FIELD PERFORMANCE TEST PROCEDURE FOR LITHIUM BROMIDE ABSORPTION CHILLER PACKAGES

Johnson Controls offers to conduct a Field Performance Test for chilling systems. The test requirements may be detailed by project specifications or quoted as part of a project bid package for new equipment. In such testing, Johnson Controls's Test Group (JCTG) will be responsible only for testing equipment manufactured by Johnson Controls and installed, as recommended by Johnson Controls.

TEST STANDARDS

Air-Conditioning & Refrigeration Institute Standard AHRI 560 details rating, certification and testing of water chilling packages. Absorption chillers fall within the certification program and Johnson Controls follows AHRI 560 guidelines in rating the chilling systems. The test procedures detailed by AHRI 560 appendix C will be followed as closely as practical for the Field test. It should be recognized that some of the tolerances defined by AHRI 560 may need to be relaxed due to site conditions. For instance:

- It may be difficult to obtain 3 sets of data at 5 minute intervals if the load conditions are not steady.
- Flow measurement may be difficult dependent on the device and measurement location. See Appendix A for discussion of tolerance adjustments based on expected accuracies.
- It may be necessary to adjust the chilled water flow rate beyond +5% if the return temperature is not at design (this may affect chiller lbs/hr/TR).
- Heat balance may exceed tolerance due to inaccuracies of site test equipment. It may be desired to average the capacities measured by chilled water and cooling water heat measurements.
- It may be difficult to control design entering condenser water temperature within 0.5°F.
- Fouling factors on site may be difficult to determine or control.

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. standards:

- ANSI/ASHRAE 30 Method of Testing Liquid-Chilling Packages is referenced by AHRI 560 for flow measurement. This standard can be used for field testing and basically describes the same test procedures as AHRI 550/590. But, this standard does not cover chiller rating guidelines.
- ANSI/ASHRAE 41.1 Standard Method for Temperature Measurement applies to temperature measurement techniques.
- ANSI/ASHRAE 41.8 Standard Methods of Measurement of Flow of Liquids in Pipes Using Orifice Flowmeters.

GENERAL POLICY

1) Field Test(s) shall be conducted in accordance with AHRI 560 Standard (latest edition in place when the chiller is ordered). All Johnson Controls Unit Performance Data are based on AHRI Standard 560, with all applicable tolerances. For the specified operating conditions of a project, the tolerance will typically be in the range of ± 5.0% at full-load operating conditions, with increasingly broader tolerances at reduced load conditions. Where narrower tolerances are desired, they must be clearly included in the project specifications, and accounted for in the quotation. The quotation ratings must reflect adequate performance safety margins to account for the special tolerance. Owners or Consultants who specify narrower than AHRI 560 tolerance should understand that this is increasing the cost of the chiller.

2) The following test instrumentation (see also FIG. 1 thru 3, and Tables 1 thru 3) will be used for Johnson Controls Test Group conducted tests:
   a) Flows: The Owner shall supply all Liquid Flow meters. The flow meters shall be of the type required to comply with AHRI 560 Standards. Refer to Appendix A for further guidance on flow measurement devices. Design and calibration data shall be made available to JCTG to allow input to JCTG's Field Data Acquisition System. Should the Owner elect to utilize any meter other than recognized by AHRI and ASHRAE, Johnson Controls reserves the right to either accept or reject this meter selection. In the event that Johnson Controls rejects this meter selection, Johnson Controls will enter into negotiations with the appropriate Johnson Controls and Owner representatives to determine the appropriate solution and possible tolerance increase based on meter selection and installation location. This will be driven by expected accuracy based on past experiences.

   b) Temperatures: Resistance Temperature Detectors, or RTDs, shall be provided by JCTG that are National Institutes of Standards & Technology (NIST) traceable and meet the requirements of AHRI 560 Standards for all water and refrigerant measurements between the ranges of 30 to 150 Degrees Fahrenheit (special calibrations will be done for low temperature brine chillers). Temperatures above 150 Degrees Fahrenheit will be measured by Thermocouples using NIST Curves. The Owner shall supply temperature wells in all chilled/cooling piping. The wells shall accept ¼ inch OD RTDs extending to the center of the pipes. The wells shall be installed in a vertical orientation to enable filling with a liquid heat conducting material. The wells shall be installed about six pipe diameters from the exits of the chilled/cooling shell flanges to assure good fluid mixture at the point of measurement.

   c) Pressures: Pressure transducers shall be provided by JCTG that are NIST traceable and meet the requirements of all AHRI Standards. The Owner shall supply new or existing connections for evaporator and condenser refrigerant-side and water-side pressure measurements.

   d) Work input shall be defined as Steam Fired, Natural Gas/Oil Fired and Hotwater Fired. The determination of actual work input (btu/hr) to the chiller package shall be determined as defined in AHRI 560.

   e) Steam and/or hot water consumption will be measured utilizing calibrated turbine flowmeters that are NIST traceable and meets the requirements of all AHRI standards. Provisions should be made on the condensate overboard piping to install this flowmeter. Three 2" full port ball valves should be installed per the installation drawing included in this procedure.

   f) For gas/oil fired units, the customer shall be responsible for providing AHRI/ASHRAE compliant natural gas or oil flowmeters. Design and calibration data shall be made available to JCTG to allow input to JCTG's Field Data Acquisition System. Should the Owner elect to utilize any meter other than recognized by ARI and ASHRAE, Johnson Controls reserves the right to either accept or reject this meter selection. In the event that Johnson Controls rejects this meter selection, Johnson Controls will enter into negotiations with the appropriate Johnson Controls and Owner representatives to determine the appropriate solution and possible tolerance increase based on meter selection and installation location. This will be driven by expected accuracy based on past experiences.

