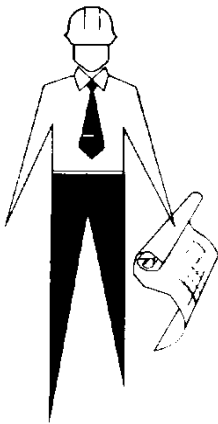


1 **PROCEDURAL STANDARDS**
2 **FOR THE TECHNICAL**
3 **RETRO-COMMISSIONING OF**
4 **EXISTING BUILDING SYSTEMS**

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2013 – SECOND EDITION



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PROCEDURAL STANDARDS FOR THE TECHNICAL RETRO-COMMISSIONING OF EXISTING BUILDING SYSTEMS



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FIRST EDITION - 2007
SECOND EDITION - 2013

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These Procedural Standards were developed using reliable engineering principles and research plus consultation with, and information obtained from, manufacturers, users, testing laboratories and others having specialized experience. They are subject to revision as further experience and investigation may show it necessary or desirable to do so. Building Systems Retro Commissioned to these standards may not be applicable if the system being commissioned contains features or components that impair the results of these standards. The National Environmental Balancing Bureau assumes no responsibility and has no liability for the application of the principles or techniques contained in these Procedural Standards. Authorities considering adoption of these Procedural Standards should review all Federal, State, local and contract regulations applicable to the specific installation.

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FOREWORD

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The purpose of NEBB *Procedural Standards for the Technical Retro-Commissioning of Existing Building Systems* is to establish a uniform and systematic set of criteria for use of the NEBB Technical Retro-Commissioning (RCx) when applied to any building's systems.

These Procedural Standards are intended as the baseline requirements a NEBB RCx Certified Firm will follow while performing NEBB Technical Retro-Commissioning. Contract document requirements or contractual agreements between the Owner and the NEBB RCx Certified Firm may supersede these NEBB requirements.

The purpose of these Procedural Standards is to provide specific requirements that each firm performing NEBB Certified RCx will meet at each phase of the NEBB RCx program. These Procedural Standards are divided into six Sections: *NEBB RCx Program, Certification Conformance, Responsibilities, Instruments and Calibration, Reports, Technical RCx Procedures, and Appendices for definitions and abbreviations and Instrumentation Requirements*

Best practice is achieved when the Retro-Commissioning firm is retained to provide all phases of these procedural standards to assure continuity of the recommended results are achieved.

The *Procedures* section is narrative in nature and describes the baseline of technical activity that all NEBB projects follow in order to be an NEBB Certified Project. The details of what is tested and documented are in Section 3 and *Appendices* sections.

This Second Edition of NEBB RCx Procedural Standards is intended to provide guidance and flexibility to the Owner and NEBB Certified Professional. These Procedural Standards allow an Owner to perform a single Phase, or any combination of phases as desired.

These NEBB RCx Procedural Standards are presented in a linear fashion for clarity of the process but the process is actually an iterative process with many cycles between the components of the site investigation phase and later phases.

When the RCx contract does not specify a specific Scope of Work the NEBB RCx firm shall provide all work as described in these procedural standards to provide an NEBB Certified RCx report.

This Second Edition of the RCx Procedural Standards, when used by NEBB RCx Certified Firms, assures the Owner the building is properly retro-commissioned to improve building performance, operation and comfort.

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271 1. NEBB RCx PROGRAM

272 1.1. NEBB PROGRAMS

273 The National Environmental Balancing Bureau (NEBB) is a not-for-profit organization founded in
274 1971 to:

- 275 a. Develop standards, procedures and programs for the performance of testing,
276 balancing and commissioning of building systems
- 277 b. Promote advancement of the industry through technical training and development
- 278 c. Operate programs to certify firms and qualify individuals who meet and maintain
279 NEBB standards with integrity.

280
281 Additional information on NEBB Programs is available at www.nebb.org.

282 1.2. NEBB DISCIPLINES

284 NEBB establishes and maintains standards, procedures, and specifications for work in its
285 various disciplines, which include:

- 286 a. Testing-Adjusting-Balancing (TAB)
- 287 b. Sound Measurement (S)
- 288 c. Vibration Measurement (V)
- 289 d. Cleanroom Performance Testing (CPT)
- 290 e. Building Systems Commissioning (BSC)
- 291 f. Retro-Commissioning (RCx)
- 292 g. Fume Hood Testing (FHT)
- 293 h. Building Envelope Testing (BET)

294
295 Each discipline is anchored by a NEBB Procedural Standards manual that provides guidelines
296 for work to be performed. NEBB also has created technical manuals, training materials and
297 programs, and seminars to enhance and support each discipline.

298 1.3. FIRM CERTIFICATION

300 NEBB certifies firms that meet certain criteria, ensuring strict conformance to its high standards
301 and procedures. Among other requirements, NEBB Certified Firms must document a record of
302 responsible performance, possess a complete set of instruments required for the sophisticated
303 techniques and procedures necessary to "fine-tune" modern environmental systems, and have
304 a NEBB Certified Professional on staff.

305 1.4. CERTIFIED PROFESSIONAL (CP) QUALIFICATION

307 NEBB also establishes professional qualifications for the supervision and performance of work
308 in its various disciplines. NEBB Certified Professionals must have extensive experience, and
309 they must pass appropriate, written examinations and demonstrate certain practical working
310 knowledge and proficiency in the use of instruments required for the various disciplines.

311 1.5. RECERTIFICATION REQUIREMENTS

313 Through the recertification procedures, the firm must verify that its NEBB Certified Professional
314 is still on staff and that it continues to possess a complete set of instruments and equipment that
315 are in current calibration. In addition, the firm's NEBB Certified Professional renews his or her
316 certification. Among other requirements, Supervisors must keep abreast of developments in
317 their discipline by successfully completing continuing education requirements as outlined by
318 NEBB.

319

320 **2. CONFORMANCE CERTIFICATION**

321 The credibility of NEBB is built by maintaining integrity through high standards, quality
322 programs, and demonstrated capabilities of its certified firms. The NEBB Quality Assurance
323 Program guarantees that NEBB certified work is done in compliance with NEBB Procedural
324 Standards. The NEBB Certificate of Conformance Certification is an integral element of the
325 program. It assures that the NEBB Certified Firm will perform specified services in conformity
326 with the current applicable NEBB Procedural Standards.

327 **2.1. PROGRAM ADVANTAGES**

328 The NEBB Quality Assurance Program affords building owners, architects, engineers and other
329 agents a reliable basis for specifying work within the various disciplines of NEBB. The program
330 promotes proper execution of projects by ensuring compliance with NEBB standards and
331 procedures.
332

333 **2.2. NEBB QUALITY ASSURANCE PROGRAM CERTIFICATE**

334 The NEBB RCx Certified Firm shall make application to the NEBB Office for a Certificate of
335 Conformance Certification if specified in the contract documents. The NEBB Quality Assurance
336 Program Conformance Certification is also available for any project.
337

338 **2.3. QUALITY CONTROL AND COMPLIANCE**

339 Building owners are entitled to a professional service by every NEBB RCx Certified Firm on
340 every project, whether the job is NEBB-specified or not. It is the responsibility of the NEBB RCx
341 Certified Firm and its NEBB RCx Certified Professional to establish and maintain procedures
342 and practices that will assure a consistent pattern of high quality work on all projects.
343

344 **2.4. RCX WORK COMPLIANCE**

345 The scope of work shall be performed as specified in the contract documents or as agreed to
346 between the NEBB RCx Certified Firm and the Owner/Buyer. Each relevant or applicable item
347 as identified in the scope of work by description, or by reference, shall be performed by the
348 NEBB Certified RCx Firm or by sub-consultants under his supervision and recorded in the
349 NEBB RCx Final Report. Data presented in a NEBB RCx report shall provide an accurate
350 record of the system tests, measurements, data and information.
351

352 Regardless of what is specified, in all cases the processes followed, the commissioning
353 activities, the requirements of each phase included in the scope of work, and the testing results
354 shall conform to the current edition of the NEBB *Procedural Standards for the Retro-
355 Commissioning of Existing Building Systems*.
356

357 References to desired procedures may include statements such as "the work will be performed
358 in accordance to NEBB Standards." When specifications indicate that the RCx work shall be
359 performed in accordance with NEBB standards, the RCx procedures will conform to the current
360 Edition of the NEBB *Procedural Standards for the Retro-Commissioning of Existing Building
361 Systems*.
362

363 The NEBB RCx Certified Firm and the NEBB RCx CP are allowed to sign and stamp a
364 commissioning report as a NEBB Certified Commissioning Report only when the procedures
365 and requirements as identified in these Procedural Standards have been followed.
366

367

368 A commissioning report that does not meet NEBB requirements, for the phases specified in the
369 scope of work shall not be signed and stamped as a NEBB certified report. All references to
370 NEBB, including NEBB logos, stamps, certifications, etc. shall be removed from the report.
371

372 **2.5. RCX CP RESPONSIBILITIES**

373 It is the responsibility of the NEBB RCx CP to control the quality of the commissioning work.
374 This means that the NEBB RCx Certified Firm, through its NEBB RCx CP, shall satisfy the
375 contract obligations as defined in the contract documents or as agreed to with the Owner/Buyer.
376

377 **2.6. EXECUTION OF RCX PROCEDURES**

378 The NEBB RCx CP shall have project responsibility, which includes authority to represent the
379 NEBB RCx Certified Firm. Examples of project responsibility may include labor decisions,
380 negotiating change orders, committing to contract interpretations and implementing changes in
381 job schedules.
382

383 The NEBB RCx CP has the responsibility to assure that the systems have been retro-
384 commissioned properly in accordance with these Procedural Standards and the contract scope
385 of work to assure the accuracy of all data included in the final Retro-Commissioning Report.
386 Factors such as training, instrument use, coordination / supervision, work instructions, and
387 project communication play a critical role in achieving this requirement.
388

389 **2.7. INSTRUMENT AND EQUIPMENT USE AND MAINTENANCE**

390 NEBB RCx CPs shall possess knowledge and skill in the proper use and care of the equipment
391 and instruments required to perform the associated tests required of the retro-commissioning
392 effort. This shall include a thorough understanding of the operating principles and use of
393 equipment and instruments. Considerations for the delicate nature of many of the instruments
394 typically used, as well as the adverse effects of dirt, shock, jarring movements and exceeding
395 rated capacities, shall be addressed along with the proper methods for storing and transporting
396 the instruments.
397

398 **2.8. COORDINATION / SUPERVISION**

399 The NEBB RCx CP shall be in responsible charge for directing retro-commissioning team
400 members/ technicians in performing the commissioning work.
401

402 **2.9. PROJECT COMMUNICATION**

403 The NEBB RCx CP shall report on progress made toward work completion, when required, as
404 well as report and address problems if encountered. When a problem exists, the NEBB RCx
405 CP should notify the appropriate personnel. The NEBB RCx CP may provide input as to the
406 cause of the problem and recommend possible solutions. Deficiencies and problems should be
407 reported in the Issues Log through resolution.
408

409 **2.10. WORK COMPLETION**

410 The NEBB RCx CP shall determine when the retro-commissioning work has been completed.
411 Generally, the specified RCx work is complete when all applicable systems, components and
412 assemblies are properly retro-commissioned, the results of the investigation have been
413 analyzed and recommended solutions are presented to the Owner in the final Retro-
414 Commissioning report.
415

416 Based on the contractual requirements, the RCx work may continue through the Improvement
417 Phase. The NEBB RCx Certified Firm / CP should be involved in the Remedial Design and
418 Construction of the Corrective Actions and all work should be commissioned by the NEBB RCx
419 Certified Firm.

420

421 Reasonable efforts within the extent of the retro-commissioning process should be performed in
422 an effort to achieve acceptable system performance. The NEBB RCx CP shall notify the
423 appropriate project personnel of any system deficiencies preventing retro-commissioning
424 completion also requiring additional work before the final Retro-Commissioning Report is
425 submitted. Any variances, deficiencies, or issues unresolved in the Issues Log shall be noted in
426 the final Retro-Commissioning Report.

427

428 2.11.COMPILED AND SUBMISSION OF FINAL COMMISSIONING REPORTS

429 Reports shall include information and data to provide an accurate quantitative record of system
430 measurements and information. Reports also shall include notes and comments, as
431 appropriate, to provide the reviewer with additional details related to the results of the retro-
432 commissioning efforts for all equipment, systems and components that were included in the
433 RCx scope. Reports shall meet the criteria listed in the procedural standard.

434

435 The certification page shall bear the stamp of the NEBB RCx CP. The stamp on the certification
436 page shall be signed as evidence that the NEBB RCx CP has personally reviewed and
437 accepted the report.

438

439 **Paper Certified Report:** An ink stamp issued by NEBB with an original signature or ink signature
440 stamp shall be applied to the certification page. The signature and date shall not obscure the
441 Certified Professional's name or Certified Firm's number in the seal/stamp.

442 **Electronic Certified Report:** An electronic version of the NEBB issued seal/stamp (digital
443 representation) shall be applied to the certification page, along with an electronic version of the
444 Certified Professional's signature. This allows the Certified Professional to affix a computer
445 generated seal/stamp and an electronic signature to a document.

