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TVA **Environmental Data Station Manual**	**Clinch River Nuclear Plant** **Module I** **OVERVIEW**	**EDS-CRN** **Rev. 0001** **Page 1 of 11**
		Quality Related ☑ Yes ☐ No
		Effective Date

Level of Use: Reference Use

Prepared by: Kenneth G. Wastrack (EMA), Meteorologist

Reviewed by:	Thomas E. Adkins (NPG), Manager, Emergency Preparedness Systems	Date
Concurred by:	Jeffery N. Perry (P&O) Senior Project Manager, SMR Technology	Date
Approved by:	Walter H. Lee III (NPG), Manager, Emergency Preparedness--REMIC Chairman	Date

Revision Log

Revision or Change Number	Effective Date	Affected Page Numbers	Description of Revision/Change
0		All	Initial Release

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1.0 PURPOSE

The Environmental Data Station (EDS) is the center for collecting and transmitting of meteorological data for TVA nuclear plants. The "Environmental Data Station Manual" provides both general and site-specific information necessary for effective operation. It serves as the primary site document in the meteorological procedure process as shown in Figure I-1.

Figure I-1

Meteorological Procedure Process

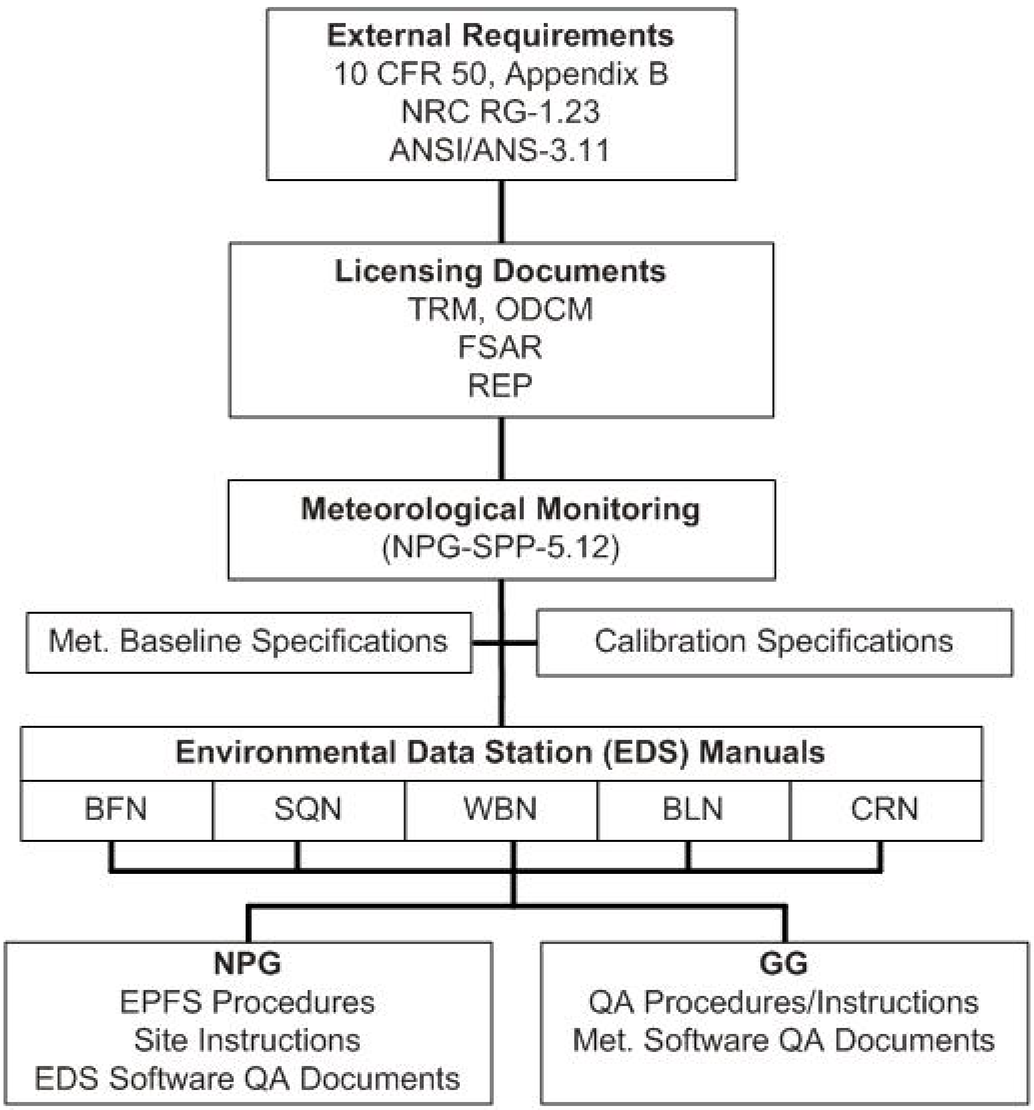

Fig. CR_I-1

1.0 PURPOSE (continued)

The EDS Manual (1) documents detailed sensor specifications, (2) provides a detailed listing of error sources for each parameter, and (3) references calibration procedures. The EDS Manual is required by NPG-SPP-5.12, “Meteorological Monitoring Program,” as the source of technical information for each site’s program.

2.0 SCOPE

The scope of the EDS Manual is as follows:

- Technical Reference: The manual provides an overview of the EDS and interfaces with other systems, detailed equipment descriptions and specifications, and a technical reference index of both documents and support personnel.
- Regulatory Information: The manual documents regulatory and compliance information not described elsewhere. This includes general and site-specific information, compliance history, and permit limits.
- Supplemental Information: The manual provides a list of reference documents, error analysis, and a summary of organizational responsibilities.

NOTE

EDS Manuals and associated requirements apply in their entirety to TVA’s operating Nuclear Plants--Browns Ferry (BFN), Sequoyah (SQN), and Watts Bar (WBN).

Since many aspects are not currently active, only data collection and processing portions apply to non-operational plants--Bellefonte (BLN) and Clinch River (CRN).

3.0 RESPONSIBILITIES

3.1 Radiological Environmental and Meteorological Instrumentation Committee (REMIC).

REMIC is responsible for implementing the Augmented Quality Assurance Program (NPG-SPP-5.9, "Radiological Control and Radioactive Material Shipment Augmented Quality Assurance Program"), resolving problems, and ensuring adequate communication between organizations responsible for calibration, training on use, and using meteorological instrumentation. REMIC provides a forum to bring together data users and data providers for multiple plants to address common issues.

The charter for REMIC is an appendix to NPG-SDP-RCDP-12, “Radiological Environmental and Meteorological Instrumentation Committee (REMIC) Procedure”.

REMIC is also responsible for the overall direction of the water temperature monitoring and thermal compliance program at TVA nuclear plants.

3.2 Small Modular Reactor Technology (SMR)

The SMR Technology group provides overall guidance and oversight for the CRN meteorological monitoring program.

3.3 Nuclear Power Group (NPG)

3.3.1 Corporate Emergency Preparedness (EP)

EP is responsible for administrative and senior technical oversight of the meteorological program to include evaluation of program compliance with existing and new requirements, evaluation and implementation of modifications to the program, and coordination necessary for implementation of the program.

The Emergency Preparedness Manager is the REMIC chairperson.

3.3.2 Emergency Preparedness Field Support (EPFS)

EPFS is responsible for the operation and maintenance of the data collection, computer, and data transfer systems. In addition, EPFS tests or calibrates the thermal compliance equipment and software, radiation, and meteorological equipment as required. EPFS keeps backup components for the important equipment to assure minimum downtime. EPFS contacts other organizations for help if needed in solving system problems. EPFS may contact contractors for assistance as needed.

The Emergency Preparedness Systems Manager is member of REMIC.

3.3.3 Computer Process Engineering (CPE)

CPE is responsible for the software used in the site computer, the networking software and hardware, the Remote Access Computer, and the callout system. CPE also helps to troubleshoot hardware and software problems on the site EDS computer systems. All EDS system software is developed, modified, and maintained according to NPG-SPP-2.6, "Computer Software Control."

A CPE Instrument Engineer is a member of REMIC.

3.4 Generation Group (GG)

3.4.1 Inspection, Testing, Monitoring and Analysis; Environmental Monitoring & Analysis (EMA)

EMA is responsible for providing meteorological technical support that includes maintaining a requirements matrix, maintaining specifications, inspecting monitoring facilities, and providing data summaries used in the Offsite Dose Calculation Manual (ODCM).

EMA also identifies monitoring problems and collects, processes, validates, reports, and archives meteorological data to meet Nuclear Regulatory Commission data recovery, accuracy, and reporting requirements.

An EMA Meteorologist is a member of REMIC.

3.4.2 Inspection, Testing, Monitoring and Analysis; Instrumentation Engineering Services (IES)

IES is responsible for the design and installation of the data logging system, meteorological equipment, and data transfer equipment. IES provides help in troubleshooting equipment problems and is responsible for major repairs on some equipment. IES provides a central stock of temperature sensors and cables and a calibration facility for providing field personnel with calibrated (traceable to National Institute of Standards and Technology) temperature and wind sensors. IES also supplies adequate documentation and training for field personnel who will operate and maintain the monitoring and data transfer systems. IES provides support for the EDS data logger and data collection equipment. IES supplies and calibrates wind, air temperature, and solar radiation sensors.

The Data Acquisition & Testing Supervisor is a member of REMIC.

3.4.3 Environmental Permits & Compliance; Environmental Nuclear Generation & Construction (ENG&C)

ENG&C provides three key functions to sustain and improve environmental performance: support to operations, permitting and compliance expertise, and regulatory interface.

The Corporate Senior Manager for Environmental Nuclear Generation & Construction is a member of REMIC.

4.0 REGULATORY AND REQUIREMENT INFORMATION

In addition to serving as a technical reference, this EDS Manual summarizes regulatory and requirement information.

4.1 FAA Notification

The Federal Aviation Administration (FAA) must be notified of "any failure or malfunction that lasts more than thirty (30) minutes and affects a top light or flashing obstruction light regardless of its position" (FAA Advisory Circular, "Obstruction Marking and Lighting," AC 70/7460-1K).

4.2 Meteorological Requirements Matrix

EMA maintains the Meteorological Requirements Matrix, according to ESR-SOP-9.3 (“Maintaining Meteorological Monitoring Requirements Documentation for REMIC”). This is an item-by-item listing of all the requirements that apply to the meteorological monitoring program, how the Baseline Specifications addresses each requirement (where applicable), and a list of implementing documents.

4.3 Baseline Specifications

EMA maintains the Baseline Specifications, according to ESR-SOP-9.3 (“Maintaining Meteorological Monitoring Requirements Documentation for REMIC”). The Baseline Specifications is a technical description of the hardware and software used in the meteorological monitoring program. This description identifies the critical features that must be satisfied and describes the required interfaces with other systems.

4.4 Calibration Specifications

NPG approved specifications shall be provided to organizations on NPG's Acceptable Supplier List (ASL) that perform meteorological monitoring activities. The ASL process addresses basic QA requirements while specifications provided to the contractor by the client address any other QA requirements. IES provides instrumentation and support services and is on NPG’s ASL (as TVA Central Laboratories Services).

5.0 MATRIX OF QUALITY ASSURANCE REQUIREMENTS - METEOROLOGICAL MONITORING

NPG-SPP-5.12, "Meteorological Monitoring Program," requires an Augmented Quality Assurance (QA) Program for the Meteorological Monitoring Program as defined in NPG-SPP-5.9, "Radiological Control and Radioactive Material Shipment Augmented Quality Assurance Program". This matrix identifies specific documents that address the QA program components.

Implementing Document(s) *	QA Criteria **																	
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
Baseline Specifications					X	X			N									
ESR-SPP-03.02	X			X					O							X		
TVA-SPP-01.001		X	X						T									
TVA-SPP-31.01				X														
ET-SPP-03.01									A						X			
ESR-SOP-9.2							X		P			X						
ESR-SOP-9.4							X		P								X	
ESR-SOP-9.5	X								L									
Calibration Specs					X	X			I	X		X						
EPFS-1	X	X	X	X	X	X		X	C		X	X			X	X	X	X
EPFS-2									A				X					
EPFS-3		X		X			X		B	X			X	X				
EPFS-4		X		X			X		L	X			X	X				
EPFS-6		X		X			X		E	X			X	X				
EPFS-7		X		X			X			X				X				
EDS Manuals	X				X					X		X						
EDS Software Doc																		X
Other Software Docs																		X
NPG-SPP-2.6																		X
NPG-SPP-5.3	X																	
NPG-SPP-5.9 (default)								X			X						X	
NPG-SPP-5.12	X				X									X				

* See next page for document titles.

** QA Criteria:

A. Organization for Quality Assurance
B. Procedures, Instructions, & Drawings
C. Document Control
D. QA Records
E. Design Control
F. Procurement and Material Control
G. Inspection and Line Verification
H. Quality Assurance Assessments
I. Control of Special Processes
J. Test Control
K. Measurement and Test Equipment
L. Handling, Storage, and Shipping
M. Inspection, Test, and Operating Status
N. Control of Maintenance
O. Adverse Conditions
P. Indoctrination, Training, Qualification, and Certification
Q. Audits
R. Computer Software and Data

5.0 MATRIX OF QUALITY ASSURANCE REQUIREMENTS - METEOROLOGICAL MONITORING (continued)

NPG-SPP documents define requirements applicable to NPG as a whole and its suppliers. In the absence of other documents, they describe implementing of requirements.

REQUIREMENTS DOCUMENTS (NPG Standard Programs and Processes):

NPG-SPP-2.6	Computer Software Control • Defines software QA requirements for the meteorological monitoring program.
NPG-SPP-5.3	Chemistry Control • Defines organization responsible for the meteorological monitoring program.
NPG-SPP-5.9	Radiological Control and Radioactive Material Shipment Augmented QA Program • Defines overall requirements for the meteorological monitoring QA program.
NPG-SPP-5.12	Meteorological Monitoring Program • Defines specific requirements applicable to meteorological monitoring program.

Implementing documents are all REMIC-related (either subject to REMIC approval, prepared by organizations represented on REMIC, or designated by REMIC as applicable implementing documents). These documents identify specific requirements applicable to meteorological monitoring or describe QA criteria implementation.

IMPLEMENTING DOCUMENTS (REMIC-Related):

Baseline Specs	Baseline Specifications - Meteorological Monitoring for TVA Nuclear Plants
ESR-SPP-03.02	Quality Assurance
TVA-SPP-01.001	TVA Administration of Standard Procedures and Processes
TVA-SPP-31.01	Records Management
ET-SPP-03.01	Corrective Action Program
ESR-SOP-9.2	Validation of Meteorological Data - NPG
ESR-SOP-9.4	Inspection of Meteorological Facilities
ESR-SOP-9.5	Providing Meteorological JFD and Other Outputs to NPG
Calibration Specs	NPG Specifications for calibration and instrumentation services (provided by I&TS)
EPFS-1	Administrative Control of Procedures and Distribution
EPFS-2	Control Room Notification
EPFS-3	Servicing of Meteorological Equipment at Environmental Data Stations
EPFS-4	Environmental Data Station Meteorological Sensor Exchange
EPFS-6	Calibration of Environmental Data Station Data Logger Channels
EPFS-7	Radio and Meteorological Tower Inspection
EDS Manuals	Environmental Data Station Manuals: • Browns Ferry • Sequoyah • Watts Bar • Bellefonte • Clinch River
EDS Software Doc	Current Documentation for EDS Meteorological Monitoring System • Operability Test • Software Requirements • Verification & Validation Test
Other Software Docs	Software Documentation for Meteorological Data Applications • JFD_SPLJFD • XOQ145 • EXTRACT • 1/U • MESOPUFF

6.0 MAINTAINING THE EDS MANUAL

The EDS Manual addresses several functions that change at differing times and rates. Some changes require formal review and signoff before they can be implemented, while other changes (such as computer scan lists) can be issued without formal EDS Manual review. Therefore, instead of treating the EDS Manual as a single entity that must be reviewed (and approved) in its entirety whenever any change is required, the EDS manual is divided into individual modules. Module ownership is defined by program area and allows the review/approval process to be customized for the particular program.