JCTG supplied instrumentation is calibrated to NIST traceable standards at regular intervals. Specifications which require before and after test calibrations will incur increased test costs.

3) All data from RTDs, pressure transducers, gages, electrical measurements, and flow meters, should be collected by a high accuracy data acquisition system. When Johnson Controls is performing the test, JCTG will utilize a high accuracy Data Acquisition System which is linked to display data on a laptop PC and record on a portable printer. The PC will update all recordings about every 10 seconds and continuously indicate all measurements as well as capacity, power consumption, and heat balance through Excel software. Upon stabilization, the printer will make a record of the test.

STABILITY DEFINITION

Stability of flow shall be defined as:
A stable conditions exists when the volume of water over time (gpm) remains within 2% of the design flow rate and cycles peak to peak in no less than 1 minute.

Stability of temperature shall be defined as:
A stable condition exists when the temperature of water over time (°F/min) remains within .5°F of design temperature and moves no more than .1°F per 1 minute on average with a 20 minute span peak to peak.

This stability allows for stable readings that can provide the 10 minute window for data collection that AHRI mandates.

4) AHRI test procedures require that a tube side fouling factor of 0.000 be assumed if heat exchanger surfaces are cleaned just prior to test. Temperature penalty adjustments to compensate for the chiller rated scaling for both evaporator and condenser would then be performed. But, for field performance tests, the job site water treatments do not meet laboratory cleanliness, nor are the tubes completely clean by the time the test is conducted.

Recognizing that tube-side fouling will begin within hours of commercial operation, full design fouling will be assumed for the test. This means there will be no water temperature corrections for clean tube fouling as detailed by AHRI 560, which apply only to new and unused tubes in a factory or laboratory test environment.

However, should fouling at time of test be above design as measured by heat exchanger small differences, Johnson Controls reserves the right to request Owner to perform tube cleaning (not in Johnson Controls scope). Evaporator approach will be determined by comparison of the liquid refrigerant temperature at the refrigerant pump discharge to the leaving chilled water temperature. Condenser approach shall be determined by comparison of the condenser refrigerant outlet temperature to the leaving cooling water temperature. This approach temperature can be used to estimate the water side fouling condition.

If tube cleaning is requested by Johnson Controls due to excessive fouling, the preferred tube cleaning to achieve zero fouling must consist of brush cleaning followed by acid cleaning. If this is done, and performance tests are run immediately, water temperature corrections would be calculated per AHRI 560 to simulate a zero fouling clean tube condition.

Alternatively, if only a brush cleaning OR acid tube cleaning method is to be done (if preferred by Owner due to costs), experience has shown that a true tube condition of zero fouling is not likely. With this one-stepcleaning mode, tube-side fouling would be assumed .0001 AHRI 560 standard for the evaporator, and .00025 AHRI 560 standard for condenser water. Temperature corrections to simulate the difference (if any) between chiller rated / specified fouling and the preceding AHRI 560 standard values would be utilized for the test.

5) After all operating conditions are adjusted for design conditions and the chiller tested for proper refrigerant charge and all system valve settings adjusted for proper operation and positioning, a state of readiness can be declared for the Field Performance Test.

6) After declaration of the state of readiness, the system should be allowed to operate overnight, under the supervision of the Owner's site personnel, at the normal plant operations requirements. If possible, load shedding of other equipment, should be incorporated to keep the proposed test equipment as fully loaded as possible during night

operations, so that on the day of the test the unit tested will require minimum stabilization to test conditions

7) On the day of the test, the test unit will have been operating overnight and the time to attain stabilized test conditions will be minimized. To attain test conditions, design flow rate will be checked and adjusted to design values. The site operators will then be requested to shed loads to maintain design entering chilled water and condenser water temperatures. Hopefully, these can be attained within a few hours. Three sets of readings taken at 5-minute intervals of temperatures, flow and power readings will fulfill the requirements of AHRI 560. Heat balance of the test runs will be checked during the test and, if within 5%, compliance with requirements of the standard will be met, the test will be concluded and a report issued.

8) Part load Field Performance Tests may be requested at additional cost. Johnson Controls publishes part load curves for typical installations. Steady state conditions are sometime difficult to achieve whereby conditions maintained per the Test Engineers request should provide suitable information. Allowable tolerances as specified per AHRI 560.