446 **Stamp Security:** Certified Professionals shall take appropriate measures to ensure security of their
447 ink stamp, electronic stamp, ink signature stamp, and electronic signature. The security and use of
448 ink stamp, electronic stamp, ink signature stamp, or electronic signature is the responsibility of the
449 Certified Professional.

3. RESPONSIBILITIES

450
451 Many approaches can be taken to deliver a successful retro-commissioning project. Retro-
452 commissioning can be initiated for comfort and operational improvement, improvement in IEQ or
453 for optimization of energy and water usage, as well as for all three. Retro-commissioning can
454 be a direct consulting service, which provides only discovery and recommendations and no
455 repair or construction services, or a turnkey service that includes all repair and construction
456 services. Retro-commissioning services are procured directly by the Owner or his
457 representative and the contract for these services is between the Owner and the retro-
458 commissioning firm.

459
460 Best practice is achieved when the Retro-Commissioning firm is retained to provide all phases
461 of these procedural standards to assure continuity of the recommended results are achieved.
462

3.2. OWNER RESPONSIBILITIES

- 463
464 a. Retains the services of the NEBB RCx Certified Firm
465 b. Approves RCx scope of work
466 c. Provides or facilitate site access
467 d. Provides original construction documents if available
468 i. OPR
469 ii. Drawings
470 iii. Specifications
471 iv. Submittals
472 v. Commissioning Reports
473 vi. TAB Reports
474 vii. Utility Data
475 viii. Maintenance Management System Data
476 e. Determines level of Owner participation in the RCx process
477 f. Determines which recommendations will be implemented
478 g. Determines or procures corrective actions design or scope of work development
479 h. Procures and manages corrective actions
480

3.3. NEBB RCx CERTIFIED FIRM RESPONSIBILITIES

- 481
482 The NEBB Certified RCx firm provides the following, if included in the scope of work:
483 a. Follows the current NEBB Procedural Standards when performing the RCx work
484 b. Directs the retro-commissioning team in the process
485 c. Creates the Current Facility Requirements (CFR)
486 d. Creates the RCx Plan
487 e. Performs issue discovery and problem analysis
488 f. Creates Corrective Action Recommendation Report
489 g. Assists Owner in selecting recommendations to implement
490 h. Provides management services for corrective action implementation
491 i. Provides commissioning services of corrective action implementation
492 j. Provides the final retro-commissioning report to the Owner
493 k. Performs system performance evaluation
494

3.4. NEBB TAB CERTIFIED FIRM RESPONSIBILITIES

495
496 If the scope of work requires performing a complete Test and Balance on the RCx project, the
497 work shall be done by a NEBB TAB Certified Firm. Their responsibilities are:

- 498 a. Follows the current NEBB standards and procedures when performing TAB work
- 499 b. Communicates on a regular basis, through proper channels, items relating to design,
- 500 installation, or function that prevent the NEBB TAB Certified Firm from achieving
- 501 completion of the TAB work in accordance with the current edition of the NEBB
- 502 *Procedural Standards for Testing, Adjusting, and Balancing of Environmental*
- 503 *Systems*
- 504 c. Performs the specified retro-commissioning support requirements
- 505 d. Publishes a NEBB Certified TAB report with TAB Report of final conditions that
- 506 accurately reflects the HVAC systems final air and hydronic flow conditions
- 507

3.5. DESIGN PROFESSIONAL RESPONSIBILITIES

- 509 When a design professional is a part of the RCx team his/her responsibilities:
- 510 a. Provides professional expertise to the retro-commissioning team for their discipline
 - 511 b. Assists RCx CP in issue analysis as required
 - 512 c. Conducts any calculations, engineering or design required
 - 513 d. Provides Construction Documents as required to facilitate recommended corrective
 - 514 actions
 - 515 e. Provides a BOD for created designs
 - 516

3.6. CONTRACTOR OR VENDOR RESPONSIBILITIES

- 518 When a contractor or vendor is a part of the RCx team his/her responsibilities:
- 519 a. Provides professional expertise to the retro-commissioning team for their discipline
 - 520 b. Assists RCx CP in issue analysis as required
 - 521 c. Provides activities as required to implement recommended corrective actions as
 - 522 directed by the RCx team. Possible activities:
 - 523 i. Repair or refurbishment
 - 524 ii. Adjustment or calibration
 - 525 iii. Construction services
 - 526 iv. Start-up services
 - 527 v. Programming
 - 528 vi. Training
 - 529 d. Provides work schedules
 - 530 e. Facilitates the commissioning of corrective actions
 - 531 f. Provides all closeout documents for corrective actions:
 - 532 i. As-Built drawings
 - 533 ii. O&M manuals
 - 534 iii. Warranties
 - 535 iv. Training documentation
 - 536

537 4. INSTRUMENTATION AND CALIBRATION

538 4.1. MINIMUM INSTRUMENTATION

539 A NEBB Certified RCx Firm will use a variety of instrumentation to perform the specialized
540 testing that is part of the retro-commissioning process. It is the responsibility of the NEBB
541 Certified RCx Firm to provide appropriate instrumentation that meets the minimum requirements
542 of the Tool List table (US or SI) located in Appendix C. In some cases the RCx project may
543 require different instrumentation with different accuracies and capabilities than the minimum
544 instruments indicated in table C. In these cases, the RCx Firm shall provide instruments best
545 suited to the project requirements. Instrumentation used on a NEBB project shall be in proper
546 operating condition and shall be applied in accordance with the manufacturer's
547 recommendations. Appendix C (US or SI) lists the minimum instrumentation that a NEBB
548 Certified RCx Firm shall own and maintain.

549 4.2. RANGE AND ACCURACY

550 A NEBB Certified RCx Firm shall possess instruments that will provide for each function and
551 range listed in Appendix C. Each instrument shall have been specifically designed to meet the
552 criteria (Minimum Accuracy, Range, and Resolution) of the function. Instrumentation with
553 multiple capabilities shall be accepted for more than one function when submitting
554 documentation for a firm's certification, providing that each separate function meets NEBB
555 requirements. Information and data regarding accuracy of all submitted instrumentation for the
556 stated functions shall be available from the manufacturer.

557 The accuracy and range as reported by the instrument manufacturer shall be verified by a
558 testing laboratory traceable to the National Institute of Standards and Technology or equivalent
559 institute in countries other than the United States. Calibration requirements for each function
560 are specified and shall be met.

561 All instrumentation shall comply with the calibration requirements of Appendix C. This condition
562 applies whether a firm has one instrument of each type or multiple instruments.

563 Instruments shall be used in accordance with manufacturer's recommendations. The most
564 suitable instrument, or combination of instruments, should be employed for a particular
565 measurement or reading. For example, a traverse may be accomplished with a pitot tube and
566 manometer (digital, analog, or incline); it is not acceptable to use a pitot tube with another
567 device that does not provide the same overall accuracy.

568

569 5. REPORTS

570 5.1. RETRO-COMMISSIONING REPORT

571 The NEBB *Procedural Standards for Retro-Commissioning of Existing Buildings* establishes
572 baseline requirements of a NEBB Certified RCx Report.

573
574 NEBB RCx Report includes:

- 575 a. Report Title page
- 576 b. Report Certification page
- 577 c. Table of Contents page
- 578 d. Executive Summary
- 579 e. Project CFR
- 580 f. Retro-Commissioning Plan
- 581 g. Data Logs
- 582 h. Interview Records
- 583 i. Testing Check Sheets
- 584 j. Utility Usage Evaluation
- 585 k. Quick Fix Report
- 586 l. Corrective Action Recommendation Report
- 587 m. Commissioning Report of Corrected Actions
- 588 n. Performance evaluations
- 589 o. TAB Report
- 590 p. Test Instrument page

591

592 5.2. REQUIRED PAGES

593 The NEBB Certified RCx Report must include the following content:

594

595 5.3. REPORT TITLE PAGE

596 The report title page includes:

- 597 a. The heading: "Certified Retro-Commissioning Report"
- 598 b. Project Name / Project Address
- 599 c. Owner Name / Address / Contact Numbers
- 600 d. NEBB RCx Certified Firm Name / Address / Contact Numbers / Certification Number

601

602 The report title page includes remaining retro-commissioning team members:

- 603 a. Design Professionals, Name / Address / Contact Numbers
- 604 b. Contractors, Names / Address / Contact Numbers
- 605 c. Vendors, Name / Address / Contact Numbers
- 606 d. Operators, Name / Address / Contact Numbers

607

608 5.4. REPORT CERTIFICATION PAGE

609 The certification page bears the stamp of the NEBB RCx Certified Professional. The stamp on
610 the certification page is signed or has a secure digital signature affixed as evidence that the
611 NEBB Certified Professional has reviewed and accepted the report.

612

613

- 614 The report certification page includes:
- 615 a. Project name
 - 616 b. RCx Certified Professional’s name
 - 617 c. Firm Name; Certification Number; Expiration Date
 - 618 d. Commissioning Phases performed to NEBB Procedural Standards
 - 619 e. RCx Certified Professional’s NEBB Stamp (signed & dated); and this exact
 - 620 language:

621
622 *“The data, conclusions and recommendations presented in this report are a record of*
623 *the retro-commissioning process used on this project in accordance with the NEBB*
624 *Retro-Commissioning Procedural Standards and the contract requirements.”*
625

- 626 f. Statement of Scope of Work and variance deviation documentation

627
628 The Report Certification Page also includes an exact description of the project commissioning
629 scope of work as per the commissioning contract. Any specific required variances from the
630 NEBB required minimum requirements are to be clearly defined.

631
632 The report certification page includes:

633
634 *“The results shown and information given in this report are certified to be true and*
635 *accurate to the extent possible due to the systems operating parameters at the time the*
636 *systems were tested. The retro-commissioning authority makes no claims or warranties*
637 *stated or implied concerning the continued performance, operation or safety or the*
638 *facility past the test date if conditions change or operating parameters were changed by*
639 *others.”*
640

641 **5.5. TABLE OF CONTENTS PAGE**

642 The Table of Contents serves as a guide to the organization of the RCx report.

643
644 **5.6. EXECUTIVE SUMMARY**

645 A NEBB Certified RCx Report includes an executive summary.

646
647 The executive summary includes:

- 648 a. Review of the Retro-Commissioning Project Processes used
 - 649 i. Refer to NEBB Procedural Standards for standard processes
 - 650 ii. Refer to Retro-Commissioning Plan for specific processes
- 651 b. Review any deviations
- 652 c. Review of each recommended corrective action and its relative priority
- 653 d. Review any areas of concern not addressed in the corrective action report and the
- 654 reasons these issues were not addressed
- 655 e. Review of each deferred system test to be performed in the future

656
657 **5.7. PROJECT CFR**

658 A NEBB Certified RCx Report includes the Current Facilities Requirements (CFR). The CFR
659 documents any changes in the existing facility from its original design intent.

662 The CFR includes:

- 663 a. Current occupancy information
- 664 b. Current space use requirements
- 665 c. Change of use documentation
- 666 d. Interior environmental desired setpoints by area
- 667 e. Energy and efficiency requirements
- 668 f. Sustainable and renewable energy requirements
- 669 g. IEQ requirements such as lighting levels, air changes per hour, special filtration, etc.
- 670 h. Operation and maintenance issues

671

672 **5.8. RETRO-COMMISSIONING PLAN**

673 A NEBB Certified RCx Report includes the final project retro-commissioning plan which
674 includes:

- 675 a. Retro-commissioning scope
- 676 b. Retro-commissioning Team
- 677 c. Retro-commissioning Team member responsibilities
- 678 d. Channels of communication
- 679 e. Retro-commissioning procedures used

680

681 **5.9. DATA LOGS**

682 A NEBB Certified RCx Report includes data log graphs used in discovery and analysis of
683 corrective action recommendations.

684

685 Data Logs include:

- 686 a. Project name
- 687 b. Date and time of data
- 688 c. Location
- 689 d. Variables recorded
- 690 e. Parameters

691

692 **5.10. INTERVIEW RECORDS**

693 A NEBB Certified RCx Report includes any interview records that pertain to information used to
694 discover or analyze corrective action recommendations.

695

696 The interview records include:

- 697 a. Project name
- 698 b. Date of interview
- 699 c. Person conducting the interview
- 700 d. Persons interviewed position
- 701 e. Interview questions
- 702 f. Interviewee responses
- 703 g. Interviewer comments

704

705 **5.11. TESTING CHECK SHEETS**

706 A NEBB Certified RCx Report includes completed copies of all testing records including check
707 sheets and forms and all functional tests and data trends or logs which indicate testing results.

708

709 **5.12. ENERGY AUDIT**

710 A NEBB Certified RCx Report will include a facility energy audit equivalent to an ASHRAE Level
711 II energy and water usage audit.

