects of hydronic and steam systems. This includes the application of boilers, chillers, terminal units, and all accessories and controls making up the total system as well as the design of the integrated system. In addition to comfort applications of both heating and cooling, snow melting systems are included. Cooperation with other TCs is recognized in areas such as control, noise and vibration, refrigeration, pumps and hydronic and service water piping.

2. Setting of the Agenda:
   The Chair passed out an updated Agenda. Motion by Don Prather, second by Niels Bidstrup. Approved 8-0-1-1 CNV.

3. Approval of Orlando Meeting Minutes:
   Motion by Donald Prather, second by Niels Bidstrup to approve the past meeting minutes. Motion passed 8-0-1-1 CNV.

4. Recognition of Liaisons:
   Aykut Yilmaz (AHRI) present, no report.

   Harvey Sachs (Section 6 Research Liaison) was present. He thanked all for their participation. He stated RAC is interested in RTARs with multiple TC sponsorship.

   No other liaisons were present.

5. **Chair's Report**
   Vice Chair Scare summarized the key items from the Section 6 Breakfast.

   (a) Any TGs, TRGs and MTGs need confirmation if they are continuing into 16-17 Society Year. We only have MTG-O&MEE which hasn't started yet.
   (b) New position e-mail alias addresses are created for each of the mandatory positions of the TC.
   (c) TAC Manual of Procedure has been reorganized and is posted on www.ashrae.org/TCs.
   (d) A new TAC Presentation template is available on the Technical Committee page of the ASHRAE website for TC members to use in presentations to their local chapters.
   (e) Basecamp is an online collaborative tool available to the TC for online meetings.
   (f) Starting in Las Vegas presenters with presentations not uploaded by the deadline will incur a 'strike' in a 3-strike policy. Once three strikes have accrued, the speaker will not be allowed to speak for up to one year.

(g) Committee members will be receiving an email offering a ‘thank you’ letter for their service to be sent to their employer.
(h) A new TAC Presentation template is available on the Technical Committee page of the ASHRAE website for TC members to use in presentations to their local chapters.
(i) The Professional Development Committee (PDC) is seeking ideas for new ASHRAE Learning Institute (ALI) courses.
(j) 2016-17 Hightower Award & Service nominations are due by September 1.
(k) CEC announcing a call for reviewers for the 2017 Winter Conference and beyond. Contact Tiffany Cox tcox@ashrae.org is you are interested.
(l) ASHRAE Journal is looking for strong technical articles for the practicing engineer. Abstracts should go to jscott@ashrae.org.
(m) ASHRAE Insights is looking for articles on examples of chapter programs to give other chapters ideas on how to engage their members. Send to jscott@ashrae.org
(n) A new web application from ASHRAE automates the calculations to show a building project’s compliance with ASHRAE/IES Standard 90.1-2010 using the Energy Cost Budget Method. Learn more at 901ECB.ashrae.org.

6. Sub-Committee Reports

A. Programs: David Lee (Chair). Subcommittee meeting minutes of June 27, 2016, are attached.

No seminars at this conference, but TC 6.1 is co-sponsoring Seminar 53 Smart Equipment: the Intelligent Buildings Revolution Is Happening in the Edge with TC 1.4.

Three seminars are being proposed for Las Vegas (the deadline is August 8).

B. Research: Tom Cappellin (Chair). Subcommittee meeting minutes of June 27, 2016, are attached.

C. Handbook: Bob Walker (Chair). Subcommittee meeting minutes of January 26, 2016, are attached.

New collaborative tool for Handbook Chapter review will be available at authoring.ashrae.org. If you are a member of the TC, you will have access to the Handbook for editing.

Motion by Bob Walker, second by Don Prather to accept Chapter 22 – Pipe Design. Motion passed 7-0-2-1 CNV.

The Handbook is going to a new collaborative tool (authoring.ashrae.org) for online editing of the chapters on line in a Word format.

D. Chilled Water Sub Committee: Steve Tredinnick (Chair). The Sub-committee met on Sunday January 26, 2016.

Chair Tredinnick reported very little progress on the new chapter since the Orlando meeting. He is still looking for co-authors for the chapter. The Committee is awaiting confirmation from Handbook Liaison Forest Yount has set up the new folders in the new Online Tool for Collaborative Content Development.

E. Membership: Larry Konopacz (Chair). Chair Konopacz reminded all to update their member profiles, especially their e-mail addresses.

F. Standards: Mike O'Rourke (Chair). Chair O'Rourke was not in attendance.

Aaron Stotko (aaron.stotko@uponor.com) discussed talks of resurrecting ASHRAE Standard 152 with TC 6.1 working with TC 6.5. Contact Aaron if interested on working on this.

Frank Myers reported 90.1-2016 version is complete and expected to be available in Las Vegas with a single column format.

Frank Myers also reported SPC 155 has been voted out of committee and is going ro advisory public review.

G. Professional Development (ALI).
Don Prather states there is no ALI, thus this position should be deleted.

H. Web: Jessica Mangeler (Webmaster). Webmaster Mangler stated she is looking at using Google Analytics to track visits to our website.

7. Liaison Reports from other TC's and Organizations.

Don Prather (donald.prather@acca.org) (ACCA) reports the ACCA Radiant and Hydronics Council has a member on the west coast who prepares questions for the California Contractor Boiler Exam. If any member has a suggestion for a question, pass it along to Don for consideration.

Aaron Stotko (aaron.stotko@uponor.com) (TC 6.5) suggested possible co-sponsorship or programs between TC 6.5 and TC 6.1.

Scott Fisher (Handbook) encourages all members participate with the revisions to the Handbook Chapters. One does not need to be a member for this. The Chair stated more examples are needing in all the Handbook Chapters.for participating with the Handbook. One does not have to be a voting member. $5 M to spend on refrigerant research. The Chair more examples are needed in all the Handbook chapters.

Jason Atkisson reminded all that many new MTGs are being formed. A member can sign up for a MTG through the ASHRAE website.

8. Old Business:

(a) MTG-O&MEE – Operations and Maintenance Activities. Jason Atkisson was told from the Chair of this MTG nothing has been done, no meetings have been scheduled, and no meeting was held in St. Louis. Says there will be a meeting in Las Vegas.

(b) SPC 208 – Method of Test for Determining Hydronic System Balance Valve Capacity. Mark Hegberg was not present . Viral Dharaiya stated there is a meeting scheduled for July 15 to review the SPC.