9) After successful test compliance with the standard, and heat balance verification, a report of the system Field Performance Test will be prepared. Johnson Controls will provide a copy of test report to the individual designated in the Contract Specifications.

CUSTOMER/OWNER RESPONSIBILITY

The following is a list of items that the Customer/Owner must retain responsibility for successful completion of the required performance and/or sound testing. The Customer should be considered an essential part of the test team. Successful acceptance of the test will not be achieved unless the Customer is engaged and involved in supporting the test. The Customer should:

- **Provide a single point of responsibility, "The Customer Representative"**

- **Schedule chiller availability**

- **Provide stable operating conditions**

  The customer/owner shall be responsible to provide the load for the test chiller, shall control the water flows and temperatures to the design conditions as specified by the performance and/or sound Test Engineer.

  A Johnson Controls technician shall monitor the system operating conditions for the duration of the performance and/or sound test. If the chiller operating conditions vary substantially from the stable conditions as defined above, all collection of official data will cease until the required conditions can be maintained.

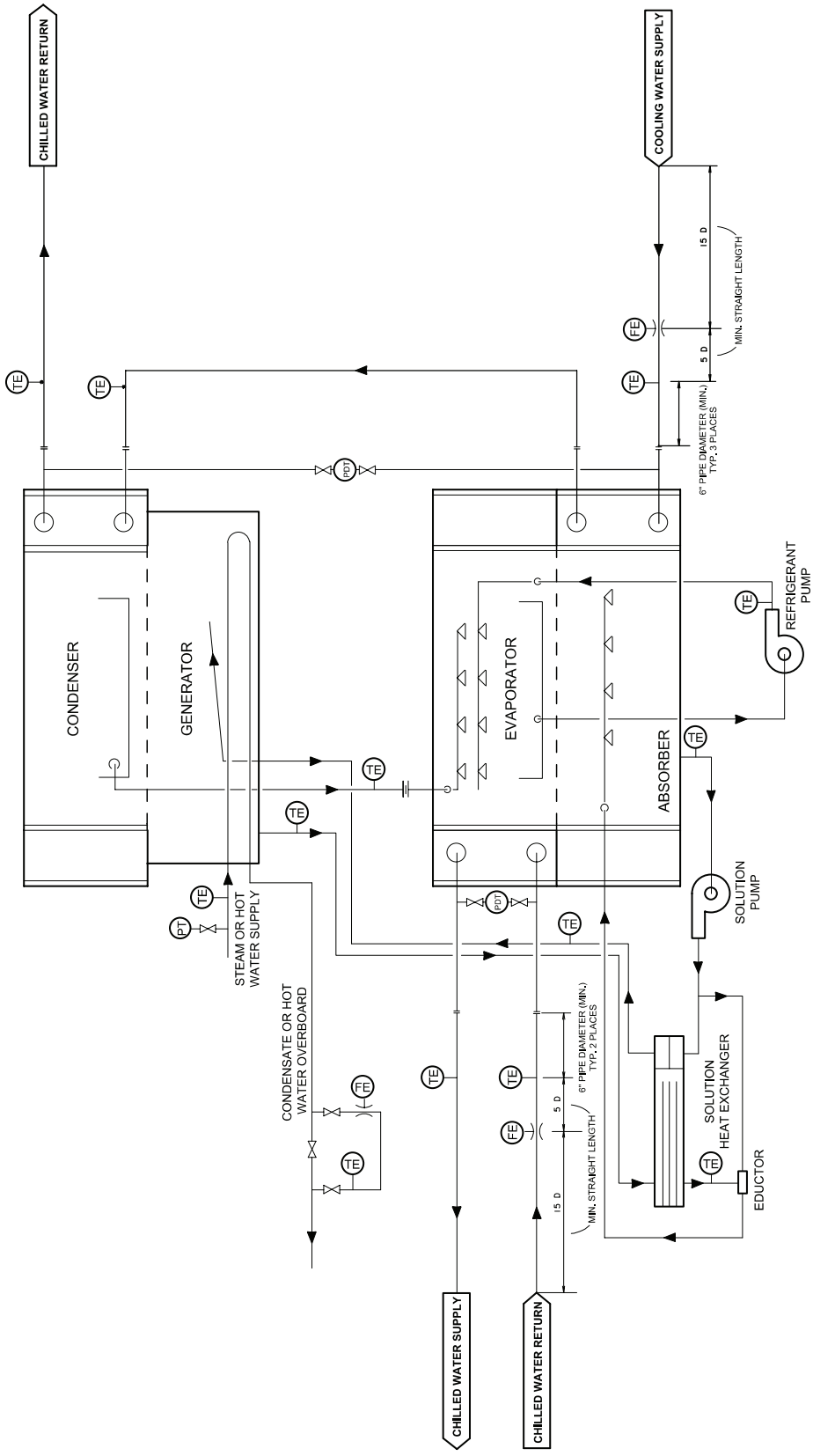
- **Assume responsibility costs of all operating utilities during the testing**

  Contracted testing delays or reschedules resulting from equipment supplied by others, will be charged on per-diem basis.