712

713 The energy and water use audit report includes:

- 714 a. Utility energy use cost per square foot per month and per year per utility
715 b. Utility energy units quantity use per month and per year per utility
716 c. Water utility use costs per occupant per month per year
717 d. Water utility Gallons per occupant per month per year
718 e. Energy baseline comparison and rating compared to past building data
719 f. Water usage baseline comparison and rating to past building data
720 g. Energy baseline comparison to peer buildings
721 h. Water usage baseline comparison to peer buildings
722 i. A summary of the current energy use and cost associated with each end use; include
723 calculations performed or name/version of software used including both input and output
724 data
725 j. A description of the facility, including typical floor plans and inventories of major energy
726 and water consuming equipment
727 k. For each practical measure provide –
728 • A description of the existing situation and how excess energy/water is being
729 consumed
730 • A description of the measure including its impact on occupant health, comfort, and
731 safety
732 • A description of any repairs that are required for a measure to be effective
733 • An outline of the impact on operating procedures, maintenance procedures, and
734 costs
735 • Expected life of new equipment and the impact of the life of existing equipment
736 • An outline of any new skills required in operating staff and training/hiring
737 recommendations
738 • Calculations performed or name and version of software used along with both input
739 and output data for both utility savings and financial analyses
740 • Any non-energy benefits for occupants or reductions in equipment operating times
741 l. A table listing estimated costs for all practical measures and recommended bundles of
742 measures, utility cost savings, and financial performance indicators
743 m. Overall project economic evaluation
744 n. Recommended measurement and verification method(s) required to determine actual
745 effectiveness of recommended measures
746 o. Listing of feasible capital intensive measures that may require further comprehensive
747 analyses

748

749 **5.13. QUICK FIX REPORT**

750 A NEBB Certified RCx Report includes a report of all quick fixes performed during the site
751 inspection phase. These items are included in the quick fix report:

- 752 a. System adjustments made
753 b. Sensor calibration performed
754 c. Repairs performed
755 d. Sequences that were changed or modified

- 756 e. Operations that were modified
- 757 f. Operator training given
- 758 g. Quick Fix report will include predicted results of quick fixes performed
- 759

5.14. CORRECTIVE ACTIONS RECOMMENDATION REPORT

761 A NEBB Certified RCx Report includes the final corrective action recommendation report.

762
763 The Corrective Action Recommendation Report includes the following information for each
764 recommended corrective action:

- 765 a. Project name
- 766 b. Description of deficiency
 - 767 i. Descriptive narrative
 - 768 ii. Pictures
 - 769 iii. Test data
- 770 c. Recommended solution
 - 771 i. Engineering calculations
 - 772 ii. Drawings & sketches
 - 773 iii. Sequence of operations or other descriptive narratives
- 774 d. Budget costs of recommended corrective action
- 775 e. Calculation of predicted payback and ROI
- 776 f. Predicted results of recommended corrective action
- 777 g. Predicted schedule of corrective action
- 778

5.15. CORRECTIVE ACTIONS DESIGN OR SCOPE OF WORK DOCUMENTS

780 If included in the scope of the RCx project the RCx team shall provide designs or scope of work
781 documents for the corrections to be made.

- 782 a. Scope of work document describing the corrective work
- 783 b. Design Drawings or Sketches if required
- 784 c. Specifications if required
- 785

5.16. COMMISSIONING REPORT OF CORRECTIVE ACTIONS

787 A NEBB Certified RCx Report includes the final commissioning report of all corrective actions
788 taken, if included in RCx scope of work. Commissioning of corrective actions are be done in
789 accordance with the latest version of the NEBB *Procedural Standard for Whole Building*
790 *Systems Commissioning of New Construction*.

791
792 The Commissioning Report includes:

- 793 a. Report title page
- 794 b. Report certification page
- 795 c. Table of Contents page
- 796 d. Executive Summary
- 797 e. Project CFR
- 798 f. Commissioning Plan
- 799 g. Final Issue Log
- 800 h. Completed pre-functional test forms and check sheets
- 801 i. Completed functional performance test forms and check sheets
- 802 j. Observation reports
- 803 k. Training verification records

- 804 I. Commissioning communications
805 m. Test instrument page
806

807 5.17. TAB REPORT

808 If the scope of work requires a whole building TAB be performed, a NEBB Certified TAB report
809 shall be included in the RCx report, the report will be in accordance with the latest edition of the
810 NEBB *Procedural Standards for Testing, Adjusting and Balancing of Environmental Systems*.
811

812 5.18. COMMISSIONING COMMUNICATIONS

- 813 A NEBB Certified RCx Report includes all pertinent commissioning communications including:
814 a. Letters between the commissioning team members pertinent to the retro-
815 commissioning process performed or not performed for the project
816 b. Emails or other written documentation covering issues or issue resolution for the
817 project
818

819 5.19. TEST INSTRUMENT PAGE

- 820 A NEBB Certified RCx Report includes a Test Instrument page including:
821 a. List of NEBB required tools employed on the project
822 b. Model number and serial number of each instrument
823 c. Certification date of each instrument
824

825 5.20. ALL REPORT PAGES

826 All tested items or systems included in the NEBB RCx Report are clearly identified with a unique
827 designation. The method of identification use unique numbers, mechanical plans identification,
828 or an appropriate narrative description.

- 829 a. All pages contain the name of the project
830 b. All pages are identified by a unique page number
831

832 Pages include a remarks section to record any information pertinent to the data reported on the
833 data sheet.

834 6. TECHNICAL RETRO-COMMISSIONING PROCESS**835 6.1. INTRODUCTION**

836 Retro-commissioning is a holistic process. The RCx Team will investigate, review, and analyze
837 the issues from a global point of view. RCx is not just troubleshooting. The RCx Team will
838 review selected systems to determine how they interrelate with the entire facility to define,
839 investigate and solve problems. The RCx process may also be utilized to evaluate and validate
840 the present operating status of a facility.

841
842 The RCx process includes: the review of all of the appropriate documentation of an existing
843 facility to understand the intent of the previous designs; conducting interviews with
844 management, operations staff and occupants to determine their perspective on current facility
845 conditions; investigation; and testing possible conditions that may influence or relate to a
846 perceived problem.

847
848 The Retro-Commissioning Certified Professional (RCx CP) will then analyze the results of the
849 investigations and recommend solutions. Recommended solutions focus on achieving the CFR,
850 while improving overall building performance. The recommended solutions may, or may not,
851 be implemented by the Owner depending upon capital availability, payback and other issues.

852
853 If the recommendations are accepted by the owner, the implementation of those
854 recommendations is completely commissioned starting with the Design Phase through the
855 Warranty Phase.

856
857 One thing that the NEBB RCx Certified Firm and the NEBB RCx CP must understand is that
858 RCx is not a linear process. The phases and activities presented in this procedural standard
859 may make it appear that once an activity or phase is complete, that activity or phase need not
860 be repeated again. The nature of retro-commissioning is exactly the opposite. The process is
861 iterative. There will be conditions where a discovery of a problem in one area will require the
862 RCx CP to return to a previous activity and start the investigative process again.

863 6.2. RETRO-COMMISSIONING PHASES

864
865 The actual scope of Retro-Commissioning services to be provided will be mutually agreed to
866 between the Owner and the NEBB RCx Certified Firm.

867
868 The Phases of retro-commissioning are:

- 869 a. Planning Phase
- 870 b. Investigation Phase
- 871 c. Improvement Phase
- 872 d. Performance Verification Phase

873
874 NEBB recommends that the four Phases of the RCx process be performed on all projects.
875 However, individual Phases may be performed at the direction of the Owner. The project retro-
876 commissioning scope may also be limited to a portion of a project by Phase.

877
878 If a project Scope of Work requires a different level of retro-commissioning than described by
879 these Procedural Standards, it must be clearly described in the project scope of work and
880 included in the Certification page of the final RCx report.

881

882 If a scope of work does not specifically delineate the retro-commissioning processes, the project
883 is required to meet all baseline language for each Phase. Any project that does not comply with
884 the statements above or involves procedures and requirements that do not include all
885 requirements listed in the NEBB *Procedural Standards for Retro-Commissioning of Existing*
886 *Building Systems* requirements, cannot be signed and stamped as a NEBB certified retro-
887 commissioning report. All references to NEBB, including NEBB logos, stamps, certifications,
888 etc. must be removed from the report.
889

PEER REVIEW ONLY - Not for Field Use

890 **6.3. PLANNING PHASE**

891 The main purpose of the Planning Phase is to clearly define the scope of the retro-
892 commissioning project. This scope of work will become the basis for a contract between the
893 RCx Firm and the Owner. Retro-Commissioning can be a direct consulting service, which
894 provides only discovery and recommendations and no repair or construction services, or a
895 turnkey service which includes all repair and construction services. Also in the Planning Phase
896 the RCx CP must prepare for the Investigation Phase by accumulating all documentation
897 available on the existing facility and its systems. The RCx CP and the RCx Team Members
898 must familiarize themselves with the facility prior to conducting the site investigation and testing.
899 This is most effectively accomplished by reviewing existing documentation of the facility;
900 drawings and specifications, utility bills, work orders, maintenance lists, contractor service
901 invoices, etc.

902 **6.3.1. TEAM MEMBERS**

904 During the Planning Phase the Owner and the RCx CP reviews the subject project to clearly
905 define the owner's expectations, of the project. The required Retro-Commissioning Team
906 members for the Planning Phase:

- 907 a. Owners representatives
- 908 b. Building Operations and Maintenance staff
- 909 c. Retro-Commissioning Certified Professional (RCx CP)
- 910 d. RCx Team members (as required)

911 **6.3.2. TEAM MEMBER RESPONSIBILITIES**

913 During the Planning Phase the Retro-Commissioning Team has the responsibility of performing
914 the following activities of the planning phase. These activities determine the overall scope of the
915 project and determine the owners intended results for the project

916 **6.3.3. SITE TOUR**

918 The RCx CP performs a site tour to determine the general condition of the facility and to
919 determine the cost of the retro-commissioning for the project proposal. The site tour is also the
920 time to discover the owner's desires for the facilities operating improvements, and to define the
921 scope of work that will become the basis of the RCx project.

923 During the site tour, the RCX CP needs to observe conditions that will directly affect the ability
924 to retro-commission the project, and to spot any apparent systems operating issues. These
925 items will also directly affect the cost and the RCx scope of work. Examples of system items:

- 926 a. Access to equipment, systems and components for inspection and testing
 - 927 i. Hard ceilings vs. lay-in tiles
 - 928 ii. Security requirements
 - 929 iii. Overtime requirements vs. normal business hours
- 930 b. Physical condition of the buildings technical systems
 - 931 i. Equipment deferred maintenance
 - 932 ii. Observe how the system is being operated
 - 933 iii. Observe the condition of duct and pipe systems
 - 934 iv. Determine the condition and utilization of control systems
- 935 c. Availability of existing documentation
 - 936 i. Drawings
 - 937 ii. Specifications

- 938 iii. Electric and gas utility bills
- 939 iv. Previous engineering reports/studies
- 940 v. TAB Reports
- 941 vi. Commissioning Reports
- 942 vii. Maintenance work order reports
- 943 d. Involvement of Owner's staff / operating personnel

944

945 **6.3.4. DEVELOP SCOPE OF WORK**

946 The RCx CP assists the owner in developing the project scope of work. Based upon the owners
947 perceived issues with the building a scope of work is developed and may include any of the
948 following:

949

950 Types of Systems that may be included in the RCx scope of investigation

- 951 a. Envelope Systems
- 952 b. HVAC Systems
- 953 c. Control Systems
- 954 d. Lighting Systems
- 955 e. Electrical Systems
- 956 f. Plumbing Systems
- 957 g. Landscape Watering Systems
- 958 h. Renewable and standby power generating systems
- 959 i. Other system such as Fire Alarm, Fire Protection, Security, etc. may also be included
960 in the scope of work if desired due to operating problems

961

962 Types of RCx activities that may be included in the scope of work

- 963 a. Quick Fixes
- 964 b. Complete Test and Balance Services
- 965 c. System Assessment
- 966 d. As Built Drawing creation or verification
- 967 e. Systems Manual Requirements
- 968 f. Operators Guide
- 969 g. Operator training
- 970 h. Performance Verification Program Creation

971

972 **6.3.5. MULTIPLE FACILITY PROGRAM PLAN (OPTIONAL)**

973 If the project is a part of a campus the RCx efforts should include a Multiple Facility Plan to
974 adequately address the needs of a multiple facility owner.

975 This plan may include:

- 976 a. Owners long range goals for his RCx program
- 977 b. Description of the method utilized of determining the RCx team makeup for each
978 building project
- 979 c. Process of weighting each building to determine order of selection for the RCx
980 process
- 981 d. Description of the RCx program results

982

983

984 **6.3.6. PROPOSAL DEVELOPMENT**

985 Develop a document that defines the RCx scope of work for the project. In general, the owner
986 will normally provide some direction as to related issues for various systems, equipment and
987 components to review. The areas for improvement may be energy savings, reduced
988 maintenance costs, improved environmental comfort or other performance improvements with
989 acceptable payback periods for capital improvements.