The EDS Manual is divided into four modules:

	Title	Owner(s)	Approval(s)
I	Overview	REMIC	NGDC REMIC
II	Meteorological Monitoring	REMIC	NGDC REMIC
III	Water Temperature Monitoring *< not applicable to CRN >*	- - -	- - -
IV	Station Data Scan Lists	CPE	REMIC (as needed)

Each module is revised and reviewed independently. The module owner is responsible for keeping the module up-to-date. This includes preparing draft module revisions, obtaining review of the revisions, and submitting revisions for distribution.

TVA **Environmental Data Station Manual**	**Clinch River Nuclear Plant** **Module II-a** **METEOROLOGICAL MONITORING**	**EDS-CRN** **Rev. 0001** **Page 1 of 30**
		Quality Related ☑ Yes ☐ No
		Effective Date

Level of Use: Reference Use

Prepared by: Kenneth G. Wastrack (EMA), Meteorologist

Reviewed by: ______________________________ ____________
Thomas E. Adkins (NPG), Manager, Emergency Preparedness Systems — Date

Concurred by: ______________________________ ____________
Jeffery N. Perry (P&O) Senior Project Manager, SMR Technology — Date

Approved by: ______________________________ ____________
Walter H. Lee III (NPG), Manager, Emergency Preparedness--REMIC Chairman — Date

Revision Log

Revision or Change Number	Effective Date	Affected Page Numbers	Description of Revision/Change
0		All	Initial Release

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1.0 SCOPE AND FORMAT OF MODULE II

EDS Manual Module II (“Meteorological Monitoring”) contains an extensive amount of information that cannot be easily presented in a single document. Therefore, this module is divided into three parts:

A. Module II-a

Introduction.

Station and Equipment Description.

Equipment Calibration and Maintenance.

Meteorological Data Processing, Validation, and Reporting.

References.

Abbreviations and Definitions.

B. Module II-b

Accuracy of Meteorological Measurements.

C. Module II-c

Site-specific Appendices.

All three parts of the Module are issued at the same time. Module II-a includes the Cover Page (with approval signatures) and the Revision Log for all three parts.

2.0 INTRODUCTION

The Tennessee Valley Authority (TVA) Clinch River Nuclear Plant (CRN) Environmental Data Station (EDS) is located at the CRN site on the Clinch River portion of Watts Bar Lake. A description of the meteorological site is given in Appendix A of Module II-c.

The EDS includes a 110-meter meteorological tower (although no data are collected above 60 meters), surface meteorological sensors, a computer-controlled data logger and associated equipment, and a building for equipment and personnel.

The meteorological monitoring site was selected so data can be collected that are representative of the general state of the atmosphere influencing the nuclear plant and surrounding areas. This requires selecting a site that is not adversely influenced by terrain, vegetation, obstructions, or activities near the site. Since changes often occur that will impact data collected at the site, periodic inspections are performed to ensure that data collected are still acceptable. These inspections are conducted annually by individuals, normally meteorologists, who are knowledgeable of conditions that might affect measurements. If adverse conditions are identified, appropriate corrective actions are taken or compensating measures are established.

Meteorological data are automatically collected at multiple levels on (or near) the tower; summarized into various formats; and transmitted to a Remote Access Computer (RAC) for further processing. Later, collected data are validated to document data quality and saved as permanent archival records. All automated instrumentation and equipment is checked and calibrated regularly to ensure continued correct operation of all system components.

3.0 STATION AND EQUIPMENT DESCRIPTION

3.1 Meteorological Tower

A single 110-meter meteorological tower is used at the EDS.

The tower has meteorological sensors mounted on the structure. It conforms to Telecommunications Industries Association Standard TIA-222-G, "Structural Standards for Steel Antenna Towers and Antenna Supporting Structures."

A. The tower will withstand the following simultaneous loads:

1. A horizontal wind pressure as specified in the Electronics Industries Association Code, TIA-222-G. This design load is for a wind velocity of 90 miles per hour (3-second gust), which is equivalent to a 50-year recurrence interval.

2. A vertical weight load of tower, guys, and equipment.

B. All members except bolts, nuts, washers, and guying hardware are hot dip galvanized in accordance with ASTM-A123 or ASTM-A153.

C. The tower is marked and lighted per FAA Advisory Circular 70/7460-1K, "Obstruction Marking and Lighting," for towers 300 to 450 feet in height.

1. The tower is painted with International Airways orange and white paint in accordance with Advisory Circular 70/7460-1K.

2. The lighting system includes lamps, insulated wiring in conduit, and a control unit enclosed in a waterproof metal cabinet. The control unit is mounted on the north side of the tower. The flashing code located on top of the tower rotates within the time specified by FAA specifications. In the event of flasher failure, the beacon lamps shall automatically turn ON and remain ON.

D. The tower is equipped with a ladder attached to one side of the tower. The ladder is furnished with a safety cable and two climbing belts as per TVA's Hazard Control Standard No. 608.

E. Tower inspection and maintenance is performed in accordance with EPFS-7. Formal inspections are scheduled at 3-year (ground-level inspection only), and 6-year (ground-level and on-tower inspections) intervals.

3.2 Grounding and Lightning Protection

The 110-meter tower is grounded by three 5/8-inch diameter 8 foot long copperweld grounding rods within 3 feet of the tower base. The top of these rods is 6 inches below ground surface and interconnected with No. 2 or larger copper ground wire. Two rods are connected to two different legs of the tower.

A continuous run of No. 2 or larger stranded copper is attached at 10-foot intervals to one leg of the tower from the top of the tower to the ground rods at the base. All bonding of ground rods and ground wire are made by standard grounding compression fittings.

3.2 Grounding and Lightning Protection (continued)

All equipment mounted on the tower shall be connected to the copper ground wire so that it will be effectively grounded.

The guy cables are grounded through their respective guy anchors are connected to a 5/8-inch diameter, 8-foot ground rod. The ground rod should be driven into the ground until the top is at least 6 inches below the surface.

The ground rods at the base of the tower are connected to the ground rods at each anchor with the same size stranded copper wire as used on the tower. The ground wire is buried 18 inches below ground surface.

3.2.1 Lightning/electrical protection

Lightning/electrical protection against damage to the computer through the sensor lines is provided to the computer in one of two ways.

A. Most of the sensor signals are transmitted to the computer through the Agilent data acquisition switch unit. This device provides a protective interface.

B. Wind sensor signal lines are directly wired to the computer. In-line optical isolators provide protection for the electrical pathway.

3.3 Meteorological Sensors and Equipment

Sensors for wind direction/speed, air temperature, and dewpoint are mounted at the 10-meter and 60-meter levels. See Table II-1 for manufacturer specifications. The pyranometer and rain gauge are located near the tower, with sensor inputs approximately one meter above ground.

Automated meteorological data processing consists of scanning instantaneous meteorological variables and executing a computer program that calculates summary results. Table II-2 lists the meteorological variables that are scanned, their scan periods, and scaling calculations (to convert from electrical units to meteorological units). Table II-3 identifies the range, resolution, limit check, normal number of interrogations, minimum number of interrogations required for valid record, and the data processing calculations for each variable.

3.3 Meteorological Sensors and Equipment (continued)

TABLE II-1
METEOROLOGICAL SENSORS

All instrumentation and measurements meet RG-1.23 (Revision 1) and ANSI/ANS-3.11 (2005) requirements, except as described below.

Sensor	Level, meters *	Manufacturer Sensor Specifications
Wind Direction (WD) and Wind Speed (WS)	10, 60	Vaisala Model 425 ultrasonic wind sensor; starting threshold, 0 mph WD: Resolution, 1°; range, 0 to 360°; accuracy ±2°. WS: Resolution, 0.1 mph; range, 0 to 144 mph; accuracy ±0.3 mph or 3% of reading, whichever is greater.
Ambient Air Temperature	10, 60	Weed Instrument Company, Model 101, R_0 = 100 RTD Temperature (platinum wire resistance temperature detector) mounted in motor-fan aspirated solar radiation shield, R. M. Young, Co. model 43408. Sensor: Data recording range -30.0 to 120.0°F; RTD stability, ±0.25°F/year; RTD repeatability, ±0.25°F; time response, 5 seconds. Aspirated Shield: Maximum radiation error, 0 to +0.4°F; delta-T error, ±0.1°F with like shields; aspiration flow rate, 3.5 to 7.6 m/s.
Dewpoint Temperature	10, 60	Vaisala, Model HMT337 Humidity and Temperature Transmitter for High Humidity Applications; capacitive humidity sensor with warmed probe head mounted in aspirated radiation shield, R.M. Young Model 43502. Sensor: Temperature range, -70 to +180°C; measurement range, 0 to 100% RH, factory calibration uncertainty, ±0.6% RH for 0...40% RH and ± 1.0% for 40...97% RH. Aspirated Shield: Aspiration flow rate, 5 to 10 m/s.
Solar Radiation	1	Eppley Laboratories Model 8-48 Pyranometer; sensitivity = 0.001 ly/min (based on 10 µV =1 W/m^2); temperature dependence = ±1.5%; linearity ±1% from 0.00 to 1400 W/m^2 (2.01 ly/min); response time 5 seconds; cosine response ±2% from 0 to 70°, ±5% from 70 to 80°.
Rainfall	1	Sutron Corporation, Model 5600-0420-1h; heated tipping bucket rain gauge. Accuracy ±0.5% at 0.5 inch/hour and ±2.0% at 2 inches/hour; sensitivity, ±0.01 inches; resolution 0.01 inch.

* Sensor elevations indicated are approximations of actual sensor heights. See Module II-c (Appendix A) for actual sensor heights.

3.3 Meteorological Sensors and Equipment (continued)

TABLE II-2
METEOROLOGICAL VARIABLES SCANNED

Variable	Period Between Scans	Scaling Calculations (X = value of measurement)
Wind Direction	5 seconds	Wind Direction (° azimuth) = X
Wind Speed	5 seconds	Wind Speed (mph) = X
Air Temperature	5 seconds	Air Temperature (°F) = $1.8*(T_C)+32$ $T_C = T_1 + A$ $A = K_2 * \left[\left(\frac{T_1}{100}\right)^2 - \left(\frac{T_1}{100}\right)\right]$ $T_1 = \frac{100*(R_T - R_0)}{K_1}$ R_T = resistance of RTD as measured by DASU = X R_0 = constant (ice point resistance) K_1 and K_2 = constants T_C = temperature in °C
Dewpoint Temperature	5 seconds	Dew Point Temperature (°F) = $(X \text{ volts} * 11.125) - 26.25$
Rainfall	1 hour, 15 minutes	Rainfall (inches) = 0.01 * ($\text{counts}_{\text{after}}$ - $\text{counts}_{\text{before}}$)
Solar Radiation (1 ly = 1 g-cal/cm^2)	5 seconds	Solar Radiation (ly/min) = $\left(\frac{X \text{ millivolts}}{\text{millivolts}/(\text{ly}/\text{min})}\right) = \frac{X}{7.26}$ Note: **7.26** is an example value. Actual values are supplied with the individual sensor.

3.3 Meteorological Sensors and Equipment (continued)

TABLE II-3
METEOROLOGICAL DATA PROCESSING

Variable	Valid Input Range	Resolution	Output Limit Check
Wind Direction	n/a (digital input)	1°	0° to 359°
Wind Speed	n/a (digital input)	0.1 mi/hr	0.0 to 99.9 mi/hr
Air Temperature	86 to 120 ohms	0.01 °F	-30.00 to 120.00 °F
Dewpoint Temperature	2.000 to 5.300 volts	0.01 °F	-4.00 to 85.00 °F
Solar Radiation	-0.02 to 30.0 mVolts	0.01 ly/min	0.00 to 3.00 ly/min
Rainfall	n/a (frequency count)	0.01 inches H_2O	0.00 to 10.00 inches H_2O

Variable	Interrogations: Hourly Normal	Hourly Min *	15-Minutes Normal	15-Minutes Min *	Calculations
Vector Wind Direction	720	180	180	45	$\arctan\left[\frac{\sum(\mathrm{WS}*\sin \mathrm{WD})}{\sum(\mathrm{WS}*\cos \mathrm{WD})}\right]$
Vector Wind Speed	720	180	180	45	$\frac{\sqrt{\left[\sum(\mathrm{WS}*\sin \mathrm{WD})^2+\sum(\mathrm{WS}*\cos \mathrm{WD})^2\right]}}{\mathrm{n}}$
Sigma Theta **	720	540	180	135	$\sqrt{\frac{\left[\sum\left(\{\mathrm{WD}-\overline{\mathrm{WD}}\}^2\right)-\left\langle\left(\sum\{\mathrm{WD}-\overline{\mathrm{WD}}\}\right)^2/\mathrm{n}\right\rangle\right]}{\mathrm{n}-1}}$
Average Wind Speed	720	180	180	45	$\sum \mathrm{WS}/\mathrm{n}$
Air Temperature	720	180	180	45	$\sum \mathrm{AT}/\mathrm{n}$
Dewpoint Temperature	720	180	NA	NA	$\sum \mathrm{DP}/\mathrm{n}$
Solar Radiation	720	180	NA	NA	$\sum \mathrm{SR}/\mathrm{n}$
Rainfall	1 ***	1 ***	1 ***	1 ***	RF

Individual Interrogations

WD - Wind Direction
WS - Wind Speed
AT - Air Temperature
DP - Dewpoint Temperature
SR - Solar Radiation
RF_i - Rainfall (current)
RF_{i-1} - Rainfall (previous)
n = number of interrogations

* Minimum number of readings required for a valid sample.
** Sigma theta is calculated using observed wind direction individual values.
*** Rainfall is also interrogated once every 15 minutes.

3.3.1 Wind direction/speed sensor

The wind direction/speed sensor uses the speed of an ultrasound signal across a known distance to determine wind speed and direction.

A. The Vaisala Model 425 ultrasonic wind sensor determines wind direction and speed based on the transit time for sound to travel from one transducer to another. The sensor determines the transit time along three horizontal axes (offset by 120 degrees with respect to each other). Using the transit times, the sensor determines the wind speed along each axis. The sensor then computes the wind speed and direction and reports them to the data logging system.

B. Calibrations of wind sensor data logger channels are performed in accordance with EPFS-6.

3.3.2 The ambient air temperature sensor

The ambient air temperature sensor is a platinum resistance thermometer whose resistance is a linear function of temperature. The temperature sensor is mounted in a motor aspirated temperature shield.

A. Motor-aspirated shields containing platinum temperature sensing elements (RTD's) are used to measure temperatures, at selected levels on the meteorological tower. Platinum RTD's are used because of their excellent stability.

B. The motor-aspirated shield is designed to protect the air temperature probe from solar and terrestrial radiation, while drawing a representative sample of ambient air over the probe. The air is drawn in by an aspirator motor and fan. The air temperature probe is mounted in the center of two coaxial shields or tube units. These tubes are separated by an open space through which air is free to pass. While the aspirator motor fan draws a sample of air over the temperature probe, it also "scrubs" the surface of the tubes, breaking the air boundary layer at each surface and reducing heat transfer by radiation and convection to the inner shield.