9. New Business:

(a) ASHRAE Residential Building Committee (RBC). Robert Bean (warmfloors@shaw.ca) discussed new committee and its function. Asked for new members to participate. 56 Seminars on Residential at this conference. Meets on Sundays and Mondays at future meetings. If you are interested in joining this committee e-mail Robert k9cave@gmail.com.

(b) TC Survey for ASHRAE Standards. Chair Scare reported on the survey results. 17 survey respondants feel ASHRAE should pursue new standards, 11 were uncertain, 1 said no. Chair Scare reviewed many of the suggestions. Majority of the respondents were uncertain if any standards, guidelines or MOTs should be withdrawn. All respondants gave ASHRAE products at least a good rating (4); very good (15) and excellent (9). 13 respondants report they use ASHRAE Standards, 6 use Guidelines, 4 use MOTs, 3 use ISO and 1 uses ICC codes.

(c) Minutes for this meeting are available on the ASHRAE website. A link will be sent to the membership when they are posted.

10. Meeting Adjournment:

Motion by Frank Myer, second by Thomas Neill to adjourn the meeting. Motion passed 8-0-1-1 CNV. Meeting adjourned at 2:09pm.

Submitted by,
Bob Walker.
TC 6.1 Secretary

ASHRAE Shaping Tomorrow's Built Environment Today

TC Sign-in Sheet

Meeting Info: TC 6.1 Committee Meeting Date: 6/28/16

Name	Affiliation	E-mail	Member (Voting, Corresponding, or Guest?)	YEA Member? (Yes/No)
Larry Konopacz	Xylem-Bell&Gossett	larry.konopacz@xyleminc.com	VM	No
ART GIESLER	PERMAPIPE	ART.GIESLER@PERMAPIPE.NET	CM	No
Ryan Mallory	UPonor	Ryan.Mallory@uponor.com	Guest	No
Tom Cappellin	Cappellin Consulting	tcappellin@msn.com	Research Ch.	No
Scott Fisher	State Farm Retired	Sfishbmi@gmail.com	VM	No
Aaron Stotko	Uponor	aaron.stotko@uponor.com	CM	Yes
Aykut Yilmaz	AHRI	ayilmaz@ahrinet.org	CM	Yes
DENNIS MANTHEI	MULTISTACK LLC	dmanthei@multistack.com	GUEST	NO
JENNIFER LEACH	PATTERSON-KELLEY	pennst8jen@yahoo.com	CM	NO
Mehdi Doura	Lochinvar	mdoura@lochinvar.com	CM	NO

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Name	Affiliation	E-mail	Member (Voting, Corresponding, or Guest?)	YEA Member? (Yes/No)
Steve Tredinnick	Burns + McDonnell	stredinnick@burnsmcd.com	VM CHW Plant SUS-Com	N
Rex Scare	Armstrong International	Rexse Armstronginternational.com	VM chair	N
Bob Walker	Belimo	robert.walker @us.belimo.com	VM Secretary	N
Don Prather	ACCA	donald.prather@acca.org	VM	N
DAVID LEE	ARMSTRONG FLUID TECHNOLOGY	dlee@armstrongfluid technology.com	VM	N
JASON ATKISSON	AEI	jatkisson@aeieng.com	vice chair	N
NIELS BIDSTRUP	GRUNDFOS	nbidstrup@grundfos.com	VM	N
JESSICA MANGLER	AEI	jmangler@gmail.com	Webmaster	Y
Hooman Daneshmand	PRO Hydronic	hooman.daneshmand@gmail.com	C.M.	Y
THOMAS NEILL	MESTEK	tneill@mestek.com	VM.	N

TC 6.1

6/28/16

Name	Affiliation	E-mail	Member (Voting, Corresponding, or Guest?)	YEA Member? (Yes/No)
STAN KUTIN	XYLEM INC.	STAN.KUTIN@XYLEMINC.COM	GUEST	N
Andrew Koppi	UPONOR INC	andrew.koppi@uponor.com	Guest	N
Scott Hellendrung	Uponor	Scott.hellendrung@Uponor.com	Guest	N
Chris Haldiman	Watts Water Tech.	chris.haldiman@wattswater.com	Guest	N
Bobby Gunter	Bekaert	Bobby.Gunter@bekaert.com	Guest	N
Viral Dharaiya	Hays Fluid Controls	viral.dharaiya@haysfluidcontrols.com	Guest	N
Harvey Sachs	ACEEE RAC Liaison	RL6@ashrae.net	Guest	N
Frank Myers	The Meyers Group	fmyers@ix.netcom.com	VM	Y

Name	Affiliation	E-mail	Member (Voting, Corresponding, or Guest?)	YEA Member? (Yes/No)
Albert Black	McClure Engr	ablack@mcclureeng.com	C or G	N
Erin Black	William Tao	eblack@wmtao.com	Guest	N
Mick Schwedler	TRANE	mschwedler@trane.com	CORRESPONDING	N
CHRIS HAWS	INTERTEK	CHRIS.HAWS@INTERTEK.COM	GUEST	N

TC 6.1 Program Subcommittee Meeting - Minutes:

June 27, 2016

Attendees:

David Lee, Armstrong Fluid Technology – Program Subcommittee Chair
Larry Konopacz – Xylem
Stan Kutin – Xylem
Jason Atkisson – AEI
Bob Walker, Belimo
Rex Scare, Armstrong International
Ryan Mallory, Uponor
Gang Wang, University of Miami
Hooman Daneshmand, PRO Hydronic
Jennifer Leach, Patterson Kelley
Mark Hegberg
Albert Black, McClure Engineering

Minutes:

- No seminars submitted by TC 6.1 for St. Louis conference
- 1 Seminar to be co-sponsored for St. Louis conference:
  - Seminar 53 - Smart Equipment: The Intelligent Buildings Revolution is Happening in the Edge! (TC 1.4)
    - Chair: Marcelo Acosta
- 3 Seminars to be submitted for Las Vegas conference (Aug 8 deadline)
  - Hydronic Commissioning - Chair: Tom Capellin, (co sponsor TC7.9) Speakers: David Cohen, Stephen Wiggins
  - Valve Sizing and Selection - Robert Walker with TC-1.4 Jim DelMonaco, Tricia Bruenn
  - ASHRAE Code Update For Hydronic System Design - 90.1- 2016 and DOE regulation on pumps, compared to EU- Chair: David, Niels, Larry Konopacz
- Conference Paper Abstracts for Las Vegas (**TBA**)
  - Comparison of Pumping Systems – Variable Primary Flow vs Constant Primary-Variable Secondary vs others - Evans J Lizardos
- Proposed papers for Long Beach conference:
  - Sequencing Control of Parallel pumps in Variable Flow Systems – Gang Wang (technical paper)
  - Impact of Multiple Parallel Pumping Arrangements for Large Chilled Water Systems - Jason Atkisson (conference paper)
  - Hydronic system control valves - Mark Hegberg (conference paper)
  - Underground jacketing of single vs multiple pipes - Aaron Stotko conference paper
- Proposed seminar for Long Beach conference:
  - PEX piping for chilled water and hot water instead of copper/steel, types of pipe fittings - Ryan Mallory
  - Geothermal sizing and selection for residential - Larry Konopacz