- **Understand the implications of less than ideal testing conditions.**

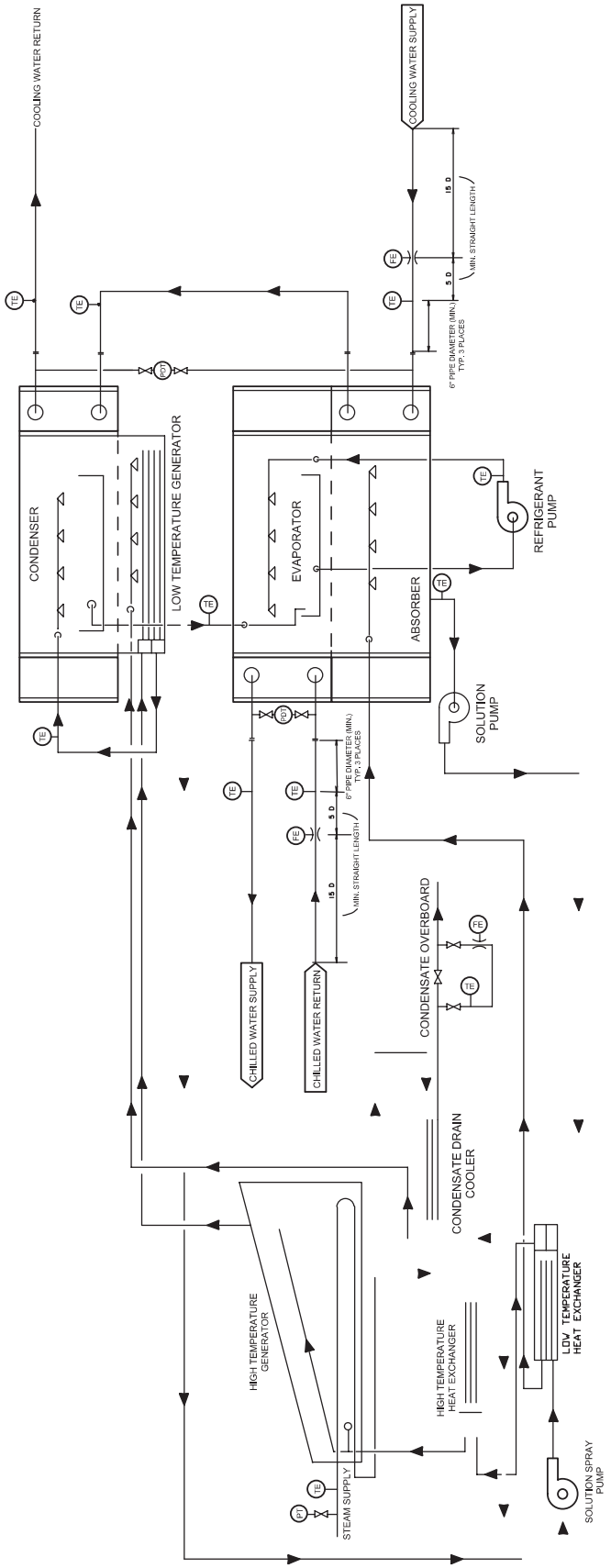
  Customer should accept that less than ideal test instrumentation selection, instrumentation installation and or system stability will yield less than ideal tolerance on accuracy and some level of relaxation of the test results may be required.