C. The ambient air temperature probe is a platinum element mounted on a ceramic bobbin, covered by aluminum oxide insulation and a stainless steel sheath. The normal resistance is 100 ohms at the freezing point (32°F) and varies directly with temperature, approximately 0.22 ohm/°F of temperature change. The probe's operating range is quite large. However, the data recording equipment accepts temperature data only within the range of -30 to +120°F. Any values outside this range will be recorded as LR (i.e., lost record) by the data logger.

D. Each temperature probe is connected to the data logging equipment by four wires. Two of the wires provide a circuit for the constant current (1 mA) which flows through the resistance of the probe. The other two wires are used to measure the voltage drop across the probe. If the current source is constant and the voltage reading device has a very high input impedance, the lead resistance between the data logging equipment and the probe does not affect the reading in a four-wire system.

E. The air temperature sensors are sent to the field after being calibrated. Calibrations of air temperature sensor data logger channels are performed in accordance with EPFS-6.

3.3.3 Dew point temperature sensor

NOTES ABOUT DEWPOINT MEASUREMENTS

Measurement of atmospheric dewpoint presents special challenges because the state of water changes (i.e. freezes) within the normal sampling range. The relationship between dewpoint (32°F and higher) and frost point (below 32°F) cannot be represented by a single linear equation because the calibration curves are different. Frost point does not apply above 32°F, and is always higher below 32°F.

The following table shows the relationship between the two variables.

Frost Point (°F)	Dewpoint (°F)	Frost Point (°F)	Dewpoint (°F)	Frost Point (°F)	Dewpoint (°F)
32	32.0	20	18.5	8	5.2
30	29.7	18	16.2	6	2.9
28	27.5	16	14.0	4	0.7
26	25.2	14	11.8	2	-1.5
24	22.9	12	9.6	0	-3.7
22	20.7	10	7.4	-2	-5.8

For temperatures below 32°F, it is not always certain which variable (dewpoint or frost point) is being measured and reported by the sensor because of the sensor characteristics.

- Chilled-mirror sensors measure dewpoint directly by determining the temperature at which a mirror is covered by dew (and does not reflect light). For values below freezing, the mirror is normally covered by frost rather than dew, so the sensor reports the frost point value as the dewpoint. However, for some values just below 32°F, water may still be in liquid form, so the dewpoint is reported.
- Capacitive humidity sensors measure relative humidity and convert to dewpoint. For values below 32°F, the relative humidity will be based on frost point, so frost point will be reported instead.

Historically, TVA has not been concerned with frost point values.

- Only dewpoints at the high end of the measurement range were of concern because of impacts on cooling tower operations.
- Calibration standards did not work for values below 32°F.

Because the sensors are not calibrated below 32°F, it is assumed that the sensors accurately operate below 32°F. Data users are responsible for recognizing that “dewpoint” values below 32°F are more likely to be frost point.

The dewpoint temperature system utilizes a capacitive humidity sensor with warmed probe head. The transmitter and the warmed head probe are mounted at the 60- and 10-meter level on the meteorological tower.

A. The Vaisala Humidity and Temperature Transmitter HMT337 warmed probe maintains a temperature difference between the probe head and external environment to avoid condensation on the sensor (since a wet probe cannot observe the actual humidity in the ambient air). Even though the temperature is higher than the environment, the dewpoint remains the same.

3.3.3 Dew point temperature sensor (continued)

B. The HMT337 probe head also contains a heater that speeds up the recovery of the sensor from condensation. The heater is configured to operate with the following default settings.

1. Start Threshold = 95% Relative Humidity.
2. Heating Duration = 30 seconds.
3. Heater Temperature = 100°F.

C. The HMT337 provides reliable humidity measurement in wide range of applications. The transmitter can be configured to measure, calculate, and output dewpoint as an analog signal.

D. Although the Vaisala Humidity and Temperature Transmitter has a full range of -94°F to +356°F, the system is operated to measure only the normal range of atmospheric dewpoint temperatures based on site climatology. Consequently, the data logging equipment accepts only dewpoint temperatures within the range of -4°F to +85°F (which corresponds to sensor output of 2.000 to 10.000 V).

E. Because of problems associated with dewpoint versus frost point, the actual sensor calibration range is +34°F to +86°F.

F. Calibration of the dewpoint sensor is performed according to [CLS] 605.01-004. Calibration of dewpoint temperature channel is performed in accordance with EPFS-6.

3.3.4 Solar Radiation Sensor

The 180-degree pyranometer measures the total sun and sky radiation received on a horizontal surface. The pyranometer detects radiation by means of a differential thermopile. The thermocouple hot-junctions contact blackened surfaces and the cold-junctions contact whitened surfaces that alternate in a radial pattern.

A. The Eppley Model 8-48, 180° pyranometer measures solar radiation received on a horizontal surface. The detector is a differential thermopile enclosed in a precision ground, optical glass envelope with the hot-junction receivers blackened and the cold-junction receivers whitened. A network, consisting of a thermistor and two resistors, mounted internally, provides temperature compensation from -20°C to +40°C (-4°F to +104°F).

B. The Eppley Pyranometer is sent to the field after being calibrated at the factory by the vendor yearly. Semiannual field calibration is performed in accordance with EPFS-6.

3.3.5 Rain Gauge

The rain gauge is a tipping-bucket type, which reports precipitation in 0.01-inch increments.

A. Mechanical--The rain gauge collects rainfall within an 8-inch diameter area created by the knife-edge collector portion of the sensor. Collected water is funneled to a mechanical device (tipping bucket), which incrementally measures the accumulation and causes the momentary closure of a switch for each increment. The tipping bucket is designed to measure in increments of 0.01 inch of rain. As water is collected, the tipping bucket fills to the point where it tips. This action empties the bucket in preparation for additional measurements, closes the momentary switch, and signals another 0.01 inch of precipitation.

B. Electrical--A continuous 5-volt signal is provided to the rain gauge, but since the circuit is normally open so no signal is transmitted. When the bucket tips, the circuit is momentarily closed and a pulse is transmitted.

C. Output--Rainfall amounts are determined by counting the number of pulses during a period of time (either 15 minutes or 1 hour) and multiplying by 0.01 inch. To determine total rainfall over a given period of time, add the individual 15-minute or hourly values within the period.

D. Rain gauges are calibrated in accordance with EPFS-6.

3.4 Data Logger

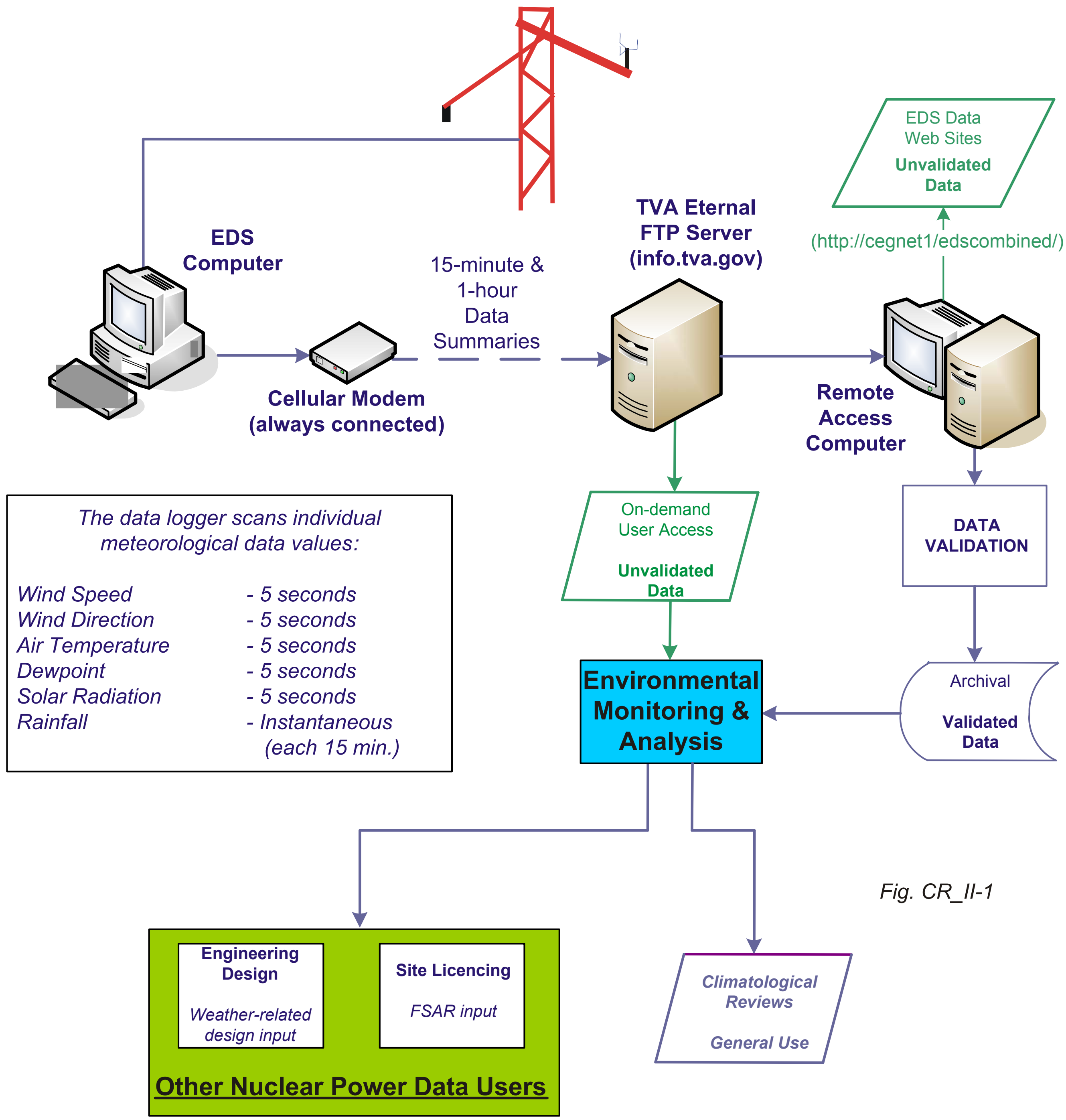
The data logger collects, processes, transmits, and records meteorological and hydrological data. See Figure II-1 for a flowchart of the meteorological data users.

The data logger system (Module II-c, Figure IIC-2) at the EDS consists of a Microsoft Windows™ based server running a Digital Equipment Corporation (DEC) VAX/VMS real time emulator, an instrument multiplexer, a data acquisition switching unit and communications equipment. The server also has two network connections to the TVA Wide Area Network (WAN). One WAN connection is dedicated to the Microsoft Windows™ server and the other WAN connection is dedicated to the VAX emulator.

3.4 Data Logger (continued)

Figure II-1

EDS DATA FLOW



3.5 Data Logger Operation and Equipment

All data logger functions are controlled by the computer program. The output of each meteorological sensor connected by cable to the logger, is scanned periodically, scaled, and stored in the computer.

A. The Agilent 34970A Data Acquisition Switch Unit is used to select the desired analog (sensor) input and convert all analog input signals to a digital form for processing by the computer. The unit has high accuracy and resolution, and is controlled remotely by digital signals from the computer. This allows the computer to control the scale, range, and frequency of measurement. Front panel controls and display allow manual use during maintenance and calibration activities.

   The Agilent Data Acquisition Switch Unit is a microprocessor controlled instrument that can measure voltage, current, and resistance over a wide number of ranges. Range, functions and trigger rate are set remotely by the DEC Computer. Resistance measurements are made utilizing the standard four-wire technique.

   The Agilent Data Acquisition Switch Unit includes two plug-in modules.

   1. A 20-Channel Multiplexer module (module 34901A) scans electrical resistance and voltage signals from temperature, dewpoint, and solar radiation sensors.

   2. A Multifunction module (module 34907A) counts rain gauge tips.

The data are recorded on magnetic disc and periodically transferred to and offsite computer. Data are transferred using an “always-connected" cellular modem, a TVA public access external FTP server, and the TVA wide area network (WAN).

3.6 Uninterruptible Power Supply and Emergency Power Generator

3.6.1 The uninterruptible power supply system (UPS)

The uninterruptible power supply system (UPS) is a microcomputer controlled *dc-to-ac* converter that has the capacity to maintain the instrumentation power load up to 30 minutes. In normal operating mode (normal utility power supplied), the UPS is conditioning line power to remove spikes, sags, surges, and noise. When utility power fails, the UPS provides ac power from its internal batteries.

3.6.2 Emergency power generator

This section is not applicable since no emergency power generator is currently installed.

3.7 Remote Access Computer

The EDS data logger is linked to a computer network in Chattanooga that provides secure and high speed data transfers from the EDS system. Meteorological data collected at the EDS is available in near real time to technical users. EDS programmers have read and write access to data files and programs stored on the EDS minicomputer and can manage the EDS system remotely via this computer network.

The Remote Access Computer (RAC) is a central location for all EDS information.

3.7 Remote Access Computer (continued)

- For general users, information available on the RAC includes the current scan sheets and raw meteorological data in real time. Data are available by internet access on TVA InsideNet using **http://cegnet1/edscombined/**.

- For data validation, the hourly and 15-minute data streams can be downloaded from the RAC using anonymous FTP.

4.0 EQUIPMENT CALIBRATION AND MAINTENANCE

The inspection, servicing, and maintenance program for meteorological instrumentation and associated equipment has the overall objective of ensuring an annual joint data recovery of 90 percent for atmospheric stability (ΔT, temperature difference), wind speed, and wind direction at levels representing effluent release points.

4.1 Calibration

A. A schedule of calibration due dates is maintained at the responsible field office. All signal processing units, and the rain gauge are calibrated in place. The DASU, wind sensors, air temperature sensors, the dewpoint temperature sensor, and Eppley pyranometer are exchanged and calibration is performed elsewhere.

B. All sensor calibrations are performed using quality assurance procedures and instrument lab calibration procedures (according to NPG Specifications for calibration and instrumentation services). Surveillance Instructions are performed using instructions written and maintained by nuclear plant personnel. Reporting forms are illustrated in each procedure.

C. Sonic wind sensors, air temperature sensors, and dewpoint sensors shall remain in service no longer than 184 days or beyond the calibration due date, whichever comes first. Eppley pyranometers shall be exchanged within one year of the last calibration. Rain gauges are not routinely exchanged.

D. The following calibration standards and methods are used in the meteorological monitoring program.

Wind Sensor	Calibrations are performed in a wind tunnel.
• Speed	• Anemometer (NIST certified)
• Direction	• Sonic Wind sensor (NIST certified)
Temperature sensors	Certified platinum resistance thermometer (PRT)
Solar radiation sensors	Manufacturer standard (factory calibrated)
Dewpoint temperature	Calibration in laboratory environmental chamber.
Rain gauge	Known amount of water (enters the sensor at a rate of approximately 2 inches per hour).