990
991 The proposal identifies:

- 992 a. Scope of the RCx services to be performed
- 993 b. Cost (Lump Sum, GMP, T&M)
- 994 c. Anticipated schedule
- 995 d. Owner involvement
- 996 e. Retro-Commissioning Team
- 997 f. Qualifications and exclusions

998 **6.3.7. CONTRACT**

1000 The Owner and RCX CP work together to develop an RCx contract or agreement that meets the
1001 Owner's needs. At a minimum, the agreement contains:

- 1002 a. The retro-commissioning scope
- 1003 b. Owner resource commitment to the Retro-Commissioning Team
- 1004 c. Contract cost agreement
- 1005 d. Retro-commissioning schedule expectations
- 1006 e. Owner responsibilities
- 1007 f. RCx provider responsibilities

1008 **6.3.8. RCX PLAN**

1010 The RCx CP develops a preliminary retro-commissioning plan to be utilized for the retro-
1011 commissioning process. The RCx Plan would be based on the actual scope of work required in
1012 the contract. The elements included in the retro-commissioning plan include:

- 1013 a. Project Scope of Work
- 1014 b. Team members and their responsibilities
- 1015 c. Means and methods to be used

1016 **6.3.9. DOCUMENT AND DESIGN REVIEW**

1018 The RCx CP requests copies of the original HVAC construction documents, any remodel or
1019 tenant improvement documents, etc. The RCx CP provides a design review of all documents to
1020 discover any possible original design or construction deficiencies. On most projects, the
1021 availability of these documents will be limited. The RCx CP will need to obtain as much of the
1022 data as possible during this Phase and supplement missing data with field observations in the
1023 Site Investigation Phase. The documents reviewed include:

- 1024 a. Original OPR and BOD
- 1025 b. Architectural, HVAC, controls, plumbing and electrical drawings
- 1026 c. Architectural, HVAC, controls, plumbing and electrical specifications
- 1027 d. Architectural, HVAC, controls, plumbing and electrical submittals
- 1028 e. O & M / systems manuals
- 1029 f. TAB Report
- 1030 g. Commissioning reports
- 1031 h. Previous engineering studies or reports

1032 **6.3.10. OPERATIONS RECORDS REVIEW**

1033 The RCX CP requests copies of all utility bills and maintenance management work order
1034 summaries for the facility for the previous 3 years. The RCX CP requests copies of all HVAC,
1035 Plumbing and electrical maintenance / service invoices and copies of all HVAC, Plumbing and
1036 Electrical equipment replacement or major repairs made since the original buildings
1037 construction. The RCX CP provides a review of maintenance and repair work order issues to
1038 determine if any pattern is present indicating a recurring problem. The following are reviewed:

- 1039 a. Maintenance Management Summary lists of work orders
- 1040 b. Electric, gas, water, steam and other utility bills
- 1041 c. Contractor maintenance / service Invoices
- 1042 d. Equipment or system repair / replacement purchase orders /documentation
- 1043 e. Work order completion status

1044

1045 **6.3.11. CURRENT FACILITY REQUIREMENTS (CFR)**

1046 The RCx CP updates the original OPR to create a current CFR. If no OPR exists, the RCx CP
1047 creates a CFR for the RCx project. The CFR will be updated and expanded as the project
1048 proceeds to completion. The CFR includes:

1049

- 1050 a. Building Requirements
 - 1051 i. Size and Type
 - 1052 ii. Use and Occupancy
 - 1053 1. Maximum Occupancy per shift
 - 1054 2. Time of occupancy per shift
 - 1055 3. Activity level of occupants
 - 1056 iii. Historic Preservation requirements
 - 1057 iv. Future Adaptability requirements
 - 1058 v. Comfort parameters, temperature, humidity, acoustics, vibration, ventilation, light
1059 level, etc.

1060

- 1061 b. Sustainability
 - 1062 i. Define Green Building Rating level
 - 1063 ii. Renewable Energy requirements
 - 1064 iii. Occupant recycling requirements
 - 1065 iv. Natural Ventilation requirements
 - 1066 v. IAQ requirements

1067

- 1068 c. Energy and Efficiency
 - 1069 i. Electrical Usage and Efficiency
 - 1070 ii. Water Usage and Efficiency
 - 1071 iii. Gas Usage and Efficiency
 - 1072 iv. Renewable Energy Utilization
 - 1073 v. Cogeneration Utilization
 - 1074 vi. Measurement and Verification requirements

1075

- 1076 d. Building Envelope Systems
 - 1077 i. List of enclosure types utilized
 - 1078 ii. Description of systems utilized
 - 1079 iii. Description of active envelope control systems utilized

1080

- 1081 e. HVAC Systems and Components
- 1082 i. List of Equipment utilized
- 1083 ii. Description of systems utilized
- 1084 iii. Description of control system utilized
- 1085 iv. List of zone and system setpoints
- 1086
- 1087 f. Electrical and Lighting Systems and Components
- 1088 i. List of Equipment utilized
- 1089 ii. Description of systems utilized
- 1090 iii. Description of control system utilized
- 1091
- 1092 g. Plumbing and Landscape Watering Components
- 1093 i. List of Equipment utilized
- 1094 ii. Description of systems utilized
- 1095 iii. Description of control system utilized
- 1096
- 1097 h. Operation and Maintenance
- 1098 i. Level of Operators technical capability
- 1099 ii. Level of Operators training requirements
- 1100
- 1101

6.3.12. PLANNING PHASE DOCUMENTATION

- 1102 These retro-commissioning documents are produced during Planning Phase:
- 1103 a. Scope of Work
 - 1104 b. Cost Estimate
 - 1105 c. Project schedule
 - 1106 d. Retro-commissioning Contract or Agreement
 - 1107 e. Multiple Facility RCx Plan (Optional)
 - 1108 f. Draft RCx Plan
 - 1109 g. Draft RCx CFR
 - 1110

1111 **6.4. INVESTIGATION PHASE**

1112 During the Investigation Phase, the RCx Team performs the required site investigations and
1113 tests to discover Current Facility Requirements (CFR) and to discover any facility deficiencies
1114 that are preventing the operating conditions desired by the Owner.
1115

1116 **6.4.1. TEAM MEMBERS**

1117 The Retro-Commissioning Team members for the Site Investigation Phase:

- 1118 a. Owners Representatives
 - 1119 b. Retro-Commissioning Certified Professional (RCx CP)
 - 1120 c. Design Team Representatives (If required)
 - 1121 i. Architect
 - 1122 ii. Mechanical Engineer
 - 1123 iii. Electrical Engineer
 - 1124 d. Technical Trade Representatives (If required)
 - 1125 i. General Construction
 - 1126 ii. Mechanical
 - 1127 iii. Electrical
 - 1128 iv. Controls
 - 1129 v. TAB
 - 1130 vi. Plumbing
 - 1131 vii. Fire protection
 - 1132 viii. Others
 - 1133 e. Operators and Maintenance staff (If required)
- 1134

1135 **6.4.2. TEAM RESPONSIBILITIES**

1136 During the Investigation Phase the Retro-Commissioning Team has the responsibility of
1137 discovering building issues that prevent the facility from meeting the desired operating
1138 parameters in accordance with the scope of work and the CFR.

1139 **6.4.3. OWNER'S STAFF TRAINING**

1140 If the owner desires to utilize their staff to assist the RCx CP with the retro-commissioning
1141 process, then the RCx CP will provide RCx training sessions to familiarize the owner's staff in
1142 the retro-commissioning process and their roles, responsibilities and expectations. This will
1143 impact the overall cost versus using the RCx CP personnel for all activities.

1144 **6.4.4. ENERGY AUDIT**

1145 The RCx CP will perform a facility energy audit equivalent to an ASHRAE Level II energy and
1146 water usage audit.
1147

1148 The energy and water use audit will evaluate and provide the following:

- 1149 a. Utility energy use cost per square foot per month and per year per utility
- 1150 b. Utility energy units quantity use per month and per year per utility
- 1151 c. Water utility use costs per occupant per month per year
- 1152 d. Water utility gallons per occupant per month per year
- 1153 e. Energy baseline comparison and rating compared to past building data
- 1154 f. Water usage baseline comparison and rating to past building data
- 1155 g. Energy baseline comparison to peer buildings

- 1156 h. Water usage baseline comparison to peer buildings
1157 i. Total KBTU / year / square foot or EUI
1158

1159 The Energy audit will benchmark the building systems usage against prior year and month
1160 performance and will provide a benchmark against similar peer buildings, normally using Energy
1161 Star Portfolio Manager or other industry databases that may be specific to the industry of the
1162 building.

1163
1164 The following energy audit activities and requirements are developed throughout the entire RCx
1165 process of investigation and testing of the buildings systems.

- 1166 a. Review mechanical and electrical system designs, installed conditions, maintenance
1167 practices, and operating methods
1168 b. Describe and analyze the facility's energy and water using systems
1169 c. Measure key operating parameters and compare to design levels
1170 d. List all possible modifications to equipment and operations that will save energy and
1171 water consumption; Perform preliminary cost and savings estimates on those the owner
1172 considers practical
1173 e. Prioritize the practical modifications per owner preference in the anticipated order of
1174 implementation
1175 f. Create integrated bundles of measures where successive efficiency measures have
1176 significant interactive effects
1177 g. Estimate the potential annual utility cost savings and utility consumption reductions
1178 along with the resulting building EUI
1179 h. Estimate the implementation cost of each practical measure
1180 i. Prepare a financial evaluation of the estimated total potential investment using the
1181 owner's chosen techniques and criteria

1182 **6.4.5. MANAGEMENT STAFF INTERVIEWS**

1183 The RCX CP conducts and documents an interview with the Owner's manager of the facility
1184 being retro-commissioned. The purpose of the interview is to determine the manager's opinion
1185 of any facility issues, if any critical areas of operation are present in the facility and to make
1186 management aware of the activities that will be conducted in the facility during the Retro-
1187 Commissioning Process.

1188
1189 This interview is also utilized to determine security issues, access requirements, schedule
1190 requirements, obtain site access master keys or access cards and to obtain the manager's
1191 permission to interview facility occupants.

1192 **6.4.6. MAINTENANCE STAFF INTERVIEWS**

1194 The RCX CP conducts and documents an interview with the Owner's maintenance staff of the
1195 facility being retro-commissioned. The purpose of the interview is to determine their opinions of
1196 any system problems or facility issues that are a concern to them. This interview also helps to
1197 identify what HVAC or other systems maintenance services they are presently performing and
1198 to discover repairs to equipment or systems they have recently completed.
1199

1200 **6.4.7. OCCUPANT INTERVIEWS**

1201 The NEBB CP checks with the building owner or the occupant manager to pre approve
1202 occupant interviews before they are conducted. Occupant interviews are conducted by the RCx
1203 CP during the investigation process of the building systems. These interviews will be conducted
1204 using either a blind voluntary email response or a by casual conversation without identifying the
1205 occupant. The purpose of the occupant interviews is to determine the occupant's satisfaction
1206 with the space performance and to assist in the discovery process.

1207
1208 **6.4.8. EVALUATION OF OPERATIONS PERFORMANCE**

1209 The RCx CP will evaluate the operations procedures utilized to operate and maintain all
1210 systems in the scope of work. This evaluation will be to determine if additional education or
1211 training is required of operators to bring system performance up to desired levels. This
1212 evaluation will include:

- 1213 a. Maintenance and Operations of HVAC systems
 - 1214 i. System operators level of technical expertise for systems operated and maintained
 - 1215 ii. System operations procedures
 - 1216 iii. Filter maintenance, belt maintenance, coil cleaning
 - 1217 iv. Major equipment maintenance, chillers, boilers, cooling towers, pumps AHU, etc.
- 1218 b. Air and Water balance maintenance
 - 1219 i. Terminal unit calibration kept current
- 1220 c. Lighting Maintenance, bulbs, ballasts and clean fixtures
- 1221 d. Control System operations
 - 1222 i. Schedules and resets maintained in place
 - 1223 ii. Management of overrides and alarms
- 1224 e. Maintenance and Operations of electrical systems
 - 1225 i. System operators level of technical expertise for systems operated and maintained
 - 1226 ii. System operations procedures
 - 1227 iii. Panel and transformer maintenance
 - 1228 iv. Major equipment maintenance, generators, ATS and UPS etc.

1229
1230 **6.4.9. SITE INVESTIGATION**

1231 The RCx CP conducts a survey of the facility to determine if the current conditions such as
1232 occupancy and space utilization have changed since original construction or tenant
1233 improvements of the space. This study will document the current use and current occupancy
1234 levels to determine if a new heat load study is required.

1235
1236 The RCx CP updates the Current Facility Requirements (CFR) with any use that does not match
1237 the original CFR created earlier in the process. The RCx CP identifies any changes in:

- 1238 a. Space utilization
- 1239 b. Total occupancy and activity level
- 1240 c. Changed environmental requirements
- 1241 d. Changed process requirements
- 1242 e. Occupancy schedules

1243
1244
1245
1246

1247 The CFR may not agree with the original OPR / Design Intent. This will be the rule more than
1248 the exception.
1249

1250 However, if during the normal course of RCx work, the RCx Team discovers a life safety issue,
1251 the RCx CP must inform the owner of the life safety issue.
1252

1253 **6.4.9.1. SYSTEM ASSESSMENT**

1254 The RCX team will provide a basic assessment of all systems and major equipment applicable
1255 to the scope of work. The system assessment will verify the following conditions for all systems
1256 and equipment included in the scope of work:

- 1257 a. General equipment data, model number, serial number, size, V, Phase, Amps, etc.
- 1258 b. General operating condition
- 1259 c. Specific deficiencies
- 1260 d. Deferred maintenance issues
- 1261 e. Age of equipment
- 1262 f. Actual operating readings such as Voltage, amperage, flow, pressure, temperature,
1263 etc.
- 1264 g. Operating load at time of inspection

1265 This data in conjunction with specific system tests and investigation data is used to quantize
1266 system performance and is used for the basis of some energy calculations.