    - Pipe Thermal Expansion Design - Bryson Borzini co-sponsor TC6.2, TBA combine with underground piping jacketing of single vs multiple (Aaron Stotko has research paper)

Key Dates for Las Vegas conference:

- Technical Papers for Las Vegas due April 18, 2016
- March 14, 2016 - Conference Paper abstracts due
- April 18, 2016 - Technical Papers Due
- April 4, 2016 - Conference Paper abstract accept/reject notifications
- June 6, 2016 - Website opens for Seminar, Forum and Workshop proposals
- July 6, 2016 - Final Conference Papers submitted for review (includes bio, learning objectives and methods of assessment)
- August 8, 2016 - Seminar, Forum and Workshop proposals due
- September 7, 2016 – Seminar, Forum Workshop accept/reject notifications

Other:

- Best approaches to getting programs approved. Technical papers are given 1st priority followed by Conference papers. Technical papers do not go through CEC. Seminars are the most competitive due to high number of submissions. If proposed program falls into one of the conference tracks (other than Fundamentals/Applications or Systems/Equipment), likelihood of acceptance is higher.

ASHRAE TC 6.1 Technical Committee

Hydronic and Steam Heating Equipment and Systems

Research Subcommittee Meeting Minutes

Marriott St. Louis Grand Hotel

3:15pm to 4:15pm - Monday, June 27, 2016

Discussion and Activity Notes:

1. Notes from the Research Subcommittee Chair's Breakfast are attached to these minutes.
2. This subcommittee meeting was attended by guest Steve Taylor, representing TC 1.4 *Control Theory and Application.* Steve asked for TC 6.1 to consider co-sponsoring TC 1.4's Work Statement 1454-WS titled *Control Valve Selection for Improved Controllability.* A copy of this work statement is attached to these minutes. The pros and cons of this work statement's viability were debated by Steve Taylor (pro) and TC 6.1's Mark Hegberg (con) who provided the subcommittee with a detailed narrative and slide presentation. The debate ended with a vote by the subcommittee to work with TC 1.4's endeavors to advance the work statement to RAC for approval.
3. Steve Taylor provided a copy (via previous E-mail) of TC 1.4's approved RP-1587 *Control Loop Performance Assessment* for TC 6.1 members to review. This is a lengthy report (over 150 pages) so this chair has attached a copy of the report's executive report and conclusions to these minutes.
4. TC 6.1 has agreed (during the Orlando conference) to participate in in bid evaluation of TC 1.4's 1711-RTAR which has been approved by RAC to move into RFP status. This project is titled *Advanced Sequences of Operation for HVAC Systems, Phase II Central Plants and Hydronic Systems.* TC 6.1 members who have volunteered to participate, on TC 6.1's behalf, are Jason Atkisson, Hooman Daneshmand, and Mark Hegberg. This RTAR is presently on hold and awaiting further contact from TC 14 when it is ready to proceed towards publish for bid.
5. Unfortunately, discussion on the above items consumed the time period allotted to this subcommittee, so there was not sufficient time to discuss additional agenda business.

End of Minutes:

Minutes prepared by Thomas E. Cappellin, Chair of TC 6.1 Research Subcommittee

Attachments: RAC Saint Louis Update Notes
1454-WS Control Valve Selection for Improved Controllability
RP-1587 Control Loop Performance Assessment

ASHRAE RP-1587 Control Loop Performance Assessment

Final Report

Prepared for
Project Monitoring Subcommittee
ASHRAE Technical Committee TC 1.4
Control Theory and Application

Principal Investigator: Zheng O'Neill, PhD, PE
Co- Principal Investigator: Keith Williams, PhD
Research Assistant: Yanfei Li, Aaron Henry
The University of Alabama

Field Testing: Ran Liu, PhD, Xiaohui Zhou, PhD, PE
Iowa Energy Center

June 2016

Executive Summary

This is the final report for the control loop performance assessment project sponsored by ASHRAE. In this project, two single control quality factors (CQFs) in the context of building heating, ventilation and air-conditioning (HVAC) controls were developed and tested. These CQFs need to be objective, quantitative metric with simple-to-interpret criteria; additionally, they need to use only typically available data from HVAC control systems, such as the control loop output.

An extensive review of control loop performance assessment in various industries reveals that few studies are available to assess HVAC control loop performance. We systematically reviewed 35 indices and their associated methods of evaluating control loop performance, including their drawbacks and merits. Fourteen of these indices were selected to assess their performance on an air handler unit (AHU) heating coil outlet air temperature control loop using simulated data from a dynamic Modelica model. Based on the review and preliminary simulation results, two CQFs — the normalized Harris Index and Exponential Weighted Moving Averages (EWMA) — were recommended for further investigation. The first CQF (i.e., CQF-Harris) is based on the normalized Harris Index, together with a reversal index that detects control response trend reversal behaviors. The second CQF (i.e., CQF-EWMA) is the EWMA-based index along with the reversal index.

A CQF scale was developed to categorize HVAC control loop performance: excellent (A), good (B), fair (C), bad (D), and fail (F). For CQF-Harris, the scale is based on the ratio of control output variance to the minimum variance. For CQF-EWMA, the scale is based on the dimensionless error ratio between control output and the set point. The scale ranges are also given for the two CQFs. The proposed CQFs were implemented on simulated HVAC control loops through offline testing. A total of 16 simulated control loops (two sets) were assessed based on data from Modelica models. The first set of models is for the AHU heating/cooling coils. The

second set of models is for the dynamic VAV system with room models. This offline testing shows that the proposed CQFs can assess control loop performance with correct scales. Sensitivity analyses were conducted for CQF-Harris with respect to unmeasured disturbance (i.e., white noise) variance, moving window length, and sampling frequency. The results show that CQF-Harris is sensitive to unmeasured disturbance variance and to the length of the moving window, although it is less sensitive to the sampling frequency. The sensitivity analysis was also conducted for the CQF-EWMA with respect to the sampling frequency and unmeasured disturbance variance, and the results show that it is not sensitive to these two parameters.