Digital voltmeters	Direct voltage calibrator (Manufacturer certification) Resistance calibrator (Manufacturer certification) Standard resistors (Manufacturer certification)
Frequency meters	Frequency measurement system (Manufacturer certification)
DC voltage standards	DC reference standard (Manufacturer certification)

4.2 Maintenance

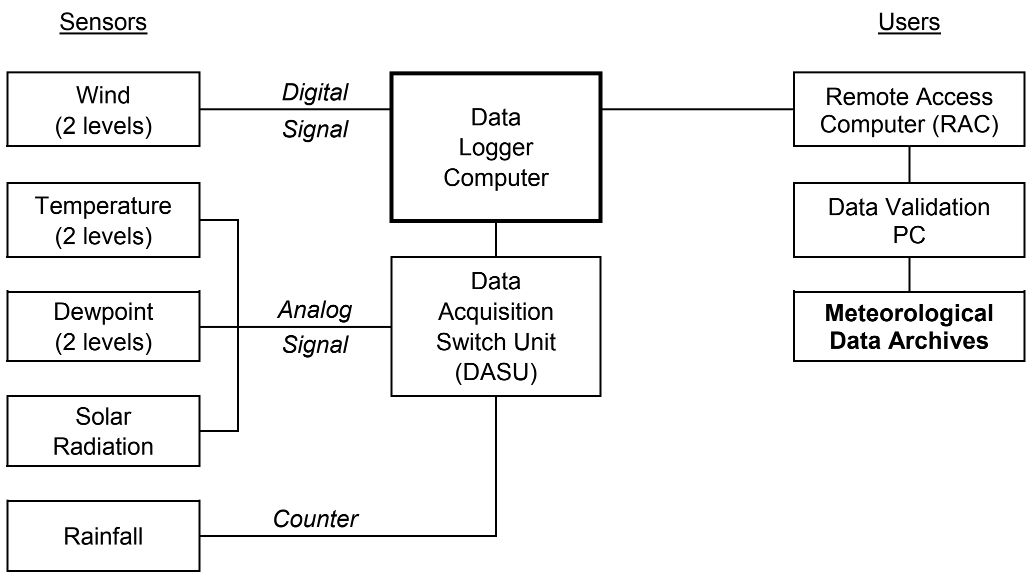
A. The EDS is routinely serviced a minimum of bi-weekly according to EPFS-3.

B. The tower maintenance and inspection is performed according to EPFS-7.

C. Non-routine maintenance is performed whenever necessary. An adequate spare parts inventory is maintained to minimize extended periods of system outage. This includes a spare EDS computer, spare sensors, and spare equipment components.

4.3 Data Traceability

Meteorological data traceability is documented through calibrations and data checks that encompass entire data channels (from sensors to data displays or validated data). Meteorological data are transmitted from five different types of sensors through the data logger computer to the users:



Sensors and equipment are calibrated or replaced at least every six months of service (except for solar radiation sensors, which are replaced annually).

- Wind sensors, air temperature sensors (RTD's), dewpoint sensors, and Data Acquisition Switch Unit (DASU) remain in service no longer than 184 days or beyond the calibration due date, whichever comes first. Solar radiation sensors (Eppley cells) are exchanged within one year of the last calibration. Rain gauge sensors are not routinely exchanged, but are calibrated in place.

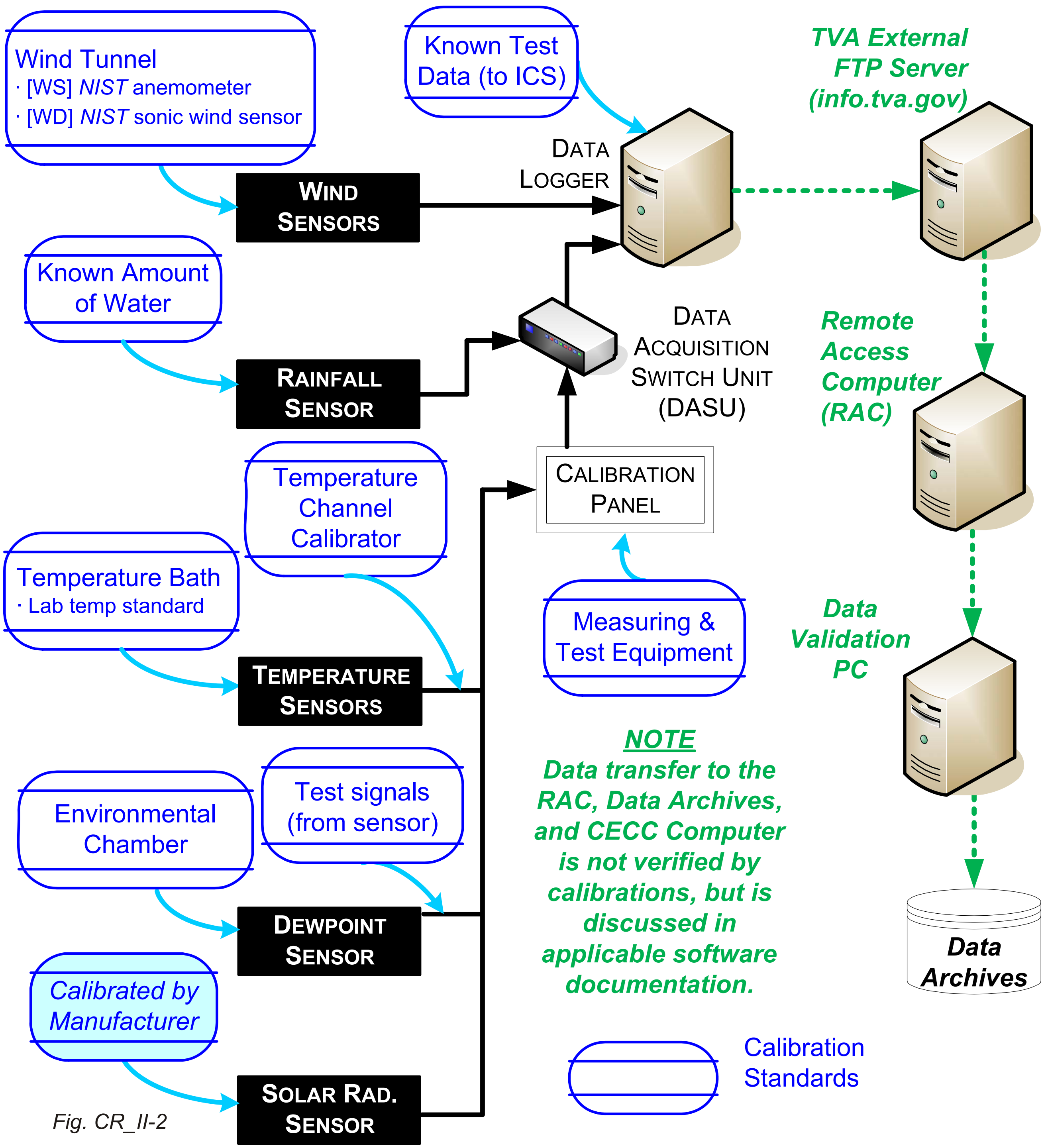
- Channel calibrations are performed every 184 calendar days of service, and as required when maintenance is performed.

- Checks of the Archival data channel are performed each workday.

Figure II-2 illustrates the meteorological measurement traceability for each variable. Tables II-4a through II-4e list the data channel segments for each variable and summarize the documentation and standards that apply to each segment.

4.3 Data Traceability (continued)

Figure II-2
METEOROLOGICAL MEASUREMENT TRACEABILITY



4.3 Data Traceability (continued)

Table II-4a
METEOROLOGICAL DATA CHANNEL CHECK/CALIBRATION
(WIND)

Channel Segment	Relevant Procedure(s) *	Checks/Calibrations **
Sensor to TVA Met Data Archives		
Sensor	450.01-019	Wind Tunnel ∞ NIST-traceable anemometer ∞ NIST-traceable sonic wind sensor
Sensor Channel to Data Logger	EPFS-4	∞ Margin Verifier Device
Data Logger	EPFS-4 EPFS-6	Verification of digital output Verification of known test data
Data Logger to Remote Access Computer (RAC)	MET_SRS_SDD ***	- - -
RAC to **TVA Met Data Archives**	ESR-SOP-9.2	Manual data comparison

* The procedure titles are listed after Table II-4e.

** Standards are indicated by "∞".

*** Data transfer to the RAC and TVA Met Data Archives is not verified by calibrations, but is discussed in applicable software documentation and procedures.

Table II-4b
METEOROLOGICAL DATA CHANNEL CHECK/CALIBRATION
(TEMPERATURE)

Channel Segment	Relevant Procedure(s) *	Checks/Calibrations **
Sensor to TVA Met Data Archives		
Sensor	450.01-005	∞ Temperature Bath ∞ Lab. Standard Thermometer
Sensor Channel to Data Logger	450.01-011 450.01-014 EPFS-4	∞ Temp. Channel Calibrator ∞ Measuring and Test Equipment (M&TE)
Data Logger	EPFS-4 EPFS-6	Verification of digital output ∞ Known Test Data
Data Logger to Remote Access Computer (RAC)	MET_SRS_SDD ***	- - -
RAC to **TVA Met Data Archives**	ESR-SOP-9.2	Manual data comparison

* The procedure titles are listed after Table II-4e.

** Standards are indicated by "∞".

*** Data transfer to the RAC and TVA Met Data Archives is not verified by calibrations, but is discussed in applicable software documentation and procedures.

4.3 Data Traceability (continued)

Table II-4c
METEOROLOGICAL DATA CHANNEL CHECK/CALIBRATION
(DEWPOINT)

Channel Segment	Relevant Procedure(s) *	Checks/Calibrations **
Sensor to TVA Met Data Archives		
Sensor	504.02-001	∞ Laboratory Environmental Chamber
Sensor Channel to Data Logger	450.01-014	(Included in sensor calibration)
Data Logger	EPFS-6	Verification of digital output
Data Logger to Remote Access Computer (RAC)	MET_SRS_SDD ***	- - -
RAC to **TVA Met Data Archives**	ESR-SOP-9.2	Manual data comparison

* The procedure titles are listed after Table II-4e.
** Standards are indicated by "∞".
*** Data transfer to the RAC and TVA Met Data Archives is not verified by calibrations, but is discussed in applicable software documentation and procedures.

Table II-4d
METEOROLOGICAL DATA CHANNEL CHECK/CALIBRATION
(RAINFALL)

Channel Segment	Relevant Procedure(s) *	Checks/Calibrations **
Sensor to TVA Met Data Archives		
Sensor	EPFS-6	∞ Known Amount of Water (calibration bottle)
Sensor Channel to Data Logger	EPFS-6	(Included in sensor calibration)
Data Logger	EPFS-6	Verification of digital output
Data Logger to Remote Access Computer (RAC)	MET_SRS_SDD ***	- - -
RAC to **TVA Met Data Archives**	ESR-SOP-9.2	Manual data comparison

* The procedure titles are listed after Table II-4e.
** Standards are indicated by "∞".
*** Data transfer to the RAC and TVA Met Data Archives is not verified by calibrations, but is discussed in applicable software documentation and procedures.

4.3 Data Traceability (continued)

Table II-4e
METEOROLOGICAL DATA CHANNEL CHECK/CALIBRATION
(SOLAR RADIATION)

Channel Segment	Relevant Procedure(s) *	Checks/Calibrations **
Sensor to TVA Met Data Archives		
Sensor	EPFS-4	∞ Calibrated by Manufacturer
Sensor Channel to Data Logger	450.01-014 EPFS-4 EPFS-6	∞ Measuring and Test Equipment (M&TE)
Data Logger	EPFS-6	Verification of digital output
Data Logger to Remote Access Computer (RAC)	MET_SRS_SDD ***	- - -
RAC to **TVA Met Data Archives**	ESR-SOP-9.2	Manual data comparison

* The procedure titles are listed after Table II-4e.

** Standards are indicated by "∞".

*** Data transfer to the RAC and TVA Met Data Archives is not verified by calibrations, but is discussed in applicable software documentation and procedures.

4.3 Data Traceability (continued)

PROCEDURES REFERENCED IN TABLES II-4a THROUGH II-4e:

Instrumentation Engineering Services (IES) Procedures - Generic for all plants

- **450.01-005** - Calibration of Air Temperature Sensors - Nuclear
- **450.01-011** - Certification of Temperature Channel Calibrators
- **450.01-014** - Calibration of Meteorological Monitoring Process Digital Voltmeters
- **450.01-019** - Calibration of Vaisala WAS425 Ultrasonic Wind Sensor
- **504.02-001** - Temperature and/or Humidity Recorders and Indicators

Emergency Planning Field Support (EPFS) Procedures - Generic for all plants

- **EPFS-4** - Environmental Data Station Meteorological Sensor Exchange
- **EPFS-6** - Calibration of Environmental Data Station Data Logger Channels

Computer Process Engineering (CPE) Software Documentation - Plant-specific

- **MET_SRS_SDD** - Meteorological Software Program (MET) - Software Requirements Specification and Design Document

Environmental Monitoring & Analysis (EMA) [previously Environmental Science and Resources (ESR)] Procedures - Generic for all plants

- **ESR-SOP-9.2** - Validation of Meteorological Data - Nuclear

5.0 METEOROLOGICAL DATA PROCESSING, VALIDATION, AND REPORTING

5.1 Development/documentation of Software

CPE develops, tests, documents, and oversees installation of software used in the meteorological monitoring program. This includes verifying the proper operation of software prior to implementation by means of benchmark testing and/or independent reviewers. In addition, CPE prepares and distributes software documentation and ensures adequate control and security of software used for online data processing (e.g., data logger and data validation software). REMIC is the owner of the software and CPE maintains applicable documentation.

5.2 Data Handling and Processing

CPE operates the RAC that receives data from plant data loggers for further processing. EMA accesses the RAC for validation of meteorological data. EMA identifies problems and notifies appropriate personnel.

5.3 Data Validation and Dissemination

EMA reviews meteorological data to identify possible data problems and notify appropriate personnel. EMA validates all meteorological data before it is placed into permanent archival storage to ensure that the amount of valid data in the master record meets regulatory requirements for minimum data collection. Validation includes running data validation software as an aid to review of raw data, identifying and editing questionable or invalid data, recovering data from backup sources, and adjusting data to reflect calibration results.

EMA provides meteorological data to specific users either routinely or on request.

6.0 REFERENCES

All references are most recent revisions unless noted otherwise.

6.1 Vendor maintenance/instruction manuals

6.1.1 Data Acquisition Switch Unit

A. AGILENT 34970A Data Acquisition/Switch Unit User's Guide, P/N 34970-90002, Agilent Technologies Company, November 1999

B. HP 34970A Data Acquisition/Switch Unit Quick Reference Guide, P/N 34970-90007, Hewlett-Packard. Company, October 1997

Note: Agilent was part of Hewlett-Packard until 1999.

6.1.2 Wind Speed and Direction

A. User's Guide, Vaisala WINDCAP® Ultrasonic Wind Sensor WS425, Vaisala, 2010.

6.1.3 Temperature Aspirated Radiation Shield

A. Instruction Manual, Model 43408 Gill Aspirated Radiation Shield, R. M. Young, Co., March 1995.

6.1.4 Dew Point Temperature

A. Users Guide, Vaisala HUMICAP Humidity and Temperature Transmitter Series HMT330, Vaisala, November 2004.

6.1.5 Pyranometer

A. "Black and White Pyranometers, Installation, Operation, and Maintenance", The Eppley Laboratory, January 1, 1970

B. "Instrumentation for the Measurement of the Components of Solar and Terrestrial Radiation", The Eppley Laboratory

6.1.6 Rain Gauge

A. Sutron 5600-0420-1H User's Guide

6.2 Work procedures and instruction manuals

6.2.1 Emergency Planning Field Support Procedures

A. EPFS-3, "Servicing of Meteorological Equipment at Environmental Data Stations"

B. EPFS-4, "Environmental Data Station Meteorological Sensor Exchange"

C. EPFS-6, "Calibration of Environmental Data Station Data Logger Channels"

D. EPFS-7, "Radio and Meteorological Tower Inspection"

6.2.2 Laboratory Calibration Procedures

Applicable laboratory procedures are internal documents maintained by IES. The specific requirements for meteorological instruments and related equipment are included in Calibration Specifications provided to IES by REMIC.

6.2.3 Environment and Technology Procedures

These procedures are available from EMA.

A. ESR-SOP-9.2 - Validation of Meteorological Data - Nuclear

B. ESR-SOP-9.4 - Inspection of Meteorological Facilities

6.3 Information documents

A. Environmental Data Station Network Maintenance Manual, CPE

B. SPP-2.6, "Computer Software Control" -- standard for NPG software QA

C. "Quality Assurance Handbook for Air Pollution Measurement Systems: Volume IV. Meteorological Measurements," EPA-600/4-82-060, February 1983, U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory.