1267 **6.4.9.2. SITE DATA LOGGER UTILIZATION**

1268 During the early stages of the Site Investigation Phase the RCX CP launches data loggers
1269 throughout the facility to quantify existing operating parameters such as temperature, humidity,
1270 lighting levels, pressure, timed events, etc. If the control system has been calibrated, the
1271 control system can be utilized to obtain data trends in place of using data loggers.
1272

1273 The information obtained by the data loggers will be utilized to determine actual operating
1274 conditions and the accuracy and effectiveness of the controlling systems. This information can
1275 determine which areas have issues and need additional investigation.
1276

1277 **6.4.9.3. DESIGN CALCULATION STUDIES**

1278 The building may require design calculations where site investigations have determined that
1279 significant changes have occurred from previous designs. These studies / calculations may
1280 include: existing load studies, new energy load calculations, electrical power and lighting
1281 calculations, domestic water usage and sanitary / storm drainage calculations, etc. The studies
1282 / calculations may be performed by any member of the RCx Team who is qualified to do so. If
1283 performed by an RCx Team Member other than the RCx CP, the RCx CP reviews the
1284 calculations. This information will be utilized to determine required changes to the existing
1285 building systems. Normally these studies are not complete engineering studies but are sufficient
1286 to determine if a correction is required. Final recommendations can include full engineering
1287 design studies for each recommendation.
1288

1289 **6.4.9.4. BUILDING SYSTEMS INVESTIGATION AND TESTS**

1290 The RCx team is required to test all systems sufficiently to determine if the systems are
1291 operating correctly. This required testing may be control trending, space temperature and
1292 humidity measurements, data logger trending, TAB measurements, observation measurements

1293 or through occupant interviews. This testing activity is used to determine which systems or
 1294 equipment will require further investigation or testing and is not intended to be the final
 1295 evaluation of performance or energy efficiency.

1296 6.4.9.5. TESTING TYPES

1297 The RCx CP will need to investigate the condition, operation and performance of all equipment,
 1298 systems and components of the various building systems contained in the scope of work. The
 1299 basic investigation process is to provide system testing to determine which systems are not
 1300 performing in an optimized condition. Once an area of concern is identified additional
 1301 investigations and testing is utilized to drill down into the system until the source of the issue is
 1302 discovered. Retro-commissioning will usually involve these building systems and testing types
 1303 in the discovery process:

- 1304 a. Building Envelope systems
 - 1305 i. Inspect envelope barrier for air, vapor, water and thermal intrusion
 - 1306 ii. Inspect fenestration for shading and water control
 - 1307 iii. Inspect door seals and operators
 - 1308 iv. Verify building pressurization
- 1309 b. Landscape lighting and irrigation systems
 - 1310 i. Verify landscape watering schedule
 - 1311 ii. Verify lack of leaks in landscape watering system
 - 1312 iii. Verify landscape lighting schedule control
 - 1313 iv. Inspect landscape lighting type and efficiency
- 1314 c. HVAC systems and equipment
 - 1315 i. Take as found air flow and water flow readings to meet scope of work
 - 1316 ii. Measure OSA flow
 - 1317 iii. Verify terminal unit calibration
 - 1318 iv. Take as found temperature and pressure readings at major equipment
- 1319 d. HVAC Control Systems
 - 1320 i. Trend room temperature, humidity and CO₂ and setpoints over a several day
 - 1321 period. Compare trends for offsets between setpoint and actual readings
 - 1322 ii. Test control system schedule control
 - 1323 iii. Test Major equipment reset control sequence
 - 1324 iv. Test economizer operation and building pressurization control
 - 1325 v. Inspect current system alarms and alarm logs
 - 1326 vi. Verify room sensor and AHU sensor calibration
 - 1327 vii. Verify operators use of physical overrides and graphic overrides
 - 1328 viii. Observe usability of the graphics for operator productivity
- 1329 e. Plumbing Systems
 - 1330 i. Verify incoming water pressure
 - 1331 ii. Inspect system for leaks
 - 1332 iii. Verify flush valve flow and timing for auto flush valves
 - 1333 iv. Verify hot water supply temperature
- 1334 f. Electrical Lighting and Control Systems
 - 1335 i. Verify type of light tubes and ballasts
 - 1336 ii. Test lighting levels
 - 1337 iii. Verify lighting control schedule
- 1338 g. Electrical Power systems
 - 1339 i. Verify voltage and power factor
 - 1340 ii. Verify standby and emergency power function
 - 1341

1342 **6.4.9.6. PERFORM QUICK FIXES**

1343 The RCX CP and his/her team Perform non-capital repairs, system adjustments, and
1344 corrections as a part of the site investigation. The reason for this activity is to improve the
1345 operation of the facility and to eliminate all obvious issues so they do not mask any underlying
1346 major issues. The RCX CP provides documentation for all quick fixes performed. These quick
1347 fixes can include:

- 1348 a. Temperature control sensor calibration, control parameters, control connections, etc.
- 1349 b. Control setpoints, overrides, schedules and alarm adjustments
- 1350 c. Minor piping repairs such as minor leaks, clean strainers, etc.
- 1351 d. Ductwork repairs such as obvious duct leaks, open/closing dampers, duct
1352 connections, device repairs, etc.
- 1353 e. Correcting Test & balance of HVAC systems to match current conditions as per
1354 scope of work
- 1355 f. Electrical repairs of loose terminations, lighting repairs, etc.
- 1356 g. Building envelope repairs such as air leaks, water intrusion, defective building
1357 openings, etc.

1359 These Quick Fixes may, or may not, be of a nature that would significantly impact the overall
1360 cost of the RCx efforts. This issue is addressed in the scope of work and a budgetary amount
1361 may be identified in the contract. This work may be accomplished by the RCx Team or by the
1362 Owner's operating personnel or by other contractors depending upon the contract scope of
1363 work. The RCX CP maintains a list of all items repaired, corrected or adjusted while doing
1364 these quick fixes.

1365 **6.4.9.7. PERFORM SYSTEM OPTIMIZATION**

1367 The RCx process is intended to not only find issues and recommend corrections; it is also
1368 intended to optimize existing systems to operate at the best possible level of performance using
1369 the existing systems and their condition without capital improvements. This activity provides the
1370 owner with value from the RCx process, not just from the capital improvements. Performance
1371 Optimization is done by the RCx team. If the work required to optimize a system becomes
1372 extensive or if the RCx team does not have team members who are capable of performing
1373 these specific optimization activities they may become recommendations for Capital
1374 Improvements.

1376 Performance optimization involves the following activities:

- 1377 a. Adjustments of control setpoints and schedules
- 1378 b. Correction of control sequences
- 1379 c. Quick Fixes
- 1380 d. Operator Training
- 1381 e. Remediation of deferred maintenance issues

1382 **6.4.10. UPDATE CFR**

1384 Update the CFR for any changes discovered during the Site Investigation Phase.

1385
1386 These retro-commissioning documents are produced during the Site Investigation Phase:

- 1387 a. Revised Current Facility Requirements (CFR)
- 1388 b. Building use study documentation
- 1389 c. Site Investigation and test reports (for scope of work activities)
- 1390 d. Building load calculations (If required)

1391 e. Quick fix report

1392

1393 **6.4.11. ISSUE ANALYSIS**

1394 From the inspection and test data collected the RCx CP must now analyze all of the issues
1395 discovered, synthesize possible solutions, and create final recommendations for the facility's
1396 improvements to the owner. Although the Issue Analysis is described as a separate event, in
1397 actuality, issues are being analyzed during the entire Investigation Phase. Methods used to
1398 analyze issues range from reviewing trend graphs to comparing field measurements with an
1399 appropriately known range of values. When abnormal operation is identified, then possible
1400 causes are listed and the process of root cause analysis begins. The use of Fault Detection
1401 and Diagnostics (FDD) or Smart Building Controls (SBC) software may also be used to perform
1402 advanced data analytics.

1403

1404 **6.4.11.1. DEFINE ISSUES**

1405 The RCx CP and the RCx Team will review the information from the previous activities to
1406 determine the appropriate issues that are affecting the building's performance. As much as
1407 possible, the RCx CP outlines each issue into its simplest corrective action and groups these
1408 issues in a single corrective action statement.

1409

1410 **6.4.11.2. ANALYZE ISSUES**

1411 The RCx CP and RCx Team will provide a technical analysis of all defined issues to correctly
1412 identify the potential solutions affecting building performance issues. Possible, root causes of
1413 each issue are listed, and analyzed by comparing data such as test measurements and trend
1414 graphs obtained during the Investigation Phase. These solutions may include energy
1415 optimization, reduced maintenance costs, improved indoor environment conditions, improved
1416 comfort performance, and customer / client satisfaction / retention. The technical analysis may
1417 include:

- 1418 a. Analysis of each issue's effect on indoor comfort and environmental conditions
- 1419 b. Calculations of each issue's effect on energy or water consumption
- 1420 c. Estimated budget cost of each recommended corrective action
- 1421 d. Calculation of simple payback or ROI if applicable for each recommended corrective
1422 action
- 1423 e. Analysis on how each issue impacts other issues
- 1424 f. Analysis of the criticality of each issue

1425

1426 Remember, retro-commissioning is an iterative process. After defining and analyzing the
1427 issues, the RCX CP and the RCx Team may be required to go back and perform additional Pre-
1428 Site or Site Investigation activity to validate or clarify an issue.

1429

1430 **6.4.11.3. TREND DATA ANALYSIS**

1431 Trended data from either portable data loggers or a calibrated BAS is an excellent analysis tool
1432 to help identify issues and possible corrective actions. By analyzing trend data, the RCX CP is
1433 better able to triangulate information between reviewing the construction documents, the O&M
1434 and occupant interview process, and actual field testing performed during the Site Investigation
1435 Phase.

1436 Trends have a day and time stamp, allowing for issues to be identified such as incorrect
1437 operating schedules, no use of temperature setbacks during unoccupied modes and poor

1438 operation of economizers. Additionally, detailed analysis of trended data for AHUs and VAV
1439 boxes can indicate opportunities such as resetting of discharge air temperature or duct static
1440 pressure

1441 **6.4.11. UPDATE RCx PLAN**

1442 Update the RCx Plan for any changes or additions due to discovered issues changing the
1443 required commissioning team or the RCx processes or testing utilized.

1444 **6.4.12. RECOMMEND PROBLEM RESOLUTIONS**

1446 The RCX CP and the RCx Team creates solutions that are based on the technical analysis of
1447 each issue. Corrections are recommended that will solve systems issues such as:

- 1448 a. System functionality (Make it work)
- 1449 b. Improve Building Comfort
- 1450 c. Reduce maintenance time and costs
- 1451 d. Reduce utility use and costs

1452

1453 Each recommendation will include:

- 1454 a. Issue description
- 1455 b. Recommended solutions
- 1456 c. Technical description of the solution implementation
- 1457 d. Solution calculations (If Applicable)
- 1458 e. Implementation sketches or drawings (If Applicable)
- 1459 f. Expected results of recommended correction
- 1460 g. Energy Savings Calculations (If Applicable)

1461

1462 When a recommended solution has an energy cost savings associated with it, then an energy
1463 calculation is required to help build the financial cost justification necessary for the owner to
1464 approve the measure. In addition to the energy savings calculation, the cost to implement the
1465 measure is also required, so the Simple Pay Back (SPB) can be calculated.

1466

1467 Additional cost justification metrics such as Return on Investment (ROI), Net Present Value
1468 (NPV) and Life Cycle Cost (LCC) should also be used as required.

1469

1470 **6.4.13. RECOMMENDED IMPROVEMENT REPORT**

1471 The RCX CP develops a Recommended Improvement Report for the Owner's use in evaluating
1472 the costs and benefits of each recommendation. The recommendations are placed in order of
1473 importance to achieve the requirements of the CFR. The report includes:

- 1474 a. Issue description
- 1475 b. Recommended solution
- 1476 c. Budgetary cost of solution
- 1477 d. Anticipated savings or results
- 1478 e. Priority of the recommendation
- 1479 f. Anticipated implementation schedule

1480

1481 All improvements approved by the Owner and implemented during the Corrective Actions Phase
1482 would be fully commissioned and all related documentation would be found in the Final Retro-
1483 commissioning Report.

1484

1485 **6.4.14. RECOMMENDED IMPROVEMENT REPORT PRESENTATION**

1486 The RCx CP will meet with the owner to present the findings and recommendations.
1487 Specifically the meeting identifies how the recommended solutions improve the building
1488 performance issues based on the identified CFR. The approved recommendations become the
1489 basis of the OPR for commissioning the corrective actions.