- **Accept the test results and report**



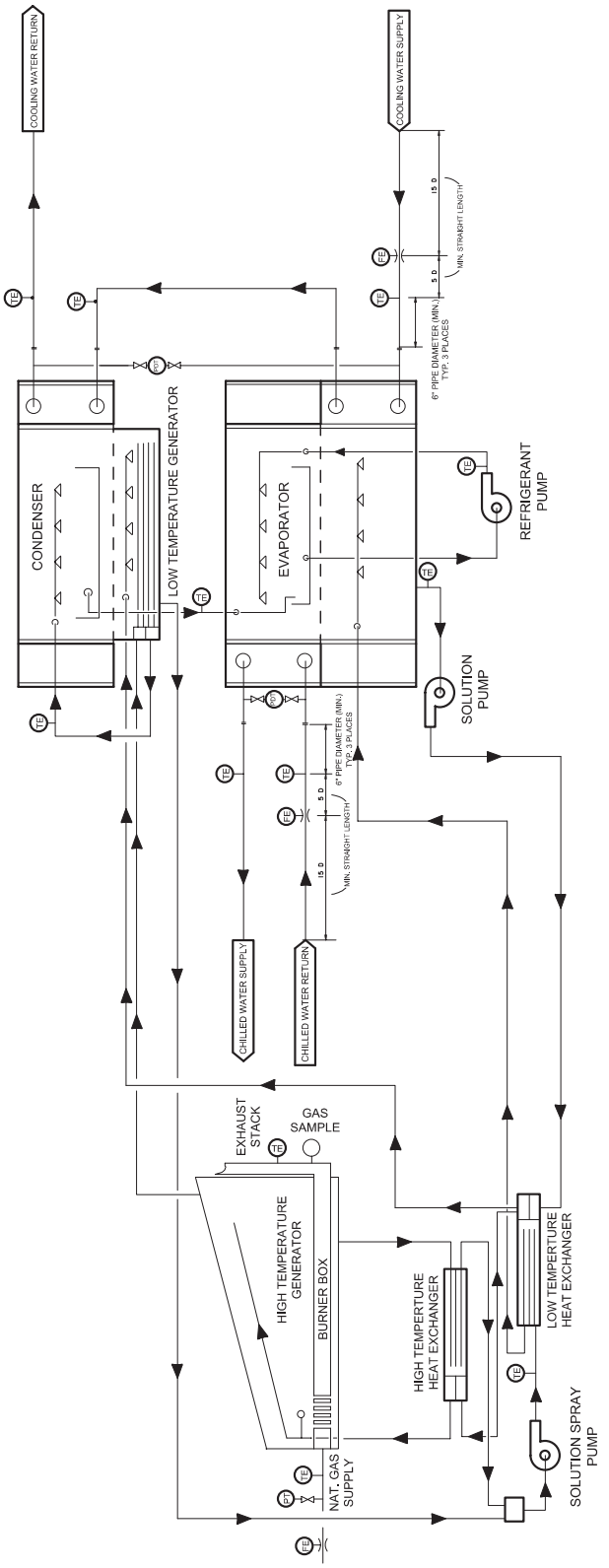
NOTE: Refer to project specifications and plans for instrumentation scope of supply.

FIG. 1 - JCIA PIPING AND INSTRUMENTATION DIAGRAM



NOTE: Refer to project specifications and plans for instrumentation scope of supply.

FIG. 2 - YPC STEAM PIPING AND INSTRUMENTATION DIAGRAM



NOTE: Refer to project specifications and plans for instrumentation scope of supply.

FIG. 3 - YPC GAS PIPING AND INSTRUMENTATION DIAGRAM

APPENDIX A FLOW MEASUREMENT

SCOPE

The water or brine (and steam) piping are generally not within the chiller manufacturer's scope of supply. AHRI 560 in conjunction with ASHRAE 30 require flow devices meeting an accuracy of 1% or better. Although field performance testing does not fall under this factory laboratory testing standard as AHRI 560 defines it, we do try wherever possible to adhere to this requirement to give our customers confidence in our methods. Devices meeting 1% accuracy requirement are generally full pipe flow devices, which are integral to the piping system. Unless dictated otherwise by contract, the Owner is responsible to provide and install calibrated flow measurement devices which will meet these accuracy requirements. These measurements are required for chilled water (or brine), condenser water and (if applicable) steam condensate flows.

Process flow measurement devices are critical in chiller performance testing, since flow is a direct factor in establishing chiller capacity, efficiency and also heat balance test validation. For steam turbine driven chillers the steam or condensate flow measurement also establishes power consumption. AHRI 560 and ASHRAE 30 standards on chiller performance testing require a 1% measurement accuracy (of reading at specified design point) for each flow measurement device.

INSTALLATION

All flow measurement devices are dependent upon a uniform velocity profile within the pipe. The placement of flow measurement devices within the piping system must be considered by the customer or their representative during the project design phase. Flow elements shall not be installed after control valves, or multiple elbows unless flow straightening vanes are utilized. Most insertion type and differential pressure flow elements require straight pipe runs of at least 20 pipe diameters upstream and 5 downstream to operate accurately without a flow straightening bundle. Most insertion type and differential pressure flow elements require straight pipe runs of at least 10 pipe diameters upstream and 5 downstream to operate accurately with a flow straightening bundle This can vary based upon piping configurations and device selection. The flow device manufacturer's recommendations must be followed for specific installation requirements. The flow element design and calibration shall be based upon the wall thickness or I.D. of the piping in which it will be installed.

CALIBRATION ACCURACY

Flow device manufacturer accuracy claims should not be taken at face value. The accuracy needs to be based on reading at design point, not full scale. The accuracy of secondary measurement or transmission devices should also be considered. Accuracy should not be confused with repeatability. To ensure accuracy, the flow device must be calibrated to an NIST (National Institute of Standards & Technology) traceable source. For most large flow meters this will require that a weight flow calibration test be performed on the actual flow device prior to installation.

INTERFACE TO TEST EQUIPMENT

In field testing, it is best that all data be taken simultaneously by a modern data acquisition system. The signal reading should be taken as close to the flow element source as possible, and not a retransmission from other sources. The Owner shall make allowance for the Test Engineer to make the necessary connections to the process ΔP taps via block valves, or direct to the electronics primary loop for electronic flow devices. When using a differential pressure device, such as an orifice, Venturi or Pitot tube, the flow calibration report must be provided to the Test Engineer. A calibrated differential pressure transmitter and flow characteristics can then be provided with the data acquisition system. For other types of flow devices, the calibration report and details on electronic signal type shall be provided to the Test Engineer. The electronic signal may be analog or pulse. When available current loop signals may be preferable.