The proposed CQFs were also tested using data from real control loops. A total of 213 real control loops were tested in six data sets. These loops covered VAV room air temperature control, AHU supply air temperature control, AHU static pressure control, water loop differential pressure control, and VAV airflow control, etc. The first four sets are from an office building in Chicago, Illinois. The fifth set is from the Iowa Energy Center's Energy Resource Station. The sixth set is from a classroom and laboratory building on campus at the University of Alabama. The test results show that the both CQFs are effective in assessing control loop performance. The assessments using these two indices are aligned with each other for the majority of the test cases.

Furthermore, sensitivity analyses for the real VAV control loops were conducted with respect to sampling frequency and length of the moving window. From the results, it is recommended that a moving window length of 80 or 100 minutes (i.e., 20 samples with a sampling frequency of four or five minutes) be used for VAV control loops. A weighted CQF for an evaluation of the averaged control loop performance over a given assessment time period is also proposed for the two CQFs with applications for real control loops.

Real-time field-testing with actual HVAC system and local VAV controllers were conducted at the Iowa Energy Center's Energy Resource Station. Both single maximum and dual maximum control logics were tested. Both proposed CQFs were able to be successfully programmed and downloaded to four real DDC (direct digital control) local controllers. The real-time CQFs values are consistent with those from offline Matlab computations. However, the effort in implementing CQF-Harris index was quite involved, and required significant computational resources for the controllers. It is recommended to adopt the CQF-Harris index for DDC controllers with a higher CPU power and larger memory, for example, higher than 2MB. It should be programmed by controller manufactures as a standard “calculation block”. Implementing the CQF-EWMA index on these DDC controllers was easy and straightforward, and can be implemented in most of modern DDC controllers by engineers who are familiar with DDC programming.

Chapter 9 Conclusions

This project developed an objective and quantitative index with simple-to-interpret criteria, namely, Control Quality Factor (CQF) for HVAC control applications. Two CQFs (i.e., CQF-Harris and CQF-EWMA) were proposed and tested using offline modelica-based dynamic simulation as well as on real HVAC control loops (online test). The focus of this project is assessment of the effectiveness of the two CQFs on normal HVAC control loop operation after recovering from a setpoint change or a disturbance (e. g., load change).

Based on the offline simulation cases (16 control loops), offline real cases (213 control loops), and online real cases of the HVAC control loops (2 control loops for HIL online tests and 4 control loops for IEC online tests), it is concluded that both CQF-Harris and CQF-EWMA have shortcomings and strengths. Both of them can consistently assess the control loop performance with their own assessment scales (0~1). The assessments using these two indices are aligned with each other for the majority of the test cases. HVAC control loops included in the assessment covered VAV room air temperature control, AHU supply air temperature control, AHU static pressure control, water loop differential pressure control, and VAV airflow control etc. Both CQFs only need inputs from control outputs and setpoints. Reversal behaviors assessment is included in both CQFs. It should be noted that the proposed CQFs cannot automatically diagnose the cause of a bad control loop (e.g., equipment failure, broken sensors, equipment saturation, etc.)

The strength of CQF-Harris is that the unmeasured disturbances of control loops are considered. The shortcoming of CQF-Harris is that it is relatively complicated in terms of computational resources (memory, data storage, CPU processing power and speed, etc.) required from the controllers. To correctly program this index on DDC controllers may be challenging and will require careful debugging.

The strength of CQF-EWMA is that it is simple, easy to program, and takes up much less computational resources comparing to CQF-Harris. The shortcoming of CQF-EWMA is that it does not take into account unmeasured disturbances stochastically.

Based on the field test at the Iowa Energy Center using BACnet-compatible controllers with 1MB flash memory and 2MB storage memory, the CQF-Harris implementation on one control loop used almost 50% of the controller memories alone mainly due to the ARAM fitting for the regression, while the implementation of CQF-EWMA was very easy and used little controller resources.

We recommend the adoption of the CQF-Harris index for DDC controllers with a higher CPU power and larger memory and be programmed by controller manufactures as a standard "calculation block". The CQF-EWMA index can be implemented in most of modern DDC controllers by engineers who are familiar with DDC programming.

Future work includes:

- A field survey to better define the threshold used in reversal index
- A software-in-the-loop framework to investigate the impact from the hardware such as controller memory, precision of floating point, etc.
- An extension of limited field test to control loops from AHU, chiller, boiler, etc.
- A root cause analysis (diagnostics) of the control loop with poor performance

WORK STATEMENT # 1454-WS
Responsible TC: TC 1.4 Control Theory & Application

TITLE: Control Valve Selection for Improved Controllability

EXECUTIVE SUMMARY:

Hydronic system control valve selection in current practice is based on rules-of-thumb and time-honored practices that are largely unsupported by scientific evidence and research. These practices may also be obsolete due to recent changes in hydronic system controls (e.g. PID logic DDC systems, temperature and pressure setpoint reset, variable speed drives, and pressure-independent valves). This research project will provide the information needed to properly select valve size and flow characteristics for pressure dependent valves, and it will identify the performance and potential benefits of pressure independent valves. Potential benefits of this project include improved controllability, reduced loop tuning time, and reduced pump energy.

APPLICABILITY TO ASHRAE RESEARCH STRATEGIC PLAN:

This project will provide design techniques for control valve selection that will help optimize hydronic system controls resulting in more effective HVAC system operation, improving comfort control and potentially reducing energy usage. Applicable categories listed in the 2005-2010 Research Plan:

D1. Establish techniques to improve the energy efficiency and reliability of heating, ventilating, cooling, and refrigeration system components (e.g.., heat exchangers, compressors, pumps, fans, distribution systems).

B2. Provide an optimal indoor environment for buildings, vehicles, and facilities with respect to comfort, productivity, health, and safety.

APPLICATION OF RESULTS:

Results of the project will be incorporated into the Fundamentals Handbook: Chapter 15 - Fundamentals of Control; HVAC Applications Handbook: Chapter 45 Design and Applications of Controls; and a Special Publication on Control Valve Selection. Control valve manufacturers will also likely include the valve selection techniques determined from this project into their valve selection literature.

STATE OF THE ART (BACKGROUND):

Current practice calls for valves to have a relatively high pressure drop to improve control. However, there is no single accepted procedure for valve selection. Various procedures and rules-of-thumb have been proposed by ASHRAE and valve manufacturers, most based on experienced or time-honored practices. Examples include selecting valves for pressure drops of:

- 5 psi[i]
- equal to the drop in the coil or other load being controlled[ii]
- branch authority of 50%[iii]
- 25% of pump head[i,iv]

Other than "authority" curves in the ASHRAE Handbook[iv] and theoretical discussions, there is little scientific evidence and research to support these selection practices.