D. SPP-5.12, "Meteorological Monitoring Program".

E. ANSI/ANS-3.11-2005, "Determining Meteorological Information at Nuclear Facilities," December 2005, American Nuclear Society.

F. RG-1.23 (Revision 1), “Meteorological Monitoring Programs for Nuclear Power Plants,” March 2007, Nuclear Regulatory Commission

7.0 ABBREVIATIONS AND DEFINITIONS

ac - alternating current

ACI - American Concrete Institute

ANSI - American National Standards Institute

ANS - American Nuclear Society

ASTM - American Society for Testing and Materials

°**C** - degrees Celsius

CPE - Computer Process Engineering

CPU - central processing unit

CRN - Clinch River Nuclear Plant

DASU - Data Acquisition Switch Unit

dc - direct current

DCRM - Document Control Records Management

DEC - Digital Equipment Corporation

DVM - digital voltmeter (digital multimeter)

EDS - Environmental Data Station

EMA - Environmental Monitoring and Analysis

EPFS - Emergency Preparedness Field Support

FAA - Federal Aviation Administration

°**F** - degrees Fahrenheit

ft - foot, feet

Gbyte - gigabyte

Hz - hertz

IES - Inspection Engineering Services

IEEE - Institute of Electrical and Electronics Engineers

JFD - Joint Frequency Distribution

Kbyte - kilobyte

7.0 ABBREVIATIONS AND DEFINITIONS (continued)

Kohm - kilohms (1000's ohms)

kw - kilowatts

LAN - local area network

LR - lost record

ly/min - langleys per minute

mA - milliamps

Mbps - megabits per second

Mbyte - megabyte

mph - miles per hour

msl - mean sea level

mV - millivolts

N/A - Not applicable

NIST - National Institute of Standards and Technology (formerly National Bureau of Standards, NBS)

NOAA - National Oceanic and Atmospheric Administration

NRC - Nuclear Regulatory Commission

NWS - National Weather Service

PRT - platinum resistance thermometer

RAC - Remote Access Computer

REMIC - Radiological Environmental and Meteorological Instrumentation Committee

RG - Regulatory Guide

RSS - root sum of the squares, root sum squared

RTD - resistance temperature detector

SPP - Standard Programs and Processes

TCP/IP - Transport Control Protocol/Internet Protocol

TVA - Tennessee Valley Authority

7.0 ABBREVIATIONS AND DEFINITIONS (continued)

V, v - volts

WAN - wide area network

WD, wd - wind direction

WS, ws - wind speed

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		Quality Related ☑ Yes ☐ No
		Effective Date

Level of Use: Reference Use

Prepared by: Kenneth G. Wastrack (EMA), Meteorologist

Reviewed by:	< see module II-a >	n/a Date
Concurred by:	< see module II-a >	n/a Date
Approved by:	< see module II-a >	n/a Date

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1.0 SCOPE AND FORMAT OF MODULE II

EDS Manual Module II ("Meteorological Monitoring") contains an extensive amount of information that cannot be easily presented in a single document. Therefore, this module is divided into three parts:

A. Module II-a

Introduction.

Station and Equipment Description.

Equipment Calibration and Maintenance.

Meteorological Data Processing, Validation, and Reporting.

References.

Abbreviations and Definitions.

B. Module II-b

Accuracy of Meteorological Measurements.

C. Module II-c

Site-specific Appendices.

All three parts of the Module are issued at the same time. Module II-a includes the Cover Page (with approval signatures) and the Revision Log for all three parts.

2.0 ACCURACY OF METEOROLOGICAL MEASUREMENTS

The FSAR states that the meteorological data collection system is designed to meet requirements given in NRC Regulatory Guide (RG) 1.23 (revision 1). Replacement components will be compatible with the total system and will be chosen so that the total system accuracy will meet or exceed RG-1.23 (revision 1) specifications.

While RG-1.23 identifies accuracy requirements, it does not provide guidance for determining accuracy of meteorological components. Therefore, the most up-to-date guidance available, ANSI/ANS-3.11-2005 (ANS-3.11), is used as the basis for estimating meteorological monitoring accuracy.

2.1 Overview and General

Both sensor accuracy and system accuracy are calculated for each variable. The RG 1.23 specifications, and the ANS-3.11 specifications, the sensor accuracy, and the system accuracy, are listed for each variable.

Meteorological Data System -- Accuracy vs. Specification Comparison
(Values are converted to the same units and rounded to the same precision.)

		Specification		Sensor	System Accuracy	
Variable *	Units	ANS-3.11	RG-1.23 r1	Accuracy	Instantaneous	Time-Averaged
Wind Speed (WS)	mph					
• 8.9 mph		±0.45	±0.45	±0.36	±0.36	±0.06
• 30.0 mph		±1.50	±1.50	±0.37	±0.37	±0.06
• 100.0 mph		±5.00	±5.00	±0.38	±0.39	±0.06
Wind Direction	° azimuth	±5.0	±5.0	±3.0	±4.3	±2.1
Air Temperature	°F					
• [Day] High solar rad		±0.900	±0.900	±0.078	+0.702	+0.657
• [Day] Low solar rad		±0.900	±0.900	±0.078	-0.202	-0.157
• [Night] No solar rad		±0.900	±0.900	±0.078	±0.202	±0.157
Vertical Temp. Diff.	°F	±0.180	±0.180	±0.105	±0.148	±0.046
Dewpoint	°F	±2.700	±2.700	±2.236	N/A	±0.507
Rainfall	inches					
• 0.10 in.**		±0.010	±0.010	±0.007	±0.009	N/A
Solar Radiation (SR)	ly/min		not specified			
• 0.28 ly/min		±0.014		±0.006	N/A	±0.021
• 0.45 ly/min ***		±0.023		±0.015	N/A	±0.022
• 1.50 ly/min		±0.075		±0.027	N/A	±0.026

* If a condition or value is listed, error values are specific for that condition/value. Otherwise, error values apply to the entire expected sampling range.

** ANS-3.11-2005 and RG-1.23 (r1) specify that accuracy be estimated for a specific volume (2.54 mm, 0.10 inch).

*** 0.45 ly/min is the lowest value at which the ANS-3.11-2005 specification is satisfied.

2.1 Overview and General (continued)

ANS-3.11-2005 uses the root-sum-squared (RSS) method to determine system accuracy. The individual random error components are combined and evaluated using the RSS approach. These RSS results are then adjusted by bias components to determine the final System Accuracy (SA). This approach is described below.

1. Identify the individual components that contribute to system accuracy.
2. Classify the error type for each component.
   - Bias errors ($b_1, b_2, \cdots, b_n$).
   - Random errors ($r_1, r_2, \cdots, r_n$).
3. Estimate the values of the component errors based on engineering analysis, vendor specifications, accuracy tests, or operational experience.
4. Perform time-average adjustments for each random error component.

   $$a = r/\sqrt{n}$$

   Where: r is the unadjusted random error component.

   n is the number of samples.

   a is the adjusted random error component.

   Note: For instantaneous values (where n = 1), a = r.
5. Calculate "root sum of the squares" (RSS) for the adjusted random error components.

   $$RSS = \sqrt{(a_1)^2 + (a_2)^2 + \cdots + (a_x)^2}$$

   Where: $a_1, a_2, \cdots, a_x$ are adjusted random error components.

   x represents the number of random error components.
6. Add bias errors to obtain system accuracy (SA).

   $$SA = RSS + b_1 + b_2 + \cdots + b_y$$

   Where: $b_1, b_2, \cdots, b_y$ are bias error components.

   y represents the number of bias error components.

   Note: Repeat as necessary with different bias values to determine extreme values.
7. Compare the extreme SA values with applicable requirements to evaluate system performance.

2.1 Overview and General (continued)

ANS-3.11-2005 requires that accuracy be examined for both sensor accuracy and system accuracy values.

- When the vendor provides sensor accuracy, that value is compared with accuracy requirements and used as an error component in the system accuracy calculation.
- When the sensor is calibrated by TVA, the ANS-3.11 method is used to determine the sensor accuracy that is compared with accuracy requirements and used as an error component in the system accuracy calculation.
- The system accuracy is calculated using the ANS-3.11 method and compared with accuracy requirements.

Meteorological Measurement Error Sources--Identifiable error sources have been divided into three major categories (Figure II-3). Within these categories, the individual sources of error are evaluated for each type of meteorological measurement.

Note about Time Intervals
For the purposes of error analyses; semi-annual, 6 months, & 184 days are the same time interval.

2.1 Overview and General (continued)

Figure II-3

METEOROLOGICAL MEASUREMENT ERROR SOURCES

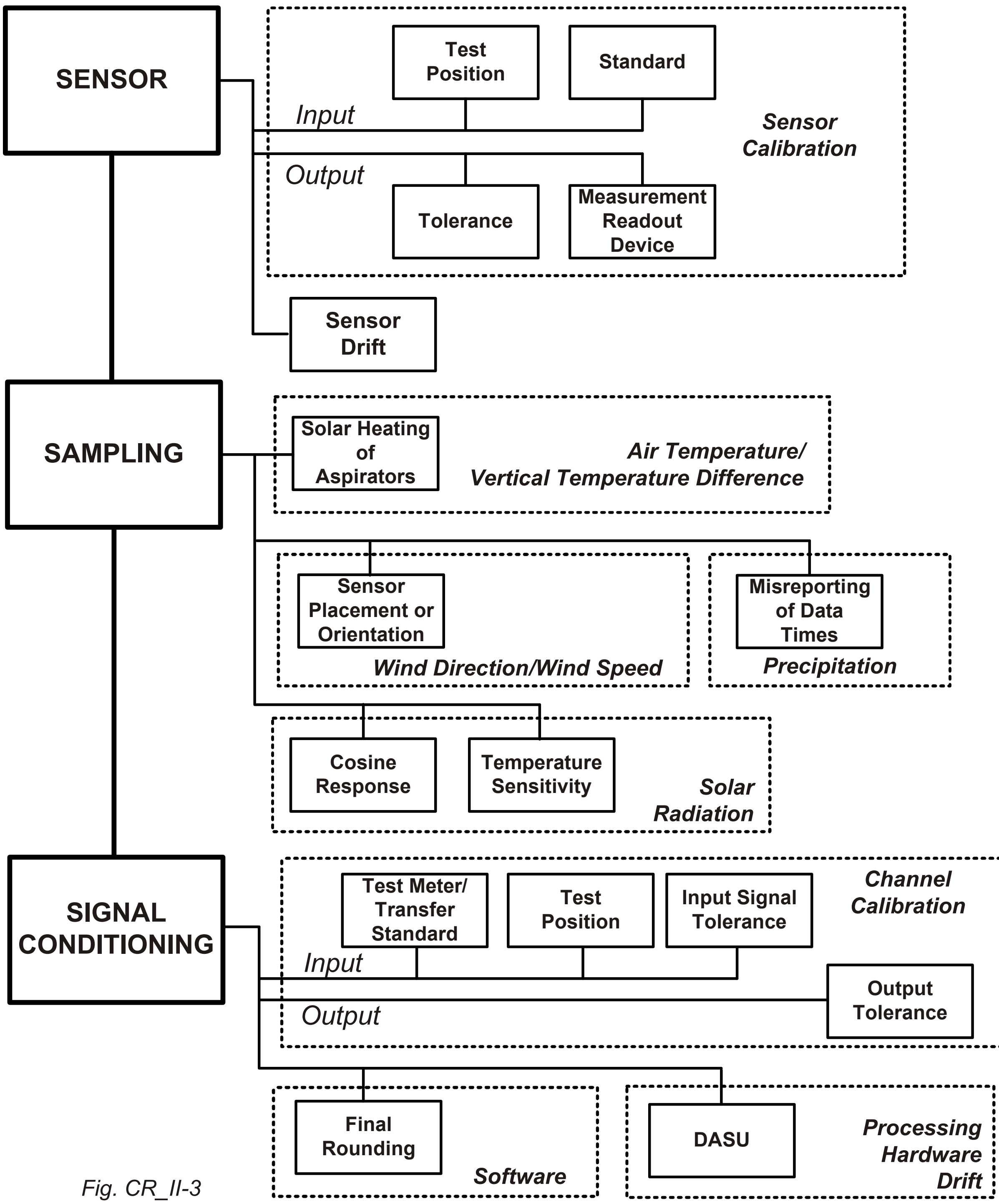

Fig. CR_II-3

2.1.1 SENSOR ACCURACY

Sensor accuracy is associated with calibration of the sensor and the drift between calibrations. A single sensor error value is calculated, compared with the sensor requirements, and used in the system accuracy calculation.

A. Sensor Calibration -- Errors associated with comparison to a standard of higher accuracy.

1. Input

a. Standard -- Accuracy of the standard that is certified using a national standard (NIST or equivalent).

b. Test position -- Accuracy associated with sensor orientation or location in the test apparatus.

2. Output

a. Measurement/Readout device -- Accuracy of test meter or display.

b. Tolerance -- Allowable accuracy of test results.

B. Sensor Drift -- Errors associated with loss of accuracy between calibrations.

2.1.2 SYSTEM ACCURACY

The system accuracy is based on the sensor error, sampling errors, and signal conditioning errors are used for calculating the system error. The system accuracy is compared with the system requirements. Based on the specific variable, one or two system accuracy values are calculated--one assuming instantaneous data (primarily for in-plant displays) and/or one using time-averaging assumptions (primarily for archival data).

A. Sensor Error

The sensor error values used in the system error are based on the calculated sensor errors and adjusted for the number of readings used to determine the final reported value.

2.1.2 SYSTEM ACCURACY (continued)

B. Sampling Errors

Sampling errors are those errors due to interference in the sensing of the exact physical quantity being measured. Since the nature of the sampling errors is different for each type of sensor, these errors are described separately for each measurement, as appropriate.

• Air Temperature/Vertical Temp. Difference	- Solar Heating of Aspirators
• Wind Direction/Wind Speed	- Sensor Orientation or Placement
• Precipitation	- Misreporting of Data Times
• Solar Radiation	- Cosine Response
	- Temperature Sensitivity

C. Signal Conditioning Errors

Signal conditioning errors are those errors associated with calibration of the data channel, the drift of hardware components, and software rounding errors between calibrations.

1. Channel Calibration -- Errors associated with comparison to a standard of higher accuracy.

   a. Input

      (1) Input signal tolerance -- Accuracy of the test signal.

      (2) Test meter or transfer standard -- Accuracy of the standard that is used for the actual calibration.

      (3) Test position -- Accuracy associated with sensor orientation or location in the test apparatus.

   b. Output tolerance -- Allowable accuracy of test results.

2. Processing Hardware Drift -- Errors associated with hardware components used for signal processing.

   a. Data Acquisition Switch Unit -- Accuracy associated with selecting the correct input signal and converting the electrical signal to input for the data logger computer.

3. Software -- Errors associated with software computations.

   a. Final rounding of hourly average value -- Accuracy of data values as output.