PREFERRED FLOW MEASUREMENT DEVICES

Magnetic Flowtube flowmeters have been widely approved by AHRI for use in factory test facilities. JCI uses these meter types in our large tonnage test facilities and have received certification from AHRI for the facilities using them. JCI has experienced very good and repeatable results using these meters. The specification for use for fluid flow measurement is defined by ASME MFC-16-2007, Measurement of Fluid Flow in Closed Conduits be Means of Electromagnetic Flowmeters. JCI prefers the use of these devices for flow measurement since there is a history through factory use and

calibration that these meters deviate very little from calibration to calibration and there are no moving parts to affect future calibration. Further, these flowmeters provide very good results when properly installed on any pipe size for which there is a flowmeter available.

Orifice Plates are listed in AHRI 560 test procedures. Their specification and use for flow measurement is defined by ASHRAE 41.8 .Standard Methods of Measurement of Flow of Liquids in Pipes Using Orifice Flowmeters. JCI has no objection to using an orifice for flow measurement as the characteristics are well established and there are no moving parts to affect future calibration. However, the high pumping costs associated with an orifice plate make it practical only for temporary installation, or for projects where a test bypass loop is part of the design.

Venturi Flow nozzles are listed in AHRI 560, with requirements defined by ASME standard MFC-3M, Measurement of Fluid Flow in Pipes Using Orifice, Nozzle and Venturi.. The Venturi is more expensive than an orifice, but has a lower pressure drop and reasonable pumping costs. For most permanent installations in large water flow lines a weight flow calibrated Venturi will provide accurate results.

Turbine Flowmeters are listed in AHRI 560 when they are applied per the requirements of ISA standard RP31.1 .Recommended Practice Specification, Installation and Calibration of Turbine Flowmeters. Axial turbine flow meters are recommended for use in measuring small pipe sizes. Axial turbine meters are preferred for steam condensate measurement on steam turbine driven chillers, and can be installed temporAHRIly.

Insertion type turbine flow meters are generally not recommended by JCI for flow measurement to determine guaranteed capacity and efficiency because of the potential uncertainties for these meters. They are very dependent on installation location, depth, proximity to turbulence, etc. and on many occasions have proven to be less than reliable for this purpose.

Other types of flowmeters are not recognized by the AHRI 560 standard on chiller testing. The attached chart is intended for general compAHRIson of the vAHRIous types of flow metering which are available

Important Note
Should the Owner decide to use a meter with less accuracy than prescribed by AHRI 560, the test tolerances in capacity, power and heat balance must be relaxed by the difference in flow meter accuracy (JCI's expected accuracy based on past experiences as shown on the chart minus 1% allowable AHRI 560 flow accuracy will be added to the AHRI chiller tolerances).

Liquid Flow Metering Devices					*Accuracy, %	
Meter	**Type**	**Pros (P) & Cons (C) associated**		**Signal type**	**Typical Mfg Claim**	**JCI expectation**
Magnetic (ASME MFC-16M)	F	P	Needs less straight run of piping than other devices. High degree of accuracy when properly installed and calibrated. Very little pressure drop associated. No moving parts or pressure ports to clog.	Electronic	.25 to .5	0.5
Magnetic		C	Full pipe diameter device.			
Orifice Plate (ASHRAE 41.8)	F	P	AHRI/ASHRAE accepted. Established Theory. No moving parts. High accuracy when properly installed.	ΔP	1	1
		C	High ΔP equates to high pumping costs. System debris may clog pressure ports.			
Venturi (ASME MFC-3M)	F	P	AHRI/ASME accepted. Established theory. No moving parts. Lower pumping costs than orifice. High accuracy when weight flow calibrated and properly installed.	ΔP	.5 to 1	1
Venturi		C	System debris may clog pressure ports.			
Turbine Axial (ISA RP31.1)	F	P	AHRI/ISA accepted. Linear output provides good turn down.	Electronic	1	1
Axial turbine		C	Moving parts makes long reliability questionnable. Not feasiblefor large diameter piping.			
Turbine Insertion	I	P	Can be “hot tapped”. Lower initial costs.	Electronic	1	15
Insertion Turbine		C	Moving parts that are prone to reliability issues. Insertion devices are generally subject to installation methods, location, velocity profile changes, etc.			
Ultrasonic, Time Transit	N	P	Portable strap on device. Can be used when customer meters do not meet minimum requirements, there are no site meters or as a second meter.	Electronic	1 to 2	2.5
Ultrasonic, Time Transit		C	Installation reqiures fully developed flow profiles. System foaming/aeration will negatively affect funtionality of meter, may cause device not to function.			
Vortex Shedding & Target	I	P	Can be “hot tapped”. Lower initial costs.	Electronic	1.5	5
Vortex Shedding & Target		C	Insertion devices are generally subject to installation methods, location, velocity profile changes, etc.			
Pitot tube, Annubar	I	P	Can be “hot tapped”. Lower initial costs.	ΔP	1	5
Pitot tube, Annubar		C	Insertion devices are generally subject to installation methods, location, velocity profile changes, etc.			