Similar time-honored selection practices have also been applied to the selection of valve flow characteristic. Most controls designers and vendors recommend "equal percentage" characteristics to compensate for the non-linear performance of typical coils and for two-way valve systems to absorb the increased differential pressure that valves generally must absorb at part load.

But recent changes in the way hydronic systems are been designed and controlled may well cause the foundation of these selection practices to be obsolete:

- The use of advanced control algorithms such as proportional+integral+derivative (PID) and fuzzy logic. These improved algorithms, commonly available with direct digital controls (DDC) and electronic controls used on almost all new commercial and industrial construction projects, reduce the need for high valve authority and linear valve/coil performance.

- The use of variable speed drives (VSDs). VSDs reduce the differential pressure that two-way control valves must absorb at part loads, reducing the value of high valve authority and equal percentage flow characteristics.
- The use of chilled and hot water supply temperature reset controls and a trend to size coils using very high water-side temperature differences (delta-T), both of which linearize coil performance, perhaps making linear rather than equal percentage flow characteristic the better choice.
- The use of pressure-independent (P/I) control valves. P/I valves have internal controllers that maintain a constant differential pressure across the control valve despite higher available system differential pressure, potentially improving stability and obviating the need for high valve pressure drop and authority.

ADVANCEMENT TO THE STATE OF THE ART:

The control valve is one of the most critical elements in a hydronic HVAC system. Yet, valve selection is based on rules-of-thumb and traditional practices that largely have little scientific basis and that do not reflect modern HVAC design and control system capabilities. Improving control valve selection will improve comfort control and has the potential to reduce energy usage.

JUSTIFICATION AND VALUE TO ASHRAE:

This project will provide the information designers and control equipment vendors need to properly select valve size and flow characteristics for pressure dependent valves, and it will identify the performance and potential benefits of pressure independent valves. Potential benefits of this project include improved controllability, reduced loop tuning time, and reduced pump energy (if it is found that valve pressure drop and authority required for stable control can be lower than current practice, or if stable control is found to provide higher coil temperature difference).

OBJECTIVE:

To update techniques for selecting valve size (C_v) and flow characteristic for two-way pressure dependent valves as a function of HVAC application, controller capability, and temperature and pressure control strategies, and to investigate the potential benefits of pressure independent valves.

SCOPE:

Task 1. Background Literature Survey

The contractor shall conduct a literature search of current techniques for selecting valve size and characteristics. The contractor shall also determine commercial quality valve types available in the market place, including modern P/I valves. Finally the contractor shall investigate past research projects that compared the control system performance to see how different systems were objectively compared. This background information shall be summarized in a Task 1 report.

Task 2. Control Quality Factor Development

The contractor shall develop a way to compare control system performance based on the literature survey of past experiments and/or developed from control theory fundamentals with a single "control quality factor," (CQF). The CQF shall be determined from the statistical ability of a control system to maintain its control point at setpoint (such as root mean square error) without excessive movement of the controlled device. The tighter the control (the closer the control point is maintained at setpoint over time), the higher the CQF. The CQF shall be defined to be 1.0 for a perfect control system, one able to maintain the control point exactly at setpoint over time.

Task 3. Experimental Platform Design

The contractor shall prepare detailed design documents of the laboratory experimental platform that will be used to conduct the control experiments. Design and instrumentation shall comply with ANSI/ISA 75.02–1996[v]. The platform shall be similar to that shown in Figure 1 and shall include at a minimum the following:

1. Airflow meter. The meter shall be an orifice type meter that can be calibrated from basic principals (i.e. not require a more accurate external device for calibration). The meter shall be tested against precisely calibrated airflow meters as a check of accuracy.

2. Filter. MERV 15 or better to protect coils from particles.
3. Conditioning coil. This coil shall be capable of heating or cooling the air that will then challenge the test coil.
4. Test coil. The test coil duct section shall allow for the insertion and removal of various test coils as defined in the next section. Coil size shall have smooth entering and leaving airflow conditions.
5. Test valve. The test valve piping section shall allow the insertion and removal of various test valves and reducers as defined in the next section. Installation shall follow manufacturer's recommendations.
6. Industrial process controllers. Industrial quality controllers shall have self-tuning PID capability. The intent of using this type of controller to control the test valve is to minimize the impact of the controller itself on the CQF. The controller shall include anti-dithering logic to prevent continuous valve adjustments. The controller shall be automatically tuned for each valve under identical conditions, such as 50% of design coil load using adjustment of coil supply air temperature to simulate coil load.
7. Industrial control valve. This valve controls the conditioning coil and must perform precisely to maintain near-constant air temperature off the conditioning coil. The CQF of this valve and controller shall be tested and be near 1.0.
8. Supply fan. The design supply fan design airflow rate shall be 3,000 cfm or larger and shall have a variable speed drive or other means to vary airflow.
9. Pumps. Conditioning coil pump shall be constant volume to improve control stability. Test coil pump shall have variable speed drive to allow valve differential pressure to be adjusted.
10. Flow meter. A full bore magnetic flow meter shall be used to measure flow through the test coil.
11. Temperature sensors. Temperature sensors shall be accurate to ±0.1ºF, NIST traceable. The temperature sensors in the test coil loop shall be a matched pair capable of measure differential temperature to ±0.15ºF.
12. Chiller/boiler. The laboratory shall have a source of hot and chilled water that can be used to supply hot or chilled water to both the conditioning coil and test coil. Heat exchangers are recommended to ensure that coils are not fouled by the primary system and to allow easy changeover from heating to cooling.