1490
1491 **6.4.15. INVESTIGATION PHASE DOCUMENTATION**

1492 These retro-commissioning documents are produced during the Investigation Phase:

- 1493 a. Updated RCx Plan
- 1494 b. Updated Current Facility Requirements (CFR)
- 1495 c. Building use study documentation
- 1496 d. System Assessment
- 1497 e. Site Investigation and test reports (for scope of work activities)
- 1498 f. Building load calculations (If required)
- 1499 g. Quick fix report
- 1500 h. Recommended Solutions Report
- 1501 i. Drawings or other design documents created during this phase of the process

1502
1503

PEER REVIEW ONLY - Not for Field Use

1504

1505 **6.5. IMPROVEMENT PHASE**

1506 Once the Recommended Improvement Report has been presented to the owner, the owner
1507 controls the direction of the process. The Owner may elect to approve and implement all, some,
1508 or none of the recommendations. The Recommended Solutions Report can include measures
1509 ranging from low cost control programming changes to large capital improvement projects. If the
1510 Owner elects to implement any of the recommendations, the work falls under the Improvement
1511 Phase of the process.

1512

1513 There are various delivery systems that provide the approved Improvement projects. An owner
1514 may elect to self-perform the design and construction with their personnel, have the remedial
1515 design prepared by a design professional of his/her choice and bid the work to a selected group
1516 of contractors, have the design and construction performed on a design/build approach or have
1517 the Retro-Commissioning Team design and construct the improvements. For any approach the
1518 RCx CP is retained to commission the design and construction of the Improvement Project.
1519 The responsibilities and activities identified below are generic and would apply to any selected
1520 delivery system.

1521

1522 **6.5.1. TEAM MEMBERS**

1523

- a. Owners Representatives
- b. Retro-commissioning Authority (RCx CP)
- c. Design Team Representatives (If required)
 - i. Architect
 - ii. Design Engineers
- d. Contractors' Representatives (If required)
 - i. General Contractor
 - ii. Mechanical Contractor
 - iii. Electrical Contractor
 - iv. Plumbing Contractor
 - v. Controls Contractor
 - vi. TAB Firm
 - vii. Specialty Contractors or Vendors (As required)

1530

1531

1532

1533

1534

1535

1536

1537

6.5.2. TEAM RESPONSIBILITIES

1538 During the Corrective Action Phase the Retro-Commissioning Team has the responsibility of
1539 facilitating and/or performing the corrective actions as outlined by the Owner.

1540

1541

6.5.3. APPROVAL OF RECOMMENDATIONS

1542

1543

1544

1545

1546

6.5.4. SCOPE OF WORK DEVELOPMENT

1547

1548

1549

The owner selects the method of implementing the corrective actions which will determine who is responsible for creating detailed scope of work documents for the corrective actions. If creating scope of work documentation is included in the RCx project scope of work the RCx

1550 team will develop detailed scope of work documentation for each corrective action selected. The
1551 scope of work documents shall include:

- 1552 a. Description of the work to be performed
- 1553 b. List of applicable codes or standards
- 1554 c. Description and/or model numbers of required equipment or devices
- 1555 d. Description of the intended results
- 1556 e. Sketches as required

1557
1558

6.5.5. REMEDIAL DESIGN

1559 If remedial design is required to properly define a capital project, a design professional or other
1560 qualified person must prepare the required contract documents. As previously stated, the
1561 Owner may elect any of the various delivery approaches. The RCx CP commissions the
1562 remedial design by employing the elements of Design Phase Commissioning, if remedial design
1563 is required.

1564
1565

6.5.6. CONSTRUCTION

1566 The remedial design is implemented in the Construction Phase. The Owner may elect to
1567 engage outside contractors or may elect to utilize the RCx CP and his/her RCx Team Members.
1568 The RCx CP commissions the construction by employing the elements of Construction Phase,
1569 Acceptance Phase and Warranty Phase Commissioning.

1570
1571

6.5.7. COMMISSIONING

1572 All construction and corrections made during the Improvement Phase must be commissioned.
1573 For the sake of continuity, Commissioning will preferably be performed by the RCx CP. The
1574 following Phases are commissioned:

- 1575 a. Design Phase (Remedial Design)
- 1576 b. Construction Phase
- 1577 c. Acceptance Phase
- 1578 d. Warranty Phase

1579 Although not specifically re-printed in this Procedural Standards, all activities, responsibilities,
1580 and documentation requirements as identified in the current edition of the NEBB *Procedural*
1581 *Standards for Whole Building Systems Commissioning of New Construction* will be followed.

6.5.8. IMPROVEMENT PHASE DOCUMENTATION

1583 The following documentation is provided at completion of the Improvement Phase:

- 1584 a. List of corrective actions selected
- 1585 b. Scope of work or design documentation of the corrective actions
- 1586 c. Commissioning report of corrective work

1587

1588 **6.6. PERFORMANCE VERIFICATION PHASE**

1589 The Performance Verification Phase is used to validate the facility's performance after the
1590 implementation of the Retro Commissioning project and any Improvements made. It is also
1591 used to conduct a Lessons Learned Workshop to improve the delivery of future projects and to
1592 implement an ongoing commissioning and performance evaluation process for the owner.

1593
1594 **6.6.1. TEAM MEMBERS**

- 1595 a. Owners representatives
1596 b. Retro-Commissioning Authority (RCx CP)
1597 c. Design Team representatives (If Required)
1598 d. Contractors' representatives (If Required)
1599 i. Mechanical contractor (If Required)
1600 ii. Controls contractor (If Required)
1601 iii. TAB firm (If Required)
1602 iv. Operator or maintenance staff (If Required)

1603
1604 **6.6.2. TEAM RESPONSIBILITIES**

1605 During the Performance Verification Phase the Retro-Commissioning Team verifies the
1606 performance of the facility and its systems.

1607
1608 **6.6.3. PERFORMANCE VERIFICATION**

1609 The RCx CP validates the improved performance of the facility by performing these procedures
1610 as appropriate to the application.

- 1611 a. Compare energy and water usage against previous usage data utilizing
1612 measurement protocols established in the CFR. Document the change in energy
1613 and water usage for the facility. If necessary normalize readings for:
1614 i. Equal number of days in the billing cycle
1615 ii. Weather
1616 iii. Change in occupancy
1617 iv. Change in facility use and operation
1618 v. Change in utility rate or rate structure
1619
1620 b. Compare current usage to selected peer benchmark data. Provide rating for current
1621 performance, normally using Energy Star Portfolio Manager.
1622
1623 c. Interview Occupants for comfort issues and review maintenance management
1624 records since completion of the corrective actions and adjustments made during the
1625 original retro-commissioning process. Document the change in maintenance and
1626 trouble calls for the facility.
1627
1628 d. Review specific improvement goals of the owner and determine if they were
1629 achieved.
1630 i. Trends of space temperatures and humidity's performance
1631 ii. Trends of other key variables to determine level of performance
1632
1633 e. Document performance in a Performance Verification Report
1634

1635 **6.6.4. ONGOING PERFORMANCE VERIFICATION**

1636 The RCx CP will establish or verify an ongoing performance verification system for the
1637 operators of the facility. That ongoing performance verification system will consist of a
1638 methodology of measuring energy and water usage and building comfort in a cyclic manner is in
1639 place to continuously verify the performance of the systems.

1640

1641 The RCx CP will provide an ongoing performance verification system with the following:

- 1642 a. OCx Performance Verification manual which provides written procedures for operators
1643 performing the ongoing verification process
- 1644 b. Standard procedures for obtaining, recording and reporting energy and water usage
- 1645 c. Standard procedures for calculating and comparing usage to past usage data including
1646 desired normalization of data
- 1647 d. Standard procedures for evaluating comfort and building IEQ performance and reporting
- 1648 e. Standard procedures for reporting of data and performance rating

1649

1650 **6.6.5. LESSONS LEARNED WORKSHOP**

1651 When included in the Scope of Work, the NEBB RCx CP conducts a Lessons Learned
1652 Workshop at the conclusion of the Improvement Phase. The meeting identifies areas where
1653 improvements could be made in future RCx projects. The NEBB RCx CP acts as facilitator. The
1654 Owner and all appropriate team members should be invited to participate and provide input in
1655 the workshop.

1656

1657 The NEBB RCx CP produces a Lessons Learned Report as a written record of the meeting.

1658

1659 **6.6.6. PERFORMANCE PHASE DOCUMENTATION**

1660 This documentation is provided at completion of the Follow-Up Phase:

- 1661 a. Performance Verification Report
- 1662 b. Ongoing Performance Verification System Program Documentation
- 1663 c. Lessons Learned Report

1664 **APPENDIX**1665 **A. APPENDIX ACRONYMS**

1666	AHU	Air Handling Unit
1667	ANSI	American National Standards Institute
1668	ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
1669	ATS	Automatic Transfer Switch
1670	BAS	Building Automation Software
1671	BET	Building Envelope Testing Certification
1672	BOD	Basis of Design
1673	BSC	Building Systems Commissioning
1674	CA	Commissioning Authority
1675	CD	Contract Documents
1676	CFM	Cubic Feet per Minute
1677	CFR	Current Facility Requirements
1678	CM/GC	Construction Manager / General Contractor
1679	CO	Carbon monoxide
1680	CO ₂	Carbon dioxide
1681	CP	Certified Professional
1682	CPT	Clean Room Performance Test Certification
1683	CW	Chilled Water
1684	Cx	Commissioning
1685	Cx-NC	Commissioning – New Construction
1686	DD	Design Development
1687	DDC	Direct Digital Control
1688	DPC	Design Phase Commissioning
1689	EUI	Energy Utilization Index
1690	FDD	Fault Detection Diagnostics
1691	FHT	Fume Hood Testing Certification
1692	FPT	Functional Performance Test
1693	GPM	Gallons per Minute
1694	HVAC	Heating, Ventilation, Air Conditioning
1695	HW	Hot Water
1696	ID	Identification
1697	IEQ	Indoor Environment Quality
1698	IP	Inch-Pounds measurement system
1699	LCC	Life Cycle Costing
1700	NEBB	National Environmental Balancing Bureau
1701	NVP	Net Present Value
1702	O&M	Operating and Maintenance Manual
1703	OPR	Owner's Project Requirements
1704	OSA	Outside Air
1705	PVT	Performance Verification Testing
1706	RCx	Retro Commissioning
1707	ROI	Return on Investment
1708	S	Sound Testing Certification
1709	SBC	Smart Building Controls
1710	SI	International System of measurement
1711	SO	Site Observation
1712	SOW	Scope of Work

1713	SP	Set Point
1714	SPB	Simple Pay Back
1715	TAB	Testing, Adjusting and Balancing
1716	T&M	Time and Material
1717	UPS	Uninterruptable Power Supply
1718	V	Vibration Testing Certification
1719	VAV	Variable Air Volume
1720		
1721		

PEER REVIEW ONLY - Not for Field Use

1722 **B. APPENDIX DEFINITIONS**

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Acceptance Criteria:

1. The value, or range of values, compared to the measured value that determines if the test results pass or fail.
2. A test made upon completion of fabrication, receipt, installation or modification of a component unit or system to verify it meets the requirements specified.

Acceptance Phase Commissioning: Commissioning tasks executed after the construction has been completed, all Site Observations and Static Tests have been completed and all Pre-Functional Testing has been completed and accepted. The main commissioning activities performed during this phase are verification that the installed systems are functional as verified by conducting Functional Performance tests and Owner Training.

Accuracy: The capability of an instrument to indicate the true value of a measured quantity.

Activities: The individual steps or action items necessary to complete a course of action in the NEBB RCx program.

Analysis: The process of discovering underlying issues from a set of test data or observations

Basis of Design (BOD): The Engineer's Basis of Design is comprised of two components: the Design Criteria, and the Design Narrative. These documents record the concepts, calculations, decisions, and product selections used to meet the Owner's Project Requirements (OPR) and to satisfy applicable regulatory requirements, standards, and guidelines.

Building Envelope: The boundary or barrier separating the interior volume of a building from the outside environment.

Calibrate (Calibration): The act of comparing an instrument of unknown accuracy with a standard of known accuracy to detect, correlate, report, or correct by adjustment unacceptable variation in the accuracy of the tested instrument.

Certificate of Compliance (Conformance): A written statement, signed by a qualified party, attesting the items or services are in accordance with specified requirements, and accompanied by additional information to substantiate the statement.

Certification: The process of validation required to obtain a Certificate of Compliance.

Checklist: List of data or inspections verified to ensure proper system or component installation, operation and function.

Commissionability: A design component or construction process with the necessary elements to allow a system or component to be effectively measured, tested, operated and commissioned.

Commissioning Authority (CA): The NEBB Certified BSC Professional (NEBB BSC CP) who administers the Technical Commissioning Process by managing the Cx team. The CA is responsible, in the standard, to identify the NEBB BSC or RCx CP, members of his staff, or appointed members of the commissioning team.