2.2 WIND SPEED

VARIABLE:	Wind Speed (Vaisala Model 425 ultrasonic wind sensor)
MEASUREMENT METHOD:	Ultrasonic wind sensor, direct output of 1-second average wind speed samples
VALID DATA RANGE:	0.0 – 99.9 mph
CALIBRATED RANGE:	1.0 to 30.0 mph
NUMBER OF SAMPLES ASSUMED:	180 samples in 15 minutes

REQUIREMENTS SPECIFICATIONS	
ANSI/ANS-3.11-2005	• ±0.2 m/s [0.45 mph] *for WS < 8.9 mph* • ±5% of observed *for WS ≥ 8.9 mph*
RG-1.23 (Revision 1)	• ±0.2 m/s (0.45 mph) *for WS < 8.9 mph* • ±5% of observed *for WS ≥ 8.9 mph*

<u>SOURCES OF ERROR - SENSOR</u>

		POTENTIAL ERROR (mph)		
SENSOR ACCURACY	# Samples	8.9 mph	30.0 mph	100.0 mph
A. Sensor Calibration				
1. Input				
a. Standard	1	±0.20	±0.20	±0.20
b. Test position [bias]	---	±0.00	±0.01	±0.02
2. Output				
a. Measurement/Readout device	---	---	---	---
b. Tolerance	1	±0.30	±0.30	±0.30
B. Sensor Drift	---	---	---	---
ROOT-SUM-SQUARE ERROR (with bias adjustments)		**±0.36**	**±0.37**	**±0.38**
Specification (mph)		±0.45	±1.50	±5.00
Meets Specifications?		Yes	Yes	Yes

2.2 WIND SPEED (continued)

SOURCES OF ERROR - INSTANTANEOUS CHANNEL

SYSTEM ACCURACY	# Samples	POTENTIAL ERROR (mph) 8.9 mph	30.0 mph	100.0 mph
A. SENSOR ERROR (from above)				
±0.36, ±0.37, or ±0.38	1	±0.36	±0.37	±0.38
B. SAMPLING ERRORS				
• Sensor Placement	1	±0.00	±0.02	±0.04
C. SIGNAL CONDITIONING ERRORS				
1. Channel Calibration				
a. Input				
(1) Input signal tolerance	---	---	---	---
(2) Test meter/ transfer standard	---	---	---	---
(3) Test position	---	---	---	---
b. Output tolerance	---	---	---	---
2. Processing Hardware Drift				
a. Data Acquisition Switch Unit	---	---	---	---
3. Software				
a. Rounding of final average value	1	±0.05	±0.05	±0.05
ROOT-SUM-SQUARE ERROR (with bias adjustments)		**±0.36**	**±0.37**	**±0.39**
Specification (mph)		±0.45	±1.50	±5.00
Meets Specifications?		Yes	Yes	Yes

SOURCES OF ERROR - TIME-AVERAGED CHANNEL

SYSTEM ACCURACY	# Samples	POTENTIAL ERROR (mph) 8.9 mph	30.0 mph	100.0 mph
A. SENSOR ERROR (from above)				
±0.36, ±0.37, or ±0.38	180	±0.03	±0.03	±0.03
B. SAMPLING ERRORS				
• Sensor Placement	180	±0.00	±0.00	±0.00
C. SIGNAL CONDITIONING ERRORS				
1. Channel Calibration				
a. Input				
(1) Input signal tolerance	---	---	---	---
(2) Test meter/ transfer standard	---	---	---	---
(3) Test position	---	---	---	---
b. Output tolerance	---	---	---	---
2. Processing Hardware Drift				
a. Data Acquisition Switch Unit	---	---	---	---
3. Software				
a. Rounding of final average value	1	±0.05	±0.05	±0.05
ROOT-SUM-SQUARE ERROR (with bias adjustments)		**±0.06**	**±0.06**	**±0.06**
Specification (mph)		±0.45	±1.50	±5.00
Meets Specifications?		Yes	Yes	Yes

2.2 WIND SPEED (continued)

WIND SPEED, ERROR SOURCE/VALUE EXPLANATION

Both ANSI/ANS-3.11-2005 and RG-1.23 (Revision 1) use a two-part specification for wind speed accuracy—a constant value of ±.2 m/s (±0.45 mph) for all wind speeds 4 m/s (8.9 mph) and below, and a ±5% of observed value for all wind speeds above 4 m/s (8.9 mph).

To encompass the full range of expected conditions, accuracy is calculated for 3 speeds:

- 8.9 mph -- This is the breakpoint between the constant value used for low-speed ranges and the 5% value used for higher ranges.
- 30.0 mph -- This is the upper limit of the calibrated range, because the calibration equipment allows calibration only over the range 1.0-30.0 mph
- 100.0 mph -- This is just above the maximum value (99.9 mph) that the TVA measurement system can report, and is the upper limit for the range over which the 5% error requirement applies.

Since the error relationship is linear over the range from 8.9 mph to 100.0 mph, all requirements within the range will be satisfied if requirements are satisfied at the upper and lower limits of the range.

2.2.1 WIND SPEED SENSOR ACCURACY

A. Sensor Calibration

The sensor under test is compared with an NIST-certified Climet Cup Anemometer using an open wind tunnel. The wind tunnel consists of a nozzle (with known flow characteristics) attached to a blower. The flow field downstream of the nozzle is in the open but is certified as laminar in engineering specifications. Sensors being tested in the flow field can be replaced while the wind tunnel is operating.

1. Input

Each sensor is calibrated at threshold and six test points (1, 2, 5, 10, 20, and 30 mph).

NOTE

Based on linearity tests conducted using the NOAA Oak Ridge wind tunnel, sensor calibration results are applicable to wind speeds up to 70 mph. Since the sensor has no moving parts to sense wind speed, and since the measurements are linear from 0 to 70 mph, it is assumed that the same linearity is valid up to 100.0 mph.

2.2.1 WIND SPEED SENSOR ACCURACY (continued)

Wind Speed Calibration Methodology
Threshold • The wind tunnel is turned off at the start of the test. • The test sensor is placed on the mounting. • The wind tunnel speed is slowly increased until the test sensor records a speed above 0.0 mph. • This speed is reported as the threshold speed.
Test points • For each speed test point above the threshold, the standard sensor is placed in the flow field and the blower is adjusted until the sensor reports the desired wind speed. For the remaining steps, the blower speed is not changed and the sensors are swapped while the wind tunnel continues to operate. • The standard sensor is removed from the flow field. • Each test sensor (in turn) is placed on the mounting, so that the sensing portions are in the flow field. • The speed is checked against the desired speed. After the last test sensor has been checked, the standard is replaced into the flow field to verify that the desired speed has been maintained.

a. Standard = ±**0.20 mph**.

This is a **random** error since the value reported may be either above or below the actual wind speed. The number of readings is assumed to be **1** because calibrations are performed at a single wind speed during a specific round of tests (and is treated as an instantaneous observation).

The standard, a Climet Cup Anemometer, is recertified by NIST with an uncertainty of ±0.15 mph (based on NIST certification documentation). The Climet cups control the instrument response, provided the cups and bearings are in good condition. Cup geometry is periodically checked and bearings are replaced when starting threshold test values are above normal. A conservative allowance of ±0.05 mph is added to account for slight cup abnormality and bearing wear.

±0.15 mph + ±0.05 mph = ±0.20 mph.

2.2.1 WIND SPEED SENSOR ACCURACY (continued)

b. Test position

[8.9 mph] = ±**0.00 mph**.

[30.0 mph] = ±**0.01 mph**.

[100.0 mph] = ±**0.02 mph**.

Test position concerns the sensor placement in the wind tunnel, because the wind sensor is responsive to wind components not directly perpendicular to its shaft. The laboratory calibration procedure requires the sensors to be plumb within ±1° during calibration.

This is a **bias** error since the sensor mounting will allow the sensor to be placed in only one position relative to wind flow for all tests--the maximum error is assumed.

8.9 mph:	Non-vertical placement [(1-cos 1°)x8.9 mph]:	±0.001 mph
	Conservative Approximation:	±0.001 mph
	Final Estimated Error:	±0.00 mph
30 mph:	Non-vertical placement [(1-cos 1°)x30.0 mph]:	±0.005 mph
	Conservative Approximation:	±0.001 mph
	Final Estimated Error:	±0.01 mph
100 mph:	Non-vertical placement [(1-cos 1°)x100.0 mph]:	±0.015 mph
	Conservative Approximation:	±0.005 mph
	Final Estimated Error:	±0.02 mph

2. Output

a. Measurement/Readout device = **Not Applicable (N/A)**.

The sensor is directly connected to the data logger and no interface equipment is used.

b. Tolerance = ±**0.30 mph**.

This is a **random** error since the value reported may be either above or below the actual wind speed. The number of readings is assumed to be **1** because calibrations are performed at a single wind speed during a specific round of tests (and is treated as an instantaneous observation).

The tolerance of sensor output is ±0.30 mph based on the allowable error in CLS Calibration Instruction 450.01-019.

2.2.1 WIND SPEED SENSOR ACCURACY (continued)

B. Sensor Drift = **N/A**.

The sensor is fully digital with no components that are subject to drift.

Sensor Accuracy Calculations	
8.9 mph:	$\left[\sqrt{(0.20)^2 + (0.30)^2}\right] \pm 0.00 = \pm 0.36 \text{ mph}$
30.0 mph:	$\left[\sqrt{(0.20)^2 + (0.30)^2}\right] \pm 0.01 = \pm 0.37 \text{ mph}$
100.0 mph:	$\left[\sqrt{(0.20)^2 + (0.30)^2}\right] \pm 0.02 = \pm 0.38 \text{ mph}$
Sensor errors satisfy RG-1.23 and ANS-3.11 specifications for all wind speeds.	

2.2.2 WIND SPEED SYSTEM ACCURACY

A. SENSOR ERROR

Instantaneous Data Channel	[8.9 mph] = ±**0.36 mph**.
	[30.0 mph] = ±**0.37 mph**.
	[100.0 mph] = ±**0.39 mph**.
Time-Averaged Data Channel	[8.9 mph] = ±**0.03 mph**.
	[30.0 mph] = ±**0.03 mph**.
	[100.0 mph] = ±**0.03 mph**.

The sensor error values used in the system error are based on the calculated sensor errors and adjusted for the number of readings used to determine the final reported value.

This is a **random** error since the value reported may be either above or below the actual wind speed. The number of readings is assumed to be **180** because that is the number of samples used for a 15-minute data value.

Wind Speed	Random Error	Time-adjusted Error
8.9 mph	±0.36 mph	$\pm 0.36/\sqrt{180} = \pm 0.03 \text{ mph}$
30.0 mph	±0.37 mph	$\pm 0.37/\sqrt{180} = \pm 0.03 \text{ mph}$
100.0 mph	±0.38 mph	$\pm 0.38/\sqrt{180} = \pm 0.03 \text{ mph}$

2.2.2 WIND SPEED SYSTEM ACCURACY (continued)

B. SAMPLING ERRORS

Sensor placement

1. Instantaneous Data Channel

   [8.9 mph] = ±**0.00 mph**.

   [30.0 mph] = ±**0.02 mph**.

   [100.0 mph] = ±**0.04 mph**.

2. Time-Averaged Data Channel

   [8.9 mph] = ±**0.00 mph**.

   [30.0 mph] = ±**0.00 mph**.

   [100.0 mph] = ±**0.00 mph**.

   Errors from sensor non-vertical placement on the meteorological tower are the same as explained in "Test Position" above, but are doubled to reflect problems with placement in the field.

   This is a **random** error since the wind flow can be from any direction, so the sensor can appear to be mounted in any position relative to wind flow--the maximum error is assumed. The number of readings is assumed to be **180** because that is the number of samples used for a 15-minute data value.

Wind Speed	Random Error	Time-adjusted Error
8.9 mph	±0.00 mph	$\pm 0.00 / \sqrt{180} = \pm 0.00$ mph
30.0 mph	±0.02 mph	$\pm 0.02 / \sqrt{180} = \pm 0.00$ mph
100.0 mph	±0.04 mph	$\pm 0.04 / \sqrt{180} = \pm 0.00$ mph

2.2.2 WIND SPEED SYSTEM ACCURACY (continued)

C. SIGNAL CONDITIONING ERRORS

1. Channel Calibration

The sensor is directly connected to the data logger and no interface equipment is used.

a. Input

(1) Input signal tolerance = **N/A**.

(2) Test meter or transfer standard = **N/A**.

(3) Test position = **N/A**.

b. Output tolerance = **N/A**.

2. Processing Hardware Drift

Drift errors do not apply since the sensors are connected directly to the data logger computer—No interface equipment is used.

a. Data Acquisition Switch Unit (DASU) = **N/A**.

3. Software

The sensor reports the wind speed value directly. No conversion is necessary.

a. Final rounding of hourly average values= ±**0.05 mph**.

This value applies to both the instantaneous and time-averaged data channels.

This is a **random** error since the value reported may be on either side of the actual wind speed. The number of readings is assumed to be **1** because the calculation is performed on the single final value before it is reported.

The software reports the wind speed to the nearest 0.1 mph. Therefore, the maximum rounding error is ±0.05 mph.

2.2.2 WIND SPEED SYSTEM ACCURACY (continued)

System Accuracy Calculations (Instantaneous Data Channel)	
5.0 mph:	$\left[\sqrt{(0.36)^2+(0.00)^2+(0.05)^2}\right]\pm 0.00=\pm 0.36\text{ mph}$
30.0 mph:	$\left[\sqrt{(0.37)^2+(0.02)^2+(0.05)^2}\right]\pm 0.00=\pm 0.37\text{ mph}$
100.0 mph:	$\left[\sqrt{(0.38)^2+(0.04)^2+(0.05)^2}\right]\pm 0.00=\pm 0.39\text{ mph}$
System errors satisfy RG-1.23 and ANS-3.11 specifications for all wind speeds.	

System Accuracy Calculations (Time-Averaged Data Channel)	
5.0 mph:	$\left[\sqrt{(0.03)^2+(0.00)^2+(0.05)^2}\right]\pm 0.00=\pm 0.06\text{ mph}$
30.0 mph:	$\left[\sqrt{(0.03)^2+(0.00)^2+(0.05)^2}\right]\pm 0.00=\pm 0.06\text{ mph}$
100.0 mph:	$\left[\sqrt{(0.03)^2+(0.00)^2+(0.05)^2}\right]\pm 0.00=\pm 0.06\text{ mph}$
System errors satisfy RG-1.23 and ANS-3.11 specifications for all wind speeds.	

2.3 WIND DIRECTION

VARIABLE:	Wind Direction (Vaisala Model 425 ultrasonic wind sensor)
MEASUREMENT METHOD:	Ultrasonic wind sensor, direct output of 1 second average wind direction samples
VALID DATA RANGE:	0 – 359° azimuth
CALIBRATED RANGE:	0 – 360° azimuth
NUMBER OF SAMPLES ASSUMED:	180 samples in 15 minutes

REQUIREMENTS SPECIFICATIONS	
ANSI/ANS-3.11-2005	• ±5° for all wind directions
RG-1.23 (Revision 1)	• ±5° for all wind directions

SOURCES OF ERROR - SENSOR

SENSOR ACCURACY	# Samples	POTENTIAL ERROR (°) All WD
A. Sensor Calibration		
1. Input		
a. Standard	1	±0.3
b. Test position [bias]	---	±0.0
2. Output		
a. Measurement/Readout device	---	---
b. Tolerance	1	±3.0
B. Sensor Drift	---	---
ROOT-SUM-SQUARE ERROR (with bias adjustments)		**± 3.0**
Specification (°)		± 5.0
Meets Specifications?		Yes

2.3 WIND DIRECTION (continued)

SOURCES OF ERROR - INSTANTANEOUS CHANNEL

SYSTEM ACCURACY	# Samples	POTENTIAL ERROR (°) All WD
A. SENSOR ERROR (± 3.0° from above)	1	±3.0
B. SAMPLING ERRORS		
• [BIAS] Sensor orientation and alignment = ±**1.2**	---	---
C. SIGNAL CONDITIONING ERRORS		
1. Channel Calibration		
a. Input		
(1) Input signal tolerance	---	---
(2) Test meter/ transfer standard	1	±0.5
(3) Test position	---	---
b. Output tolerance	1	±0.5
2. Processing Hardware Drift		
a. Data Acquisition Switch Unit	---	---
3. Software		
a. Rounding of final average value	1	±0.5
ROOT-SUM-SQUARE ERROR (with bias adjustments)		**±4.3**
Specification (°)		±5.0
Meets Specifications?		Yes

SOURCES OF ERROR - TIME-AVERAGED CHANNEL

SYSTEM ACCURACY	# Samples	POTENTIAL ERROR (°) All WD
A. SENSOR ERROR (± 3.0° from above)	180	±0.2
B. SAMPLING ERRORS		
• [BIAS] Sensor orientation and alignment = ±**1.2**	---	---
C. SIGNAL CONDITIONING ERRORS		
1. Channel Calibration		
a. Input		
(1) Input signal tolerance	---	---
(2) Test meter/ transfer standard	1	±0.5
(3) Test position	---	---
b. Output tolerance	1	±0.5
3. Processing Hardware Drift		
a. Data Acquisition Switch Unit	---	---
2. Software		
a. Rounding of final average value	1	±0.5
ROOT-SUM-SQUARE ERROR (with bias adjustments)		**±2.1**
Specification (°)		±5.0
Meets Specifications?		Yes

2.3 WIND DIRECTION (continued)

WIND DIRECTION, ERROR SOURCE/VALUE EXPLANATION

Both ANSI/ANS-3.11-2005 and RG-1.23 (Revision 1) use a specification of ±5.0° for all wind directions.