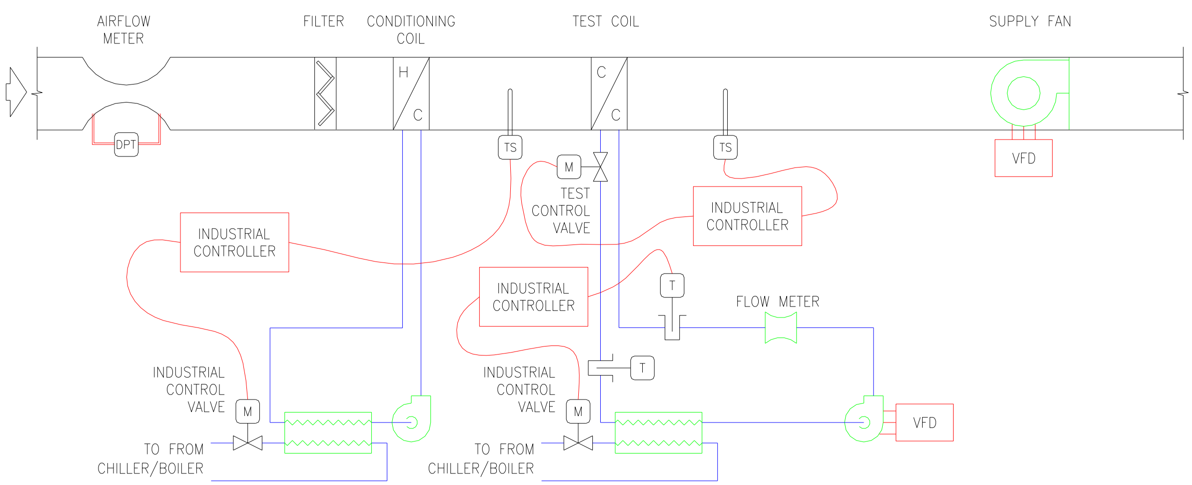

Figure 1: Test Rig Schematic

The design of the test rig shall be submitted to the Project Monitoring Committee (PMC) for approval prior to Task 4.

Task 4. Experimental Plan Development

The test plan shall be developed to test the CQF of various cooling and heating systems and control valves based on the criteria below as informed by the literature search.

1. Test valves. Include testing as a minimum of the following (to be adjusted if necessary by literature search). For each valve except the pressure independent valve, test 4 different sizes (values of C_v) varying from very low valve authority to the largest authority recommended in literature. Two

manufacturers of pressure independent valves shall be used. This results in a minimum of 26 valves to be tested for cooling and heating, for a total of 52 tests. Electric actuators for each valve of a given type shall have identical timing (speed); actuators should have the same timing for all valve types if possible. All valves shall be submitted to the PMC for approval prior to purchase and testing.

   a. Ball valve, uncharacterized
   b. Ball valve characterized for equal percentage characteristic
   c. Globe valve with equal percentage plug
   d. Globe valve with linear plug
   e. Butterfly valve, uncharacterized
   f. Industrial rotary-segmented ball valve
   g. Pressure independent valve

2. Test coils. Coils shall be standard commercial products with ARI rated performance. Include the following four coils:
   a. Cooling coil sized for 500 fpm, 78ºF entering drybulb, 68ºF entering wetbulb, 53ºF leaving drybulb, 45ºF entering water temperature, 57ºF leaving water temperature.
   b. Cooling coil as above except designed for 43ºF EWT to 68ºF LWT.
   c. Heating coil sized for 700 fpm, 50ºF entering drybulb, 95ºF leaving drybulb, 180ºF entering water temperature, 150ºF leaving water temperature. (Coil entering air temperature is set in 50s to allow it to be achieved by conditioning coil using standard chiller water.)
   d. Heating coil as above except designed for 180ºF EWT to 120ºF LWT.
3. Test variables. Test valves under the following conditions:
   a. Varying load, constant volume. Load shall be varied by adjusting entering air conditions with constant airflow rate from 10% to 100% load.
   b. Varying load, variable volume. Load shall be varied by adjusting airflow rate with constant entering air conditions from 10% to 100% load.
   c. Varying valve differential pressure. The pressure drop across the test valve shall be varied from design DP up to 40 psi.
   d. Varying coil supply water temperature. The coil supply water temperature to the coil shall be varied linearly with load from the design SWT at 100% load to the design SWT plus 50% of the design ΔT (design LWT – SWT) at zero load.
4. Permutations. Contractor shall test all realistic combinations and simultaneity of varying test variables for each coil and for each control valve. Proposal shall include a description of the permutations the Contractor intends to test and limitations on the number of tests that will be performed. Rates of change of test variables shall be based on realistic conditions expected to be experienced in actual HVAC applications.
5. Test report. Each test shall be nearly steady-state. For each test, measure, calculate and report at least the following:
   a. Verification if published valve flow characteristic, rangeability, and close-off pressure
   b. Valve CQF
   c. Total coil energy transfer. (The intent is to see if CQF affects energy usage of a coil.)
   d. Coil performance as determined using the coil manufacturer's ARI certified coil model. (The intent is to see if there are substantial deviations in predicted vs. measured performance for the tested coil.)

The test plan shall be approved by the PMC prior to implementation.

Task 5. Implementation and Testing

Task 5 is to implement the test plan developed in Task 4. A set of tests and CQF calculations shall be done for a single coil and control valve type as a first step with results provided to the PMC for review. Revise the test plan as deemed necessary by the PMC based on these interim results prior to completing the tests on other valves.

Task 6. Reporting of Findings

The contractor shall produce a comprehensive final report detailing all the work undertaken in the project. Uncertainty of measured and calculated values shall be included in the analysis. In addition to describing the results, the report shall include recommendations for sizing control valves and selecting valve characteristics for various coil applications and control scenarios. These shall be relatively simple techniques that can be easily implemented by design engineers and controls contractors.

DELIVERABLES/WHERE RESULTS WILL BE PUBLISHED:

Progress, Financial and Final Reports, Technical Paper(s), and Data shall constitute the only deliverables and shall be provided as follows:

1. Progress and Financial Reports

   Progress and Financial Reports, in a form approved by the Society, shall be made to the Society through its Manager of Research and Technical Services at quarterly intervals; specifically on or before each January 1, April 1, June 10, and October 1 of the contract period. A report shall be submitted for approval for each Task prior to proceeding with the next task.

   The Principal Investigator, subject to the Society's approval, shall, during the period of performance and after the Final Report has been submitted, report in person to the PMC at the annual and winter meetings, and be available to answer such questions regarding the research as may arise. The Principal Investigator shall also initiate interaction (email, fax, or phone) with the PMC every six weeks concerning the progress of the research.

2. Final Report

   A written report, design guide, or manual, (collectively, "Final Report"), in a form approved by the Society, shall be prepared by the Institution and submitted to the Society's Manager of Research and Technical Services by the end of the Agreement term, containing complete details of all research carried out under this Agreement.

   Unless otherwise specified, one electronic copy of the final report shall be furnished in Microsoft Word format for review by the PMC. Following approval by the PMC and the TC/TG, in their sole discretion, final copies of the Final Report will be furnished by the Institution as follows:

   - An executive summary in a form suitable for wide distribution to the industry and to the public.
   - Two bound copies, in color if graphics are in color
   - One unbound copy, printed on one side only, suitable for reproduction, in color if graphics are in color.
   - Two electronic copies; one in PDF format and one in Microsoft Word format.
   - One electronic copy of all data collected as a part of the valve tests in database format.