- 1772
1773 **Commissioning Plan:** A document that outlines the project scope and defines responsibilities,
1774 procedures, schedules, and documentation requirements of the Technical Commissioning
1775 Process.
1776
- 1777 **Commissioning Report:** The final document that presents the commissioning results for the
1778 project, including reports, an executive summary, commissioning plan, issue log,
1779 correspondence, and all appropriate check sheets and test forms.
1780
- 1781 **Commissioning Team:** Team members whose coordinated activities are responsible for
1782 implementing the Technical Commissioning Process.
1783
- 1784 **Construction Documents:** Construction documents usually include the project manual
1785 (specifications), plans (drawings), and general terms and conditions of the contract. These
1786 documents vary from project to project, as the owner needs change and as various State,
1787 Federal, or International regulations dictate.
1788
- 1789 **Construction Phase Commissioning (CPC):** All commissioning efforts executed during the
1790 construction process after the design phase and prior to the Post Occupancy Phase
1791 Commissioning.
1792
- 1793 **Contract Document Evaluation:** A NEBB Certified Firm evaluation of the contract plans and
1794 specifications is limited to determining the scope of responsibilities and reporting.
1795
- 1796 **Control Loop Tuning:** The capability to adjust response time of a PID controlled point to meet
1797 the sequence of operation requirement.
1798
- 1799 **Contract Document Review:** A NEBB Certified TAB Firm review of the contract plans and
1800 specifications is limited to determining the proper placement of balancing devices. A NEBB
1801 Certified TAB Firm is not responsible for the review of equipment sizing, design load
1802 calculations or any other engineering function that is properly the responsibility of the design
1803 professional.
1804
- 1805 **Contract Documents (CD):** Contract documents include design and construction contracts,
1806 financial and scope of work agreements, all plans and specifications.
1807
- 1808 **Corrective Action:** Repairing, replacing, re-building, calibrating or adjusting of equipment or
1809 systems.
1810
- 1811 **Data Logger:** A test instrument used to record specific readings over time. Normally a battery
1812 operated instrument with multiple channels for more than one reading.
1813
- 1814 **Deferred Maintenance:** Maintenance procedures not done due to costs, lack of manpower or
1815 proper maintenance.
1816
- 1817 **Deferred System Test:** Tests that cannot be completed at the end of the Construction Phase
1818 due to ambient conditions, schedule issues or other conditions preventing testing.
1819
- 1820 **Deficiency:** Any installation, measurement, or finding outside the tolerances allowed by NEBB
1821 Procedural Standards or project specifications.
1822

1823 **Design Criteria:** A listing of the projects design requirements, including the source of the
1824 design requirements. These are used during the design phase review to show the design
1825 element meets the OPR.
1826

1827 **Design Intent:** Documents providing a written, detailed record of ideas, concepts and criteria
1828 defined as important by the owner. The overall term includes the OPR and the BOD.
1829

1830 **Design Phase Commissioning (DPC):** All commissioning tasks executed during the project
1831 Design Phase.
1832

1833 **Design Professional:** The design professional, architect or engineer of record of the project.
1834

1835 **Discovery Phase:** The portion of the RCx phase where drawing and specification review,
1836 document review and site investigation occur. This phase typically defines the significant issues
1837 causing comfort and maintenance problems as well as excessive energy use.
1838

1839 **Environmental Systems:** Systems using a combination of mechanical equipment, airflow,
1840 water flow and electrical energy to provide heating, ventilating, air conditioning, humidification,
1841 and dehumidification for the purpose of human comfort or process control of temperature and
1842 humidity.
1843

1844 **Executive Summary:** A section of the Commissioning Report that reviews the general
1845 outcome of the project. It includes any unresolved issues, recommendations for the resolution
1846 of unresolved issues, and all deferred testing requirements.
1847

1848 **Fenestration:** Any opening in a building structure such as windows, skylights, window walls,
1849 doors, louvers, and access panels.
1850

1851 **Functional Performance Test (FPT):** Verification of the appropriate sequential performance of
1852 automated systems and stability of these sequences under normal, upset and transitional
1853 conditions.
1854

1855 **Functionality:** A design component or construction process allowing a system or component to
1856 operate or be constructed in a manner producing the required outcome of the OPR.
1857

1858 **Graphic Verification Tests:** Tests intended to prove the graphic diagrams on the DDC screen
1859 are factual and represent the actual arrangement and operation of a system or component in
1860 the field.
1861

1862 **Greywater:** Untreated wastewater that has no come into contact with toilet waste, kitchen sink
1863 waste, dishwasher waste or similarly contaminated sources. Grey water includes wastewater
1864 from bathtubs, showers, lavatories, clothes washer and laundry tubs. (Also known as: grey
1865 water, graywater, or greywater.)
1866

1867 **Harmonics:** A sinusoidal component that is a whole number multiple of the fundamental
1868 frequency.
1869

1870 **Implementation Phase:** The portion of the project where courses of corrective actions are
1871 made to various HVAC, electrical or building envelope components of the project. Control
1872 sequences or Test and Balance adjustments are completed during this portion of the project.
1873

1874 **Indoor Environmental Quality (IEQ):** The relative quality of the indoor air environment and
1875 normally includes temperature, humidity, levels of CO₂ and amounts of particulates such as
1876 dust, ozone, formaldehyde, volatile organic compounds (VOC) and other trace elements. IEQ
1877 can also relate to biological contamination such as mold or Legionella bacteria and quality of the
1878 space for sound & vibration, views, and daylighting.

1879
1880 **Industry Accepted Best Practice:** A design component or construction procedure that has
1881 achieved industry consensus for quality performance and functionality. Refer to NEBB *Design*
1882 *Phase Commissioning Handbook* for examples.

1883
1884 **Informative Appendices** - The informative appendices to NEBB Procedural Standards and
1885 informative notes located within the Procedural Standards contain additional information and are
1886 not mandatory or part of the Procedural Standards.

1887
1888 **Infrared Imaging System:** An instrument that converts the spatial variations in infrared
1889 radiance from a surface into a two-dimensional image of that surface, in which variations in
1890 radiance are displayed as a range of colors or tones.

1891
1892 **Infrared Thermography:** The process of generating thermal images that represent
1893 temperature and emittance variations over the surfaces of objects.

1894
1895 **Installation Verification:** Observations or inspections that confirm the system or component
1896 has been installed in accordance with the contract documents and to industry accepted best
1897 practices.

1898
1899 **Issues/Deficiency Log:** A formal, ongoing record of problems or concerns – and their
1900 resolution – raised by members of NEBB Technical Commissioning or Retro-Commissioning
1901 Teams during the course of the their activity.

1902
1903 **Maintainability:** A design component or construction layout that provides clearance for
1904 equipment or components to be effectively maintained. This includes adequate room for access
1905 to adjust and repair the equipment.

1906
1907 **Maintenance Management Work Order:** Work order for building repairs or troubleshooting
1908 created from the owner's maintenance management system or procedures.

1909
1910 **May:** Indicates a course of action permissible as determined by the NEBB Certified Firm.

1911
1912 **NEBB BSC Certified Firm:** A firm that has met and maintains all the requirements of the
1913 National Environmental Balancing Bureau for firm certification in Building Systems
1914 Commissioning and is currently certified by NEBB. A NEBB Certified BSC Firm must employ at
1915 least one NEBB Certified BSC Professional in a full time management position.

1916
1917 **NEBB BSC Certified Professional:** A full time employee of the firm in a management position
1918 who has successfully passed the Certified Professional level examinations and other
1919 requirements, and maintains the Certified Professional re-qualification requirements of NEBB.

1920
1921 **NEBB Certified BSC Report:** The final report of the project Technical Commissioning
1922 Process. The commissioning report includes all testing data results, issue logs, observations
1923 and other pertinent data from the Technical Commissioning Process. NEBB Certification
1924 indicates that the Technical Commissioning Process and the report have been completed and

1925 compiled in accordance with the current edition of the NEBB *Procedural Standards for Building*
1926 *Systems Commissioning*.

1927
1928 **Normative Appendices** - The normative appendices to NEBB Procedural Standards are
1929 considered to be integral parts of the mandatory requirements of the Procedural Standards,
1930 which, for reasons of convenience, are placed apart from all other normative elements.

1931
1932 **Optimization:** The process of adjusting systems operating parameters to improve its operating
1933 characteristics to the highest level of performance without capital outlay.

1934
1935 **Owner's Current Facility Requirements (CFR):** A written document that details the project
1936 requirements and the expectations of how it is being used and operated. These include project
1937 goals, measurable performance criteria, cost considerations, benchmarks, success criteria, and
1938 supporting information.

1939
1940 **Owner's Project Requirements (OPR):** A written document that details the project
1941 requirements and the expectations of how it will be used and operated. These include project
1942 goals, measurable performance criteria, cost considerations, benchmarks, success criteria, and
1943 supporting information.

1944
1945 **Performance Verification:**
1946 1. Verifying a facilities comfort level, energy usage or water usage performance as
1947 compared to a previous set of readings or verifications.
1948 2. Activities performed during the Post Occupancy Phase of a NEBB Commissioning
1949 project.

1950
1951 **Phase:** A group of activities that outline the courses of action necessary to complete that group
1952 of activities

1953
1954 **Point-to-Point Verification:** This activity confirms a specific point device is paired and
1955 connected to the proper controller, that sensors are properly calibrated, actuators are ranged
1956 correctly and that graphic points are connected to the correct end device.

1957
1958 **Post Occupancy Phase:** During this phase the NEBB CP will revisit the project and perform
1959 performance verification. This could include trend review, staff interviews, and functional testing.

1960
1961 **Potable Water:** Water that is satisfactory for drinking, culinary, and domestic purposes and that
1962 meets the requirements of the Health Authority Having Jurisdiction.

1963
1964 **Procedure:** A defined approach that outlines the execution of a sequence of work or
1965 operations. Procedures are used to produce repeatable and defined results.

1966
1967 **Rainwater:** Natural precipitation not contaminated by use.

1968
1969 **Range:** The upper and lower limits of an instrument's ability to measure values for which the
1970 instrument is calibrated.

1971
1972 **Reclaimed (recycled) water:** Non-potable water provided by a water/wastewater utility that, as
1973 a result of tertiary treatment of domestic wastewater, meets requirements of the public health
1974 Authority Having Jurisdiction for its reclaimed (recycled) water shall be approved by the public
1975 health Authority Having Jurisdiction.

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Resolution:

1. The smallest change in a measured variable that an instrument can detect.
2. The implementation of actions that correct a tested or observed deficiency.

Retro Commissioning: The process of inspecting, testing and optimizing existing building systems for the purpose of improving system performance for comfort and utility utilization.

Should: Indicate a certain course of action is preferred but not necessarily required.

Site Observation Report: A report of periodic site inspections and observations made by the CP. Observation reports are intended to identify installation issues/deficiencies requiring correction or analysis.

Standard: A required qualification, action, or result.

Start Up Test: Test that validates the component or system is ready for automatic operation in accordance with manufacturer requirements.

Static Test: Test or inspection that validates a specified static condition such as pressure testing. Static tests may be specification or code initiated.

Systems Manual: A system-focused composite document that includes all information required for the owner's operators to operate the systems.

Technical Building Systems Commissioning (BSC): NEBB Technical Commissioning Process.

Technical Commissioning (BSC): The NEBB Technical Commissioning Certification program. Technical Commissioning is the process of verifying the performance of a building utilizing various technical procedures.

Test Procedure: A written protocol that defines methods, personnel, and expectations for tests conducted on components, equipment, assemblies, systems, and interfaces among systems.

Test Zone: A building, or a portion of a building, configured as a single zone. For detached dwellings, the test zone envelope normally comprises the thermal envelope.

Testing: The use of specialized and calibrated instruments to measure parameters such as temperature, pressure, vapor flow, airflow, fluid flow, fluid quantities, rotational speed, electrical characteristics, velocity, sound and vibration level, air and hydronic quantities, and other data in order to determine performance, operation, or function.

Testing, Adjusting, and Balancing (TAB): A systematic process or service applied to heating, ventilating and air-conditioning (HVAC) systems, and other environmental systems, to achieve and document air and hydronic flow rates. The standards and procedures for providing these services are referred to as "*Testing, Adjusting, and Balancing*" described in NEBB *Procedural Standards for the Testing, Adjusting and Balancing of Environmental Systems*.

Thermal Scan: Thermographic picture taken with an Infrared Thermographic Camera. Thermographic pictures show relative temperatures of objects and surfaces and used to identify

2027 leaks, thermal bridging, thermal intrusion, electrical overload conditions, moisture containment,
2028 and insulation failure.

2029
2030 **Thermogram:** A recorded image that maps the apparent temperature pattern of an object or
2031 scene into a corresponding contrast or color pattern.

2032
2033 **Training Plan:** The document in outline form detailing subjects for operator training. Training
2034 agendas should address instruction on how to obtain service, operate, startup, shutdown, and
2035 maintain all systems and components of the project.

2036
2037 **Trending:** The use of data loggers or DDC data trends to verify functional performance tests,
2038 troubleshoot, or document system performance.

2039
2040 **Troubleshooting:** Procedural activities for investigating a specific fault or failure of a system or
2041 piece of equipment.

2042
2043 **Validation:**

2044 1. Documented evidence that a process or system, when operated within established
2045 parameters can perform effectively and reproducibly to produce a product meeting
2046 predetermined specifications and quality attributes.

2047 2. A process where work is verified as complete and operating correctly.
2048 a. First party validation occurs when a firm or individual verifying the task is the same
2049 firm or individual performing the task.