Type: F = Full flow passes through device. I = Insertion type of device N = non intrusive

*Accuracy expectations are based upon proper installation per manufacturer’s recommendations and industry standard requirements. Improper installation or application may cause the inaccuracies to at least double. In some cases test data has shown the inaccuracies to increase to double digit values when installation requirements are not met.

This is intended as a general information source on the typical types of flow devices which may be applied to chiller tests/plant measuremnt. There are types of flowmeters not mentioned here including mass flowmeters, coriolis flowmeters, etc. which are often not applied in large flow piping requirements.

For further informational materials on flow devices, recommended readin: “Fundamentals of Flow Measurement” is available from the Instrument Society of America (ISA) by download from their website at www.isa.org.

APPENDIX B - INSTRUMENTATION INSTALLATION

TYPE OF MEASUREMENT	DESCRIPTION	INSTALLATION REQUIREMENTS	INSTALLATION RESPONSIBILITY	NUMBER OF MEASUREMENT POINTS	INSTRUMENT SUPPLIER	INSTRUMENT TYPE	CALIBRATION RESPONSIBILITY
Temperature	Cooler inlet/ outlet water temperature wells	The thermal wells shall accept ¼" OD RTDs extending to the center of the pipes. The wells shall be installed in a vertical orientation to enable filling with a liquid heat conducting material. The wells shall be installed about six pipe diameters from the entrance and exit points of the chilled shell flanges to assure good fluid mixture at the point of measurement.	Customer	2	Johnson Controls	RTD	Johnson Controls
Temperature	Condenser inlet/ outlet water temperature wells	The thermal wells shall accept ¼" OD RTDs extending to the center of the pipes. The wells shall be installed in a vertical orientation to enable filling with a liquid heat conducting material. The wells shall be installed about six pipe diameters from the entrance and exit points of the cooling shell flanges to assure good fluid mixture at the point of measurement.	Customer	2	Johnson Controls	RTD	Johnson Controls
Temperature	Surface Condenser outlet water temperature well	The thermal well shall accept ¼" OD RTD extending to the center of the leaving water pipe. The well shall be installed in a vertical orientation to enable filling with a liquid heat conducting material. The well shall be installed about six pipe diameters from the exit of the shell flange to assure good fluid mixture at the point of measurement.	Customer	1	Johnson Controls	RTD	Johnson Controls

TYPE OF MEASUREMENT	DESCRIPTION	INSTALLATION REQUIREMENTS	INSTALLATION RESPONSIBILITY	NUMBER OF MEASUREMENT POINTS	INSTRUMENT SUPPLIER	INSTRUMENT TYPE	CALIBRATION RESPONSIBILITY
Temperature	Steam Supply Temperature well	The thermal well shall accept a 1/8” OD TC Probe extending into the center of the fl ow stream. The well shall be installed in a vertical orientation to enable filling with a heat conducting compound. This well shall be installed prior to the steam supply valve.	Customer	1	Johnson Controls	TC	Johnson Controls
Temperature	Condensate Temperature well	The thermal well shall accept a 1/8” OD TC Probe extending into the center of the fl ow stream. The well shall be installed in a vertical orientation, if possible, to enable filling with a heat conducting compound. This well shall be installed as close as possible to the “flowmeter” in the condensate line, but not interfere with the fl ow stream.	Customer	1	Johnson Controls	TC	Johnson Controls
Temperature	Evaporator and Condenser liquid refrigerant temperature wells	The thermal wells shall accept ¼” OD RTDs extending to the center of the pipes. The wells shall be installed in a vertical orientation to enable filling with a liquid heat conducting material. Limits of the piping arrangements may make it necessary to install the RTD on the external pipe wall and insulate the probe. Since these measurements are reference only, this will not directly affect the accuracy of the performance data.	Johnson Controls	1 each shell	Johnson Controls	RTD	Johnson Controls

TYPE OF MEASUREMENT	DESCRIPTION	INSTALLATION REQUIREMENTS	INSTALLATION RESPONSIBILITY	NUMBER OF MEASUREMENT POINTS	INSTRUMENT SUPPLIER	INSTRUMENT TYPE	CALIBRATION RESPONSIBILITY
Temperature	Compressor Suction temperature well	The thermal well shall accept ¼" OD RTD extending to the center of the suction pipe. The well shall be installed in a vertical orientation to enable filling with a liquid heat conducting material. Limits of the piping arrangement may make it necessary to install the RTD on the external pipe wall and insulate the probe. Since these measurements are reference only, this will not directly affect the accuracy of the performance data.	Johnson Controls	1	Johnson Controls	RTD	Johnson Controls
Temperature	Compressor Discharge temperature well	The thermal well shall accept ¼" OD RTD extending to the center of the pipe. The wells shall be installed in a vertical orientation to enable filling with a liquid heat conducting material. Limits of the piping arrangement may make it necessary to install the RTD on the external pipe wall and insulate the probe. Since these measurements are reference only, this will not directly affect the accuracy of the performance data.	Johnson Controls	1	Johnson Controls	RTD	Johnson Controls
Pressure	Evaporator Pressure connection valve	The evaporator shell shall have a valve block or manifold with 1/4" pipe thread on the top of the shell to allow the connection of the pressure transducer to shell so as not to interrupt operation of the chiller to facilitate the test set up.	Johnson Controls	1	Johnson Controls	PRESSURE TRANSDUCER	Johnson Controls