3. Technical Paper

   One or more papers shall be submitted first to the ASHRAE Manager of Research and Technical Services (MORTS) and then to the "ASHRAE Manuscript Central" website-based manuscript review system in a form and containing such information as designated by the Society suitable for presentation at a Society meeting.

4. Data

   All papers or articles prepared in connection with an ASHRAE research project, which are being submitted for inclusion in any ASHRAE publication, shall be submitted through the Manager of Research and Technical Services first and not to the publication's editor or Program Committee.

5. Project Synopsis

   A written synopsis totaling approximately 100 words in length and written for a broad technical audience, which documents 1. Main findings of research project, 2. Why findings are significant, and 3. How the findings benefit ASHRAE membership and/or society in general shall be submitted to the Manager of Research and Technical Services by the end of the Agreement term for publication in ASHRAE Insights.

The Society may request the Institution submit a technical article suitable for publication in the Society's ASHRAE Journal. This is considered a voluntary submission and not a Deliverable.

LEVEL OF EFFORT:

It is expected that this project will require a duration of eighteen (18) months to complete at a total cost of $200,000. This estimate includes two (2) person-months for the principle investigator and a total of eighteen (18) person-months for one or more supporting project staff for a total of twenty (20) person-months. The test rig is expected to be existing or paid for by other sources; it is not included in the project budget. Purchasing control valves is included in the budget.

OTHER INFORMATION FOR BIDDERS:

Bidders on this work statement are expected to demonstrate expertise with control systems, control system theory, and laboratory HVAC experimentation and performance measurement. Bidders should have a thorough understanding of how large variable flow hydronic systems are designed, controlled and operated, although actual design experience is not required.

The proposals will be evaluated based on the following criteria:

PROPOSAL EVALUATION CRITERIA & WEIGHTING FACTORS:

1. Contractor's understanding of Work Statement as revealed in the proposal. (20%)
    a. Understanding of control theory and applications
    b. Concepts for defining and determining Control quality factor (CQF)
2. Quality of methodology proposed for conducting research. (30%)
    a. Proposed methodology for limiting permutations of variables and number of permutations included
    b. Proposed test stand design
    c. Proposed procedures for determining CQF
    d. Data collection techniques
    e. Organization and management plan
3. Qualification of personnel for this project. (20%)
    a. Principal investigator's experience in HVAC systems, HVAC control systems, and control system theory
    b. Time commitment of principal investigator
    c. Other team members' qualifications
4. Student involvement (5%)
    a. Extent of graduate-level student research assistant
    b. Likelihood that involvement in project will encourage entry into HVAC&R industry
5. Probability of contractor's proposal meeting objectives. (20%)
    a. Detailed work plan with major tasks and key milestones
    b. All technical and logistic factors considered
    c. Reasonableness of project schedule
6. Performance of contractor on prior ASHRAE projects (no penalty for new contractors). (5%)

REFERENCES:

None

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[i] Siemens, "Sizing and Selection of Control Valves," http://www.sbt.siemens.com/HVP/Components/Documentation/15370186.pdf, 2006
[ii] Invensys, "Valve Sizing for Water," http://www.eurotherm.com/products/valves/size_water.htm, 2006
[iii] Hegberg, M.C., "Control Valve Selection for Hydronic Systems," ASHRAE Journal, November, 2000
[iv] ASHRAE Handbook, Fundamentals, Chapter 45
[v] ANSI/ISA 75.02–1996. Control Valve Capacity Test Procedures. ISA, Research Triangle Park, North Carolina

ASHRAE RP-1587 Control Loop Performance Assessment

Final Report

Prepared for
Project Monitoring Subcommittee
ASHRAE Technical Committee TC 1.4
Control Theory and Application

Principal Investigator: Zheng O'Neill, PhD, PE
Co- Principal Investigator: Keith Williams, PhD
Research Assistant: Yanfei Li, Aaron Henry
The University of Alabama

Field Testing: Ran Liu, PhD, Xiaohui Zhou, PhD, PE
Iowa Energy Center

June 2016

Executive Summary

This is the final report for the control loop performance assessment project sponsored by ASHRAE. In this project, two single control quality factors (CQFs) in the context of building heating, ventilation and air-conditioning (HVAC) controls were developed and tested. These CQFs need to be objective, quantitative metric with simple-to-interpret criteria; additionally, they need to use only typically available data from HVAC control systems, such as the control loop output.

An extensive review of control loop performance assessment in various industries reveals that few studies are available to assess HVAC control loop performance. We systematically reviewed 35 indices and their associated methods of evaluating control loop performance, including their drawbacks and merits. Fourteen of these indices were selected to assess their performance on an air handler unit (AHU) heating coil outlet air temperature control loop using simulated data from a dynamic Modelica model. Based on the review and preliminary simulation results, two CQFs — the normalized Harris Index and Exponential Weighted Moving Averages (EWMA) — were recommended for further investigation. The first CQF (i.e., CQF-Harris) is based on the normalized Harris Index, together with a reversal index that detects control response trend reversal behaviors. The second CQF (i.e., CQF-EWMA) is the EWMA-based index along with the reversal index.

A CQF scale was developed to categorize HVAC control loop performance: excellent (A), good (B), fair (C), bad (D), and fail (F). For CQF-Harris, the scale is based on the ratio of control output variance to the minimum variance. For CQF-EWMA, the scale is based on the dimensionless error ratio between control output and the set point. The scale ranges are also given for the two CQFs. The proposed CQFs were implemented on simulated HVAC control loops through offline testing. A total of 16 simulated control loops (two sets) were assessed based on data from Modelica models. The first set of models is for the AHU heating/cooling coils. The

second set of models is for the dynamic VAV system with room models. This offline testing shows that the proposed CQFs can assess control loop performance with correct scales. Sensitivity analyses were conducted for CQF-Harris with respect to unmeasured disturbance (i.e., white noise) variance, moving window length, and sampling frequency. The results show that CQF-Harris is sensitive to unmeasured disturbance variance and to the length of the moving window, although it is less sensitive to the sampling frequency. The sensitivity analysis was also conducted for the CQF-EWMA with respect to the sampling frequency and unmeasured disturbance variance, and the results show that it is not sensitive to these two parameters.