2.3.1 WIND DIRECTION SENSOR ACCURACY

A. Sensor Calibration

The sensor under test is subjected to laminar flow at a near constant speed in a wind tunnel. Different wind directions are tested by rotating the sensor.

1. Input

Each sensor is calibrated at five points (0°, 30°, 45°, 150°, and 270° azimuth). One point (0° azimuth) verifies field orientation direction. Three directions (30°, 150°, and 270° azimuth) verify proper operation when wind speed along one axis is near 0 mph. One point (45° azimuth) verifies correct operation when no axis is near perpendicular or near parallel to wind flow.

Wind Direction Calibration Methodology
• The wind tunnel speed is set to a speed that ensures laminar flow (~10 mph).
• The standard sensor is placed in the mounting and the wind direction is obtained.
• The standard sensor is then rotated to the next position and the next wind direction is obtained. This is repeated for all five wind directions before the standard sensor is removed.
• Without changing the blower speed, each test sensor is placed on the mounting.
• Each wind direction is checked by rotating the sensor to each of the five test positions.
• After all directions have been checked, the test sensor is removed and the next test sensor is placed in the mounting.
• When the last test sensor has been checked, the standard is replaced in the mounting and the wind directions are verified for each position.

a. Standard = ±**0.3**°.

The standard, a rotary index for Vaisala wind sensor, is certified to an accuracy of ±0.210°, rounded up to ±0.3°.

This is a **random** error since the value reported may be on either side of the actual wind direction. The number of readings is assumed to be **1** because calibrations are performed at a single wind direction during a specific round of tests (and is treated as an instantaneous observation).

2.3.1 WIND DIRECTION SENSOR ACCURACY (continued)

b. Test position = ±0.0°.

Laser alignment of to the standard rotary index for Vaisala wind sensor is performed according to CLS Instruction 450.01-026, so test position errors are negligible.

This is a **random** error since the value reported may be on either side of the actual wind direction. The number of readings is assumed to be **1** because calibrations are performed at a single wind direction during a specific round of tests (and is treated as an instantaneous observation).

2. Output

The sensor is directly connected to the data logger and no interface equipment is used.

a. Measurement/Readout device = **Not Applicable (N/A)**.

b. Tolerance = ±**3.0°**.

The tolerance of sensor output is ±3.0° based on the allowable error in CLS Calibration Instruction 450.01-019.

This is a **random** error since the value reported may be on either side of the actual wind direction. The number of readings is assumed to be **1** because calibrations are performed at a single wind direction during a specific round of tests (and is treated as an instantaneous observation).

B. Sensor Drift = N/A.

The sensor is fully digital with no components that are subject to drift.

Sensor Accuracy Calculations
All WD: $\left[\sqrt{(0.3)^2+(0.0)^2+(3.0)^2}\right] \pm 0.0 = 3.0^{\circ}$
Sensor error satisfies RG-1.23 and ANS-3.11 specifications for all wind directions.

2.3.2 WIND DIRECTION SYSTEM ACCURACY

A. SENSOR ERROR

1. Instantaneous Data Channel [All WD] = ±**3.3**°.

2. Time-Averaged Data Channel [All WD] = ±**1.1**°.

The sensor error values used in the system error are based on the calculated sensor errors and adjusted for the number of readings used to determine the final reported value.

2.3.2 WIND DIRECTION SYSTEM ACCURACY (continued)

This is a **random** error since the value reported may be either above or below the actual wind speed. The number of readings is assumed to be **180** because that is the number of samples used for a 15-minute data value.

Wind Direction	Random Error	Time-adjusted Error
All WD	±3.0°	$\pm 3.0/\sqrt{180} = \pm 0.2^{\circ}$

B. SAMPLING ERRORS

Sensor orientation

1. Instantaneous Data Channel [All WD] = ±**1.2**°.

2. Time-Averaged Data Channel [All WD] = ±**1.2**°.

The sensor mountings on the tower and the orientation reference markers are permanently fixed in place.

a. Surveyor checks have determined that sensor mounting placement error is less than 1° of azimuth (1.0°).

b. The transponder prongs used for sensor orientation are about 2.5 inches off-center, so the center of the sensor measurement element can be slightly mis-aligned. Assuming the orientation reference mark is at least 100 feet away, this can result in the centerline of the sensor being mis-aligned up to 0.15°.

c. The combined effect of these two errors is 1.00° + 0.15° = 1.15°. This is rounded up to 1.2°.

This is a **BIAS** error since the sensor orientation will remain fixed for all observations.

C. SIGNAL CONDITIONING AND DATA LOGGER ERRORS

Sensor alignment on the tower is performed according to QA Procedure EPFS-4 when the sensor is exchanged.

1. Channel Calibration

Sensor alignment consists of physical orientation with an established reference point. A transit at the reference point is used to sight along the North-South axis of the sensor to verify the orientation.

a. Input

(1) Input signal tolerance = **N/A**.

No test signal is used to orient sensor.

2.3.2 WIND DIRECTION SYSTEM ACCURACY (continued)

(2) Test meter or transfer standard = ± **0.5**°.

This value applies to both the instantaneous and time-averaged data channels.

The transfer standards are permanently positioned and marked alignment control points. One point is located directly under the sonic wind sensor with the extension arm in the normal operating position. The other control point is located to the north (adjacent to the fence). These transit sighting points, established by surveying methods, are accurate to less than 0.5°.

This is a **random** error since the value reported may be on either side of the actual wind direction. The number of readings is assumed to be **1** because the installation takes place at a specific time (and is treated as an instantaneous observation).

Estimated maximum error is ±0.5°.

(3) Test position = **N/A**.

The sensor mountings on the tower are permanently fixed in place, so no tests are performed on the sensor after installation on the tower.

b. Output tolerance = ± **0.5**°.

This value applies to both the instantaneous and time-averaged data channels.

During alignment of the sensor on the tower, a person on the ground verifies the sensor alignment through a transit placed at the 'north' alignment control point. The maximum allowable sensor alignment error is ±0.5° (QA procedure EPFS-4).

This is a **random** error since the value reported may be on either side of the actual wind direction. The number of readings is assumed to be **1** because the installation takes place at a specific time (and is treated as an instantaneous observation).

2. Processing Hardware Drift

Drift errors do not apply since the sensors are connected directly to the data logger computer—No interface equipment is used.

a. Data Acquisition Switch Unit (DASU) = **N/A**.

3. Software

The sensor reports the wind speed value directly. No conversion is necessary.

2.3.2 WIND DIRECTION SYSTEM ACCURACY (continued)

a. Final rounding of hourly average values= ±**0.5**°.

This value applies to both the instantaneous and time-averaged data channels.

This is a **random** error since the value reported may be on either side of the actual wind direction. The number of readings is assumed to be **1** because the calculation is performed on the single final value before it is reported.

The software reports the wind direction to the nearest 1°. This gives a maximum rounding error of ±0.5°.

System Accuracy Calculations (Instantaneous Data Channel)
All WD: $\left[\sqrt{(3.0)^2 + (0.5)^2 + (0.5)^2 + (0.5)^2}\right] \pm 1.2 = \pm 4.3^\circ$
System error satisfies RG-1.23 and ANS-3.11 specifications for all wind directions.

System Accuracy Calculations (Time-Averaged Data Channel)
All WD: $\left[\sqrt{(0.2)^2 + (0.5)^2 + (0.5)^2 + (0.5)^2}\right] \pm 1.2 = \pm 2.1^\circ$
System error satisfies RG-1.23 and ANS-3.11 specifications for all wind directions.

2.4 AIR TEMPERATURE

VARIABLE:	Air Temperature (Weed Instrument Company, Model 101, R0 = 100 RTD)
MEASUREMENT METHOD:	100-ohm Platinum RTD, 4-wire ohms measurement, instantaneous sampling of ohms
VALID DATA RANGE:	-30.00°F to +120.00°F
CALIBRATED RANGE:	-10.00°F to +110.00°F
NUMBER OF SAMPLES ASSUMED:	180 samples in 15 minutes

REQUIREMENTS SPECIFICATIONS	
ANSI/ANS-3.11-2005	• ±0.900°F for all temperatures
RG-1.23 (Revision 1)	• ±0.900°F for all temperatures

Day (High) assumes maximum daytime solar. *Day (Low)* assumes minimum daytime solar. *Night* assumes no solar.

<u>SOURCES OF ERROR - SENSOR</u>

SENSOR ACCURACY	# Samples	POTENTIAL ERROR (°F) Day (High)	Day (Low)	Night
A. Sensor Calibration				
1. Input				
a. Standard	1	±0.036	±0.036	±0.036
b. Test position	1	±0.000	±0.000	±0.000
2. Output				
a. Measurement/Readout device	1	±0.018	±0.018	±0.018
b. Tolerance	1	±0.050	±0.050	±0.050
B. Sensor Drift	1	±0.045	±0.045	±0.045
ROOT-SUM-SQUARE ERROR (with bias adjustments)		**±0.078**	**±0.078**	**±0.078**
Specifications (°F)		±0.900	±0.900	±0.900
Meets Specifications?		Yes	Yes	Yes

2.4 AIR TEMPERATURE (continued)

SOURCES OF ERROR - INSTANTANEOUS

SYSTEM ACCURACY	# Samples	POTENTIAL ERROR (°F) Day (High)	Day (Low)	Night
A. SENSOR ERROR (±0.078°F from above)	1	±0.078	±0.078	±0.078
B. SAMPLING ERRORS				
• a. Solar Heating [bias]	---	+0.500	-0.000	±0.000
C. SIGNAL CONDITIONING ERRORS				
1. Channel Calibration				
a. Input				
(1) Input signal tolerance	---	---	---	---
(2) Test meter/ transfer standard	1	±0.045	±0.045	±0.045
(3) Test position	---	---	---	---
b. Output tolerance	1	±0.150	±0.150	±0.150
2 Processing Hardware Drift				
a. Data Acquisition Switch Unit	1	±0.100	±0.100	±0.100
3. Software				
a. Rounding of final average value	1	±0.005	±0.005	±0.005
ROOT-SUM-SQUARE ERROR (with bias adjustments)		**+0.702**	**-0.202**	**±0.202**
Specifications (°F)		±0.900	±0.900	±0.900
Meets Specifications?		Yes	Yes	Yes

SOURCES OF ERROR - TIME-AVERAGED

SYSTEM ACCURACY	# Samples	POTENTIAL ERROR (°F) Day (High)	Day (Low)	Night
A. SENSOR ERROR (±0.078°F from above)	180	±0.006	±0.006	±0.006
B. SAMPLING ERRORS				
• a. Solar Heating [bias]	---	+0.500	-0.000	±0.000
C. SIGNAL CONDITIONING ERRORS				
1. Channel Calibration				
a. Input				
(1) Input signal tolerance	---	---	---	---
(2) Test meter/ transfer standard	1	±0.045	±0.045	±0.045
(3) Test position	---	---	---	---
b. Output tolerance	1	±0.150	±0.150	±0.150
2. Processing Hardware Drift				
a. Data Acquisition Switch Unit	180	±0.007	±0.007	±0.007
3. Software				
a. Rounding of final average value	1	±0.005	±0.005	±0.005
ROOT-SUM-SQUARE ERROR (with bias adjustments)		**+0.657**	**-0.157**	**±0.157**
Specifications (°F)		±0.900	±0.900	±0.900
Meets Specifications?		Yes	Yes	Yes

2.4 AIR TEMPERATURE (continued)

AIR TEMPERATURE, ERROR SOURCE/VALUE EXPLANATION

Both ANSI/ANS-3.11-2005 and RG-1.23 (Revision 1) use a specification of ±0.900°F for all temperatures.

All Temperature system error components are identical, except for the component due to solar heating of the aspirator shield ("SAMPLING ERRORS").

2.4.1 AIR TEMPERATURE SENSOR ACCURACY

A. Sensor Calibration

RTDs are calibrated in sets of three in the laboratory. Each set of RTDs is immersed in a well-mixed constant temperature bath and compared with a standard platinum resistance thermometer.

1. Input

Calibrated at 0°C, 40°C, and 100°C (32°F, 104°F, and 212°F).

a. Standard = ±**0.036°F**.

The standard platinum resistance thermometer (PRT) has an uncertainty of ±0.02°C (±0.036°F) based on Central Laboratories Services Standards Specifications Manual.

This is a **random** error since the value reported may be either above or below the actual temperature. The number of readings is assumed to be **1** because calibrations are performed at a single temperature during a specific round of tests (and is treated as an instantaneous observation).

b. Test position = ±**0.000°F**.

There is virtually no temperature gradient in the constant temperature bath since the bath is well-mixed and data are stabilized before measurements.

This is a **random** error since the value reported may be either above or below the actual temperature. The number of readings is assumed to be **1** because calibrations are performed at a single temperature during a specific round of tests (and is treated as an instantaneous observation).

2.4.1 AIR TEMPERATURE SENSOR ACCURACY (continued)

2. Output

a. Measurement/Readout device = ±**0.018°F**.

The Azonix A1011 resistance temperature detector (RTD) thermometer used to measure sensor RTD temperatures has an accuracy of 0.01°C (0.018°F) based on manufacturer literature.

This is a **random** error since the value reported may be either above or below the actual temperature. The number of readings is assumed to be **1** because calibrations are performed at a single temperature during a specific round of tests (and is treated as an instantaneous observation).

b. Tolerance = ±**0.050°F**.

The outputs of this calibration are calibration equations for the three sensor RTDs and several test temperatures computed with the equations. The computed temperatures are compared with true temperatures to check the performance of the equations. The maximum allowable error is ±0.05°F (CLS Calibration Instruction 450.01-005).

This is a **random** error since the value reported may be either above or below the actual temperature. The number of readings is assumed to be **1** because calibrations are performed at a single temperature during a specific round of tests (and is treated as an instantaneous observation).

B. Sensor Drift = ±**0.045°F**.

Sensor RTD drift between calibrations is limited to ±0.01 ohm (±0.045°F) at the ice point (CLS Calibration Instruction 450.01-005).

This is a **random** error since the value reported may be either above or below the actual temperature. The number of readings is assumed to be **1** because calibrations are performed at a single temperature during a specific round of tests (and is treated as an instantaneous observation).