TYPE OF MEASUREMENT	DESCRIPTION	INSTALLATION REQUIREMENTS	INSTALLATION RESPONSIBILITY	NUMBER OF MEASUREMENT POINTS	INSTRUMENT SUPPLIER	INSTRUMENT TYPE	CALIBRATION RESPONSIBILITY
Pressure	Condenser Pressure connection valve	The condenser shell shall have a valve block or manifold with 1/4” pipe thread on the top of the shell to allow the connection of the pressure transducer to shell so as not to interrupt operation of the chiller to facilitate the test set up.	Johnson Controls	1	Johnson Controls	PRESSURE TRANSDUCER	Johnson Controls
Pressure	Steam Supply pressure connection valve	The steam supply piping shall have a valved connection point with 1/4” pipe thread and a siphon tube at the inlet to the trip and throttle valve to the turbine.	Customer	1	Johnson Controls	PRESSURE TRANSDUCER	Johnson Controls
Pressure	Steam Exhaust pressure connection valve	The steam surface condenser shall have a valved connection point with 1/4” pipe thread on a slight slope toward the surface condenser as close to the turbine exhaust piping as practical.	Customer	1	Johnson Controls	PRESSURE TRANSDUCER	Johnson Controls
Pressure	Evaporator Water Box Differential Pressure connection valves	There shall be a vertical up or horizontal valved connection at the inlet and outlet water nozzles of the shell water boxes. These connections shall be 1/4” pipe thread and located prior to the fi rst elbow and flange if practical.	Customer	2 per shell	Johnson Controls	DIFFERENTIAL PRESSURE TRANSDUCER	Johnson Controls
Pressure	Condenser Water Box Differential Pressure connection valves	There shall be a vertical up or horizontal valved connection at the inlet and outlet water nozzles of the shell water boxes. These connections shall be 1/4” pipe thread and located prior to the fi rst elbow and flange if practical.	Customer	2 per shell	Johnson Controls	DIFFERENTIAL PRESSURE TRANSDUCER	Johnson Controls

TYPE OF MEASUREMENT	DESCRIPTION	INSTALLATION REQUIREMENTS	INSTALLATION RESPONSIBILITY	NUMBER OF MEASUREMENT POINTS	INSTRUMENT SUPPLIER	INSTRUMENT TYPE	CALIBRATION RESPONSIBILITY
Flow	Condensate flow meter	Condensate shall be measured in the same manner as the chiller water flow rates. Johnson Controls shall provide detailed installation instructions for pipe size once the design condensate flow rate is known.	Johnson Controls	1 per loop	Johnson Controls	Axial turbine	Johnson Controls
Flow	Evaporator flow meter	The flow meters shall be of the type required to comply with AHRI Standards. Refer to Appendix A in the Johnson Controls fi eld Performance Test Procedure for further guidance on selection flow measurement devices. Design and calibration data shall be made available to JCTG to allow input to JCTG's Field Data Acquisition System. These devices shall be installed with unobstructed straight run piping with a minimum of 15 pipe diameters upstream of the flowmeter and 5 pipe diameters downstream of the fl owmeter. The upstream length can be shortened to 10 pipe diameters with the use of a flow straightening bundle. Pipe diameters is defined as the diameter of the flow meter and the pipe in which the flow is to be measured. Both shall be the same diameter.	Customer	1 per loop	Customer	To be determined by the customer	Customer

TYPE OF MEASUREMENT	DESCRIPTION	INSTALLATION REQUIREMENTS	INSTALLATION RESPONSIBILITY	NUMBER OF MEASUREMENT POINTS	INSTRUMENT SUPPLIER	INSTRUMENT TYPE	CALIBRATION RESPONSIBILITY
Flow	Condenser flow meter	The flow meters shall be of the type required to comply with AHRI Standards. Refer to Appendix A in the Johnson Controls fi eld Performance Test Procedure for further guidance on selection flow measurement devices. Design and calibration data shall be made available to JCTG to allow input to JCTG's Field Data Acquisition System. These devices shall be installed with unobstructed straight run piping with a minimum of 15 pipe diameters upstream of the flowmeter and 5 pipe diameters downstream of the fl owmeter. The upstream length can be shortened to 10 pipe diameters with the use of a flow straightening bundle. Pipe diameters is defined as the diameter of the flow meter and the pipe in which the flow is to be measured. Both shall be the same diameter.	Customer	1 per loop	Customer	To be determined by the customer	Customer

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