The proposed CQFs were also tested using data from real control loops. A total of 213 real control loops were tested in six data sets. These loops covered VAV room air temperature control, AHU supply air temperature control, AHU static pressure control, water loop differential pressure control, and VAV airflow control, etc. The first four sets are from an office building in Chicago, Illinois. The fifth set is from the Iowa Energy Center's Energy Resource Station. The sixth set is from a classroom and laboratory building on campus at the University of Alabama. The test results show that the both CQFs are effective in assessing control loop performance. The assessments using these two indices are aligned with each other for the majority of the test cases.

Furthermore, sensitivity analyses for the real VAV control loops were conducted with respect to sampling frequency and length of the moving window. From the results, it is recommended that a moving window length of 80 or 100 minutes (i.e., 20 samples with a sampling frequency of four or five minutes) be used for VAV control loops. A weighted CQF for an evaluation of the averaged control loop performance over a given assessment time period is also proposed for the two CQFs with applications for real control loops.

Real-time field-testing with actual HVAC system and local VAV controllers were conducted at the Iowa Energy Center's Energy Resource Station. Both single maximum and dual maximum control logics were tested. Both proposed CQFs were able to be successfully programmed and downloaded to four real DDC (direct digital control) local controllers. The real-time CQFs values are consistent with those from offline Matlab computations. However, the effort in implementing CQF-Harris index was quite involved, and required significant computational resources for the controllers. It is recommended to adopt the CQF-Harris index for DDC controllers with a higher CPU power and larger memory, for example, higher than 2MB. It should be programmed by controller manufactures as a standard "calculation block". Implementing the CQF-EWMA index on these DDC controllers was easy and straightforward, and can be implemented in most of modern DDC controllers by engineers who are familiar with DDC programming.

Chapter 9 Conclusions

This project developed an objective and quantitative index with simple-to-interpret criteria, namely, Control Quality Factor (CQF) for HVAC control applications. Two CQFs (i.e., CQF-Harris and CQF-EWMA) were proposed and tested using offline modelica-based dynamic simulation as well as on real HVAC control loops (online test). The focus of this project is assessment of the effectiveness of the two CQFs on normal HVAC control loop operation after recovering from a setpoint change or a disturbance (e. g., load change).

Based on the offline simulation cases (16 control loops), offline real cases (213 control loops), and online real cases of the HVAC control loops (2 control loops for HIL online tests and 4 control loops for IEC online tests), it is concluded that both CQF-Harris and CQF-EWMA have shortcomings and strengths. Both of them can consistently assess the control loop performance with their own assessment scales (0~1). The assessments using these two indices are aligned with each other for the majority of the test cases. HVAC control loops included in the assessment covered VAV room air temperature control, AHU supply air temperature control, AHU static pressure control, water loop differential pressure control, and VAV airflow control etc. Both CQFs only need inputs from control outputs and setpoints. Reversal behaviors assessment is included in both CQFs. It should be noted that the proposed CQFs cannot automatically diagnose the cause of a bad control loop (e.g., equipment failure, broken sensors, equipment saturation, etc.)

The strength of CQF-Harris is that the unmeasured disturbances of control loops are considered. The shortcoming of CQF-Harris is that it is relatively complicated in terms of computational resources (memory, data storage, CPU processing power and speed, etc.) required from the controllers. To correctly program this index on DDC controllers may be challenging and will require careful debugging.

The strength of CQF-EWMA is that it is simple, easy to program, and takes up much less computational resources comparing to CQF-Harris. The shortcoming of CQF-EWMA is that it does not take into account unmeasured disturbances stochastically.

Based on the field test at the Iowa Energy Center using BACnet-compatible controllers with 1MB flash memory and 2MB storage memory, the CQF-Harris implementation on one control loop used almost 50% of the controller memories alone mainly due to the ARAM fitting for the regression, while the implementation of CQF-EWMA was very easy and used little controller resources.

We recommend the adoption of the CQF-Harris index for DDC controllers with a higher CPU power and larger memory and be programmed by controller manufactures as a standard "calculation block". The CQF-EWMA index can be implemented in most of modern DDC controllers by engineers who are familiar with DDC programming.

Future work includes:

- A field survey to better define the threshold used in reversal index
- A software-in-the-loop framework to investigate the impact from the hardware such as controller memory, precision of floating point, etc.
- An extension of limited field test to control loops from AHU, chiller, boiler, etc.
- A root cause analysis (diagnostics) of the control loop with poor performance

TC 6.1 Handbook Subcommittee Minutes

June 26, 2016 5pm-6pm

2016 Annual Conference – St. Louis

Attendees: Sign-in sheet attached.

1. Introduction of attendees.
2. Notes from Handbook Volume/TC meeting on Sunday, June 26, 2016, from 9:00-10:00am.
    a. ASHRAE Authoring Portal (authoring.ashrae.org) is the new collaborative authoring tool for future Handbook Chapters (beginning with 2018 Handbook).
    b. Use of Google Docs is not permitted for editing Handbook chapters due to security concerns. Those users should start using authoring.ashrae.org.
    c. A presentation will be posted on Handbook Central providing an introduction to the ASHRAE Authoring Portal.
    d. The ASHRAE Handbook Online is a free member benefit option.
    e. Reminder that out-of-cycle revisions can be submitted, and are encouraged, at any time.
    f. Question concern the 'lead author' approval of on-line chapter with the portal. That is, could a person make changes in the chapter and accept the revisions for their own changes.
3. A reminder all diagrams, pictures, etc., used in a chapter must receive permission of the source for use (other than government agencies, ASHRAE, or those with a continuing permission agreement).
4. Chapter 22 Pipe Design. Final review has been completed. Voting for sending to the full TC is required. Motion by Rex, second by Niels. Vote 8-0-1.
5. A sign up sheet for Lead Authors and Reviewers for the 2020 Systems and Equipment Handbook was passed around for volunteers. Attached to the meeting notes.
6. TC 6.1 has 8 chapters for review for 2020.
    a. Chapter 15 – Medium and High Temperature Water Heating Systems is now TC 6.2 responsibility. Discussed with Forrest Yount (Handbook Liaison) as it has not been assigned to TC 6.2 yet. He is following up.
    b. 'new' Chilled Water Plant Design chapter has yet to appear on TC 6.1. Forrest Yount is following up on this item as well.

Bob Walker

'Acting' Subcommittee Chair

ASHRAE Shaping Tomorrow's Built Environment Today

TC Sign-in Sheet

Meeting Info: TC 6.1 HANDBOOK Date: 6-26-16

Name	Affiliation	E-mail	Member (Voting, Corresponding, or Guest?)	YEA Member? (Yes/No)
Rex Scare	Int'l Armstrong	Rexs@armintl.com	Voting	N
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