2050 b. Second party validation occurs when the firm or individual verifying the task is under
2051 the control of the firm performing the task or has any possible financial conflicts of
2052 interest in the resolution (e.g. architects, designers, general contractors and third-tier
2053 subcontractors or vendors).

2054 c. Third party validation occurs when the firm verifying the task is not associated with,
2055 or under control of, the firm performing or designing the task.

2056
2057 **Verification:** The process where specific documents, components, equipment, assemblies,
2058 systems, and interfaces among systems are confirmed to comply with criteria described in the
2059 Owner's Project Requirements.

2060
2061 **Verification Checklists:** are developed and used during all phases of the NEBB
2062 Commissioning and Retro-Commissioning Technical Process to verify the Owner's Project
2063 Requirements (OPR) or Current Facility Requirements are being achieved.

2064
2065 **Warranty Phase Commissioning:** Commissioning efforts executed after a project has been
2066 completed and accepted by the Owner. Warranty Phase Commissioning includes follow-up on
2067 verification of system performance, measurement and verification tasks, and assistance in
2068 identifying warranty issues and enforcing warranty provisions of the construction contract.

2069
2070 **Warranty Visit:** A commissioning meeting and site review where all outstanding warranty
2071 issues and deferred testing are reviewed and discussed.

2072
2073 **Wastewater (Sewage/Blackwater):** Any liquid waste containing animal or vegetable matter in
2074 suspension or solution and that may include liquids containing chemicals in solution.

2075

2076 **Whole Building Commissioning:** Commissioning of all building systems including Building
2077 Envelope, HVAC, Electrical, Special Electrical (Fire Alarm, Security & Communications),
2078 Plumbing and Fire Protection.

2079
2080 **Zone:** A volume of building served by a single ventilation system. For buildings with natural
2081 ventilation only, the whole building is considered a zone.
2082

2083

PEER REVIEW ONLY - Not for Field Use

2084
2085

C. TOOL LIST

NEBB RCx Commissioning Instrumentation (IP Units)					
Function	Instrument Nomenclature	Minimum Range	Accuracy	Resolution	Calibration Interval
RCx Instruments (Certification Requirement)					
Air Velocity	Airflow Multimeter				
	Digital	100 to 2,500 FPM	± 5% of reading, ± 7 FPM	1 FPM	12 months
	Analog	NA	± 5% of reading, ± 7 FPM	5 FPM	
Air Velocity	Array-type Grid or Airfoil Probe	NA			NA
Air Velocity	Rotating Vane Anemometer (Analog/Digital)	50 - 2500 FPM	± 5% of reading	20 FPM	12 months
Air CFM (1 Required either digital or analog)	Direct Reading Hood (Digital)	100 to 2,000 CFM	± 5% of reading	Digital: 1.0 CFM	12 months
			± 5 CFM	200 CFM scale: 5 CFM	
	Direct Reading Hood (Analog)	100 to 2,000 CFM	± 5% of reading ± 5 CFM	250 - 500 CFM scale: 10 CFM	12 months
				1000 scale: 20 CFM	
			2000 scale: 50 CFM		
Hydronic Differential Pressure	Hydrometer (Digital)	-30 inches hg to 60 psi	± 2% of reading	0.5 psi	12 months
		0 to 100 psi		1.0 psi	
		0 to 200 psi		2.5 psi	
Hydronic Differential Pressure	Hydrometer (Digital)	0 to 100 inches WG	± 2% of reading	1.0 inches WG	12 months
		0 to 100 feet WG		1.0 feet WG	
Relative Humidity	Hygrometer (Digital)	10 to 90% RH	2% RH	1%	12 months
Air Differential Pressure	Manometer (Digital)	0 to 10 inches WG	± 2% of reading	0.01 in WG ≤ 1 inches WG 10.0 in WG > 1 inches WG	12 months
Velocity Pressure Measurement	Pitot Tube	18 inches minimum	NA	NA	NA
Rotational Speed Measurement	Tachometer Rotational Speed - Dual Function (Digital or Analog)	0 to 5,000 RPM	± 2% of reading	± 5 RPM	12 months
Temperature Measurement	Thermometer (Digital or Analog)				
	Air	-40°F to 240°F	± 1% of reading	0.2°F	12 months
	Immersion	-40°F to 240°F	± 1% of reading	0.2°F	
Contact	-40°F to 240°F	± 1% of reading	0.2°F		
Amps and Volts Measurement	True RMS Multimeter				
	Digital	0 to 600 VAC 0 to 100 Amps	± 2% of reading ± 2% of reading	1.0 Volt 0.1 Amp	12 months
Digital Camera	Digital	NA	3 x Zoom	12.0 Mega Pixels Min	NA
Thermal Image Camera	Temperature Measurement	Min. focus distance: 18 in Field of view : 23 ° x 17 °	Accuracy: ± 2°C or 2%	Thermal Sensitivity: ≤ 0.05°C at 30°C target temp. (50 mK)	Note 3
CO ₂ Data Logging	Data Logger: Carbon Dioxide (CO₂)	0 to 2,500 PPM	± 50 PPM	1 PPM	Note 4
CO Data Logging	Data Logger: Carbon Monoxide (CO)	0 to 1,000 PPM	± 6 %	1 PPM	Note 4

NEBB RCx Commissioning Instrumentation (IP Units)					
Function	Instrument	Minimum Range	Accuracy	Resolution	Calibration
Electrical Data Logging	Data Logger: Electrical (Qty 2)				Note 4
	Volts AC	0 to 600 VAC	± 2% of reading	1.0 Volt	
	Amperes	0 to 100 Amps	± 4% of reading	0.5 Amp	
Event Data Logging	Data Logger: Event (Qty 2)	NA	NA	NA	NA
Humidity Data Logging	Data Logger: Humidity (Qty 8)	10 to 90% RH	2.5% RH	1%	Note 4
Lighting Level Data Logging	Data Logger: Lighting Levels	0 to 3,000 Foot-candles	± 10 Foot-candles	2 Foot-candles	Note 4
Temperature Data Logging	Data Logger: Temperature (Qty 8)	-4°F to 150°F	± 0.5°F @ 77°F	0.2°F	Note 4
Static Pressure Data Logging	Data Logger: Static Pressure				Note 4
	Low Range	0 to 0.25 in WC	± 2% of full scale	0.01 in WG ≤1 in WG	
	High Range	0 to 6.00 in WC	± 2% of full scale	0.10 in WG > 1 in WG	
Water Pressure Data Logging	Data Logger: Water Pressure/ Differential Water Pressure	0 to 100 psi	± 1% of full scale	1.0 psi	Note 4
Temperature Measurement	Thermal (Infrared) Thermometer	0°F to 500°F	± 2%	± 0.1°F	
Receptacle Tester	Receptacle Circuit Tester	125VAC	NA	NA	NA
Voltage Detection	Voltage Detector	50 – 1,000 VAC	NA	NA	NA
Light Level Measurement	Light Level Meter	0 - 4,000 FC	+/-4%	1 FC	Note 3

- 2086 1. Instrumentation with multiple capabilities shall be accepted for more than one function when submitting documentation for a
- 2087 firm's certification, providing that each separate function meets NEBB requirements
- 2088 2. Calibrations of all instrumentation requiring calibration shall be traceable to current NIST Standards for US firms, or
- 2089 equivalent organizations in other countries
- 2090 3. Calibration as per manufactures requirements
- 2091 4. Instrument calibration can be field verified from a calibrated instrument with current calibration certification or
- 2092 from calibration gas. If the instrument cannot be adjusted to produce calibrated data then it shall be required to be
- 2093 factory calibrated or replaced.
- 2094
- 2095

NEBB RCx Commissioning Instrumentation (SI Units)					
Function	Instrument Nomenclature	Minimum Range	Accuracy	Resolution	Calibration Interval
RCx Instruments (Certification Requirement)					
Air Velocity	Airflow Multimeter				
	Digital	0.5 to 12.7 M/Sec	± 5% of reading, ± 0.035 M/Sec	0.005 M/Sec	12 months
Analog	NA	± 5% of reading, ± 0.035 M/Sec	0.025 M/Sec		
Air Velocity	Array-type Grid or Airfoil Probe	NA			NA
Air Velocity	Rotating Vane Anemometer (Analog/Digital)	0.254 – 12.7 M/Sec	± 5% of reading	0.102 M/Sec	12 months
Air CFM (1 Required either digital or analog)	Direct Reading Hood (Digital)	50 to 950 L/Sec	± 5% of reading	Digital: 28 L/Sec	12 months
			±142 L/Sec		
	Direct Reading Hood (Analog)	50 to 950 L/Sec	± 5% of reading, ± 142 L/Sec	Low scale: 2.4 L/Sec	
				250 scale: 4.7 L/Sec	
			500 scale: 9.4 L/Sec	12 months	
			1000 scale: 25.6 L/Sec		
Hydronic Differential Pressure	Hydrometer (Digital)	-30PA to 420 KPA	± 2% of reading	3.5 KPA	12 months
		0 to 690 KPA		6.9 KPA	
		0 to 690 KPA		17.2 KPA	
Hydronic Differential Pressure	Hydrometer (Digital)	0 to 25 KPA	± 2% of reading	249 PA	12 months
		0 to 100 300 KPA		3 KPA	
Relative Humidity	Hygrometer (Digital)	10 to 90% RH	2% RH	1%	12 months
Air Differential Pressure	Manometer (Digital)	0 to 2.5 KPA	± 2% of reading	2.49 PA ≤ 249 PA	12 months
				2.49 KPA > 249 PA	
Velocity Pressure	Pitot Tube	18 inches minimum	NA	NA	NA
Rotational Speed	Tachometer Rotational Speed - Dual Function (Digital or Analog)	0 to 5,000 RPM	± 2% of reading	± 5 RPM	12 months
Temperature	Thermometer (Digital or Analog)				
	Air	-40°C to 115°C	± 1% of reading	0.1°C	12 months
	Immersion	-40°C to 115°C	± 1% of reading	0.1°C	
	Contact	-40°C to 115°C	± 1% of reading	0.1°C	
Amps and Volts Measurement	True RMS Multimeter				
	Digital	0 to 600 VAC	± 2% of reading	1.0 Volt	12 months
	0 to 100 Amps	± 2% of reading	0.1 Amp		
Digital Camera	Digital	NA	3 x Zoom	12.0 Mega Pixels Min	NA
Thermal Image Camera	Temperature Measurement	Min. focus distance: 45 CM Field of view : 23 ° x 17 °	Accuracy: ± 2°C or 2%	Thermal Sensitivity: ≤ 0.05°C at 30°C target temp. (50 mK)	Note 3
CO ₂ Data Logging	Data Logger: Carbon Dioxide (CO₂)	0 to 2,500 PPM	± 50 PPM	1 PPM	Note 4
CO Data Logging	Data Logger: Carbon Monoxide (CO)	0 to 1,000 PPM	± 6 %	1 PPM	Note 4
Electrical Data Logging	Data Logger: Electrical (Qty 2)				
	Volts AC	0 to 600 VAC	± 2% of reading	1.0 Volt	Note 4
	Amperes	0 to 100 Amps	± 4% of reading	0.5 Amp	

NEBB RCx Commissioning Instrumentation (SI Units)					
Function	Instrument	Minimum Range	Accuracy	Resolution	Calibratio
Event Data Logging	Data Logger: Event (Qty 2)	NA	NA	NA	NA
Humidity Data Logging	Data Logger: Humidity (Qty 8)	10 to 90% RH	2.5% RH	1%	Note 4
Lighting Level Data Logging	Data Logger: Lighting Levels	0 to 30,000 LUX	± 100LUX	20 LUX	Note 4
Temperature Data Logging	Data Logger: Temperature (Qty 8)	-20°C to 65°C	± 1°C @ 25°C	0.2°C	Note 4
Static Pressure Data Logging	Data Logger: Static Pressure				
	Low Range	0 to 65 PA	± 2% of full scale	2.5 PA ≤250 PA	Note 4
	High Range	0 to 1,490 PA	± 2% of full scale	25 PA > 250 PA	
Water Pressure Data Logging	Data Logger: Water Pressure/ Differential Water Pressure	0 to 690 KPA	± 1% of full scale	6.9 KPA	Note 4
Temperature Measurement	Thermal (Infrared) Thermometer	0°F to 260°C	± 2%	± 0.2°C	
Receptacle Tester	Receptacle Circuit Tester	125VAC	NA	NA	NA
Voltage	Voltage Detector	50 - 1,000 VAC	NA	NA	NA
Light Level	Light Level Meter	0 - 40,000 Lux	±4%	10 LUX	Note 3

- 2096 1. Instrumentation with multiple capabilities shall be accepted for more than one function when submitting documentation for a
 2097 firm's certification, providing that each separate function meets NEBB requirements
 2098 2. Calibrations of all instrumentation requiring calibration shall be traceable to current NIST Standards for US firms, or
 2099 equivalent organizations in other countries
 2100 3. Calibration as per manufactures requirements
 2101 4. Instrument calibration can be field verified from a calibrated instrument with current calibration certification or
 2102 from calibration gas. If the instrument cannot be adjusted to produce calibrated data then it shall be required to be
 2103 factory calibrated or replaced.
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