Sensor Accuracy Calculations
All Temperatures: $\left[\sqrt{(0.036)^2 + (0.000)^2 + (0.018)^2 + (0.050)^2 + (0.045)^2}\right] \pm 0.000 = \pm 0.078^\circ \mathrm{F}$
Sensor error satisfies RG-1.23 and ANS-3.11 specifications for all temperatures.

2.4.2 AIR TEMPERATURE SYSTEM ACCURACY

A. SENSOR ERROR

1. Instantaneous Data Channel [All Temperatures] = ± **0.078°F**.

2. Time-Averaged Data Channel [All Temperatures] = ± **0.006°F**.

The sensor error values used in the system error are based on the calculated sensor errors and adjusted for the number of readings used to determine the final reported value.

This is a **random** error since the value reported may be either above or below the actual wind speed. The number of readings is assumed to be **180** because that is the number of samples used for a 15-minute data value.

Temperature	Random Error	Time-adjusted Error
All Temperatures	±0.078°F	$\pm 0.078/\sqrt{180} = \pm 0.006^\circ\,\mathrm{F}$

B. SAMPLING ERRORS

Solar heating of aspirator

1. High solar [All Temperatures] = **+0.500°F**.

2. Low solar [All Temperatures] = **-0.000°F**.

3. No solar [All Temperatures] = ±**0.000°F**.

This value applies to both the instantaneous and time-averaged data channels.

The radiation shields housing sensor RTDs on the tower depend on multiple layers of reflective white surfaces and constant airflow through the shields to minimize the heating of RTDs above ambient air temperature by solar radiation. The manufacturer specifies the maximum temperature rise inside the shield to be +0.4°F. This assumes a clean, properly aspirated shield. Even though TVA's shields are well maintained and have fan monitors to assure proper aspiration, an additional allowance of +0.1°F accounts for some darkening of reflective surfaces due to aging and dirt.

This is a **BIAS** error since the effect of solar heating will only increase the temperature during the daytime. The maximum error is assumed for positive day-time conditions. For all other conditions, a 0.000 bias is assumed.

High solar: +0.4°F plus +0.1°F = +0.500°F.

Low solar/No solar: +0.0°F plus +0.0°F = +0.000°F.

2.4.2 AIR TEMPERATURE SYSTEM ACCURACY (continued)

C. SIGNAL CONDITIONING AND DATA LOGGER ERRORS

Sensor installation on the tower is performed according to QA Procedure EPFS-4 when the sensor is exchanged.

1. Channel Calibration

This calibration which includes DASU and computer is performed every 184 days.

a. Input

Calibrated at 94, 104, 114 ohms

(1) Input signal tolerance = **Not Applicable (N/A)**.

Fixed resistors are used in the temperature channel calibrator and require no setting by the operator.

(2) Test meter or transfer standard = ± **0.045°F**.

This value applies to both the instantaneous and time-averaged data channels.

The maximum allowable error in re-certification of Temperature Channel Calibrators is ±0.01 ohm based on CLS Calibration Instruction 450.01-011.

0.01 ohm @ 4.5°F/ohm = ±0.045°F.

This is a **random** error since the value reported may be either above or below the actual temperature. The number of readings is assumed to be **1** because calibration is performed at a single temperature (and is treated as an instantaneous observation).

(3) Test position = **N/A**.

The temperature channel calibrator is not position sensitive.

b. Output tolerance = ± **0.150°F**.

This value applies to both the instantaneous and time-averaged data channels.

The maximum allowable error is ±0.15°F (EPFS-6).

This is a **random** error since the value reported may be either above or below the actual temperature. The number of readings is assumed to be **1** because calibration is performed at a single temperature (and is treated as an instantaneous observation).

2. Processing Hardware Drift

2.4.2 AIR TEMPERATURE SYSTEM ACCURACY (continued)

Drift error is for at least 184 days and ±5°C because the air temperature measurement system is re-calibrated each 184 days and the building temperature is controlled within ±5°C.

a. Data Acquisition Switch Unit (DASU)

(1) Instantaneous Data Channel [All Temperatures] = ±**0.100°F**.

(2) Time-Averaged Data Channel [All Temperatures] = ±**0.007°F**.

This is a **random** error since the value reported may be on either side of the actual temperature. The number of readings is assumed to be **180** because that is the number of samples used for a 15-minute data value.

For the DASU, the 1-year drift on the 1000 ohm (1.0 kΩ) range has a specification of 0.010 percent of reading plus 0.001 percent of the range.

With a maximum reading of 120 ohms (122°F), this yields:

(120 ohm X 0.010%) + (1000 ohm X 0.001%)

= 0.012 ohm + 0.010 ohm

= 0.022 ohm.

Converting from ohms to degrees (using a typical scale factor):

0.022 ohm X 4.5°F/ohm

= 0.099°F -- rounded up to 0.100°F.

Temperature	Random Error	Time-adjusted Error
All Temperatures	±0.100°F	$0.100/\sqrt{180} = \pm 0.007^\circ\text{F}$

3. Software

The conversion error from resistance (in ohms) to temperature (in °F) is not applicable. The conversion equations used in the EDS computer are the same as the equations used to compute test temperatures during the sensor calibration.

a. Final rounding of hourly average values= ±**0.005°F**.

This value applies to both the instantaneous and time-averaged data channels.

The software reports the temperature to the nearest 0.01°F. This gives a maximum rounding error of ±0.005°F.

2.4.2 AIR TEMPERATURE SYSTEM ACCURACY (continued)

This is a **random** error since the value reported may be on either side of the actual temperature. The number of readings is assumed to be **1** because the calculation is performed on the single final value before it is reported.

System Accuracy Calculations (Instantaneous Data Channel)
All Temperatures:
(high solar) $\left[\sqrt{(0.078)^2+(0.045)^2+(0.150)^2+(0.100)^2+(0.005)^2}\right]+0.500=+0.702^\circ\,\mathrm{F}$
(low solar) $\left[\sqrt{(0.078)^2+(0.045)^2+(0.150)^2+(0.100)^2+(0.005)^2}\right]-0.000=-0.202^\circ\,\mathrm{F}$
(no solar) $\left[\sqrt{(0.078)^2+(0.045)^2+(0.150)^2+(0.100)^2+(0.005)^2}\right]\pm 0.000=\pm 0.202^\circ\,\mathrm{F}$
System error satisfies RG-1.23 and ANS-3.11 specifications for all temperatures.

System Accuracy Calculations (Time-Averaged Data Channel)
All Temperatures:
(high solar) $\left[\sqrt{(0.006)^2+(0.045)^2+(0.150)^2+(0.007)^2+(0.005)^2}\right]+0.500=+0.657^\circ\,\mathrm{F}$
(low solar) $\left[\sqrt{(0.006)^2+(0.045)^2+(0.150)^2+(0.007)^2+(0.005)^2}\right]-0.000=-0.157^\circ\,\mathrm{F}$
(no solar) $\left[\sqrt{(0.006)^2+(0.045)^2+(0.150)^2+(0.007)^2+(0.005)^2}\right]\pm 0.000=\pm 0.157^\circ\,\mathrm{F}$
System error satisfies RG-1.23 and ANS-3.11 specifications for all temperatures.

2.5 VERTICAL TEMPERATURE DIFFERENCE

VARIABLE:	Vertical Temperature Difference - ΔT (Paired Weed Instrument Company, Model 101, R0 = 100 RTDs)
MEASUREMENT METHOD:	Computed from pair of hourly average air temperature values
VALID DATA RANGE:	n/a; (ΔT is valid if both temperature values are valid)
CALIBRATED RANGE:	-10.00°F to +110.00°F; (Matched RTD sets are checked at calibration points)
NUMBER OF SAMPLES ASSUMED:	180 samples in 15 minutes

REQUIREMENTS SPECIFICATIONS	
ANSI/ANS-3.11-2005	• ±0.180°F for all temperatures
RG-1.23 (Revision 1)	• ±0.180°F for all temperatures

<u>SOURCES OF ERROR - SENSOR</u>

SENSOR ACCURACY	# Samples	POTENTIAL ERROR (°F) All Temps
A. Sensor Calibration		
1. Input		
a. Standard	---	---
b. Test position	1	±0.000
2. Output		
a. Measurement/Readout device	1	±0.018
b. Tolerance	1	±0.050
B. Sensor Drift	1	±0.090
ROOT-SUM-SQUARE ERROR (with bias adjustments)		**± 0.105**
Specification (°F)		±0.180
Meets Specifications?		Yes

2.5 VERTICAL TEMPERATURE DIFFERENCE (continued)

SOURCES OF ERROR - INSTANTANEOUS		POTENTIAL ERROR (°F)
SYSTEM ACCURACY	# Samples	All Temps
A. SENSOR ERROR (± 0.105°F from above)	1	±0.105
B. SAMPLING ERRORS		
• Solar heating	1	±0.090
C. SIGNAL CONDITIONING ERRORS		
1. Channel Calibration		
a. Input		
(1) Input signal tolerance	---	---
(2) Test meter/ transfer standard	1	±0.000
(3) Test position	---	---
b. Output tolerance	1	±0.045
2. Processing Hardware Drift		
b. Data Acquisition Switch Unit	1	±0.027
3. Software		
a. Rounding of final average value	1	±0.005
ROOT-SUM-SQUARE ERROR (with bias adjustments)		**±0.148**
Specification (°F)		±0.180
Meets Specifications?		Yes

SOURCES OF ERROR - TIME-AVERAGED		POTENTIAL ERROR (°F)
SYSTEM ACCURACY	# Samples	All Temps
A. SENSOR ERROR (± 0.105°F from above)	180	±0.008
B. SAMPLING ERRORS		
• Solar heating	180	±0.007
C. SIGNAL CONDITIONING ERRORS		
1. Channel Calibration		
a. Input		
(1) Input signal tolerance	---	---
(2) Test meter/ transfer standard	1	±0.000
(3) Test position	---	---
b. Output tolerance	1	±0.045
2. Processing Hardware Drift		
b. Data Acquisition Switch Unit	180	±0.002
3. Software		
a. Rounding of final average value	1	±0.005
ROOT-SUM-SQUARE ERROR (with bias adjustments)		**±0.046**
Specification (°F)		±0.180
Meets Specifications?		Yes

2.5 VERTICAL TEMPERATURE DIFFERENCE (continued)

VERTICAL TEMPERATURE DIFFERENCE, ERROR SOURCE/VALUE EXPLANATION

Both ANSI/ANS-3.11-2005 and RG-1.23 (Revision 1) use a specification of ±0.180°F for all temperature differences.

2.5.1 VERTICAL TEMPERATURE DIFFERENCE SENSOR ACCURACY

A. Sensor Calibration

RTDs are calibrated in the Laboratory. Each set of three RTDs is tested at three temperatures and a calibration equation is determined for each RTD.

This calibration is coincidental with the RTD calibration for air temperature and differs only in the criteria used to evaluate the calibration results. For air temperature the resulting calibration equation of each RTD must produce the actual temperature within 0.05°F. For vertical temperature difference the equations of all RTDs must produce the same temperature within 0.05°F.

RTDs are calibrated in sets of three, with all three RTDs being subjected simultaneously to the same calibration medium.

1. Input

Checked for differential at 0°C, 40°C, and 100°C (32°F, 104°F, and 212°F).

a. Standard = **Not Applicable (N/A)**.

No standard of temperature difference is used other than the temperature baths, which hold the RTDs to almost exactly the same temperature at each test point. Even though a standard is used to register the temperature at each calibration, the main requirement here is that all RTDs be at the same temperature.

b. Test position = ±**0.000°F**.

There is virtually no temperature gradient in the constant temperature bath since the bath is well-mixed and data are stabilized before measurements.

This is a **random** error since the value reported may be either above or below the actual temperature. The number of readings is assumed to be **1** because calibrations are performed at a single temperature during a specific round of tests (and is treated as an instantaneous observation).

2.5.1 VERTICAL TEMPERATURE DIFFERENCE SENSOR ACCURACY (continued)

2. Output

a. Measurement/Readout device = ±**0.018°F**.

The Azonix A1011 resistance temperature detector (RTD) thermometer used to measure sensor RTD temperatures has an accuracy of 0.01°C (0.018°F) based on manufacturer specifications.

This is a **random** error since the value reported may be either above or below the actual temperature. The number of readings is assumed to be **1** because calibrations are performed at a single temperature during a specific round of tests (and is treated as an instantaneous observation).

b. Tolerance = ±**0.050°F**.

The outputs of this calibration are calibration equations for the three sensor RTDs and several test temperatures computed with the equations. The computed temperatures are compared with true temperatures to check the performance of the equations. The maximum allowable error is ±0.05°F (CLS Calibration Instruction 450.01-005).

This is a **random** error since the value reported may be either above or below the actual temperature. The number of readings is assumed to be **1** because calibrations are performed at a single temperature during a specific round of tests (and is treated as an instantaneous observation).

B. Sensor Drift = ±**0.090°F**.

This drift concerns the relative change between any pair of RTDs of the set in 184 days (CLS Calibration Instruction 450.01-005).

The tolerance for a single RTD is ±0.01 ohm, and therefore it is double that, or ±0.02 ohm, for a pair.

1. 0.02 ohm @ 4.5°F/ohm = ±0.090°F.

This is a **random** error since the value reported may be either above or below the actual temperature. The number of readings is assumed to be **1** because calibrations are performed at a single temperature during a specific round of tests (and is treated as an instantaneous observation).

Sensor Accuracy Calculations	
All Temperatures:	$\left[\sqrt{(0.000)^2+(0.018)^2+(0.050)^2+(0.090)^2}\right]\pm 0.000=\pm 0.105^{\circ}\,\mathrm{F}$
Sensor error satisfies RG-1.23 and ANS-3.11 specifications for all temperatures.	

2.5.2 VERTICAL TEMPERATURE DIFFERENCE SYSTEM ACCURACY

A. SENSOR ERROR

1. Instantaneous Data Channel [All temperatures] = ±**0.105°F**.

2. Time-Averaged Data Channel [All temperatures] = ±**0.008°F**.

The sensor error values used in the system error are based on the calculated sensor error and adjusted for the number of samples used to determine the final reported value.

This is a **random** error since the value reported may be on either side of the actual temperature. The number of readings is assumed to be **180** because that is the number of samples used for a 15-minute data value.

Temperature	Random Error	Time-adjusted Error
All Temperatures	±0.105°F	$\pm 0.105 / \sqrt{180} = \pm 0.008^\circ \mathrm{F}$

B. SAMPLING ERRORS

Solar heating of aspirator

1. Instantaneous Data Channel [All temperatures] = ±**0.090°F**.

2. Time-Averaged Data Channel [All temperatures] = ±**0.007°F**.

The sampling errors concern unequal solar heating of the sensors.

This is a **random** error since the value reported may be either negative or positive based on the relationship of the actual temperatures. The number of readings is assumed to be **180** because that is the number of samples used for a 15-minute data value.

For temperature difference measurements with identical shields, the manufacturer specifies an error of ±0.05°C, which corresponds to ±0.09°F.

Temperature	Random Error	Time-adjusted Error
All Temperatures	±0.090°F	$\pm 0.090 / \sqrt{180} = \pm 0.007^\circ \mathrm{F}$

2.5.2 VERTICAL TEMPERATURE DIFFERENCE SYSTEM ACCURACY (continued)

C. SIGNAL CONDITIONING ERRORS

1. Channel Calibration

This calibration, which includes DASU and computer, is performed every 184 days.

a. Input

Calibrated or differential at 94, 104, 114 ohms

(1) Input signal tolerance = **N/A**.

Fixed resistors are used in the Temperature Channel Calibrator and require no settings by the operator.

(2) Test meter or transfer standard = ±**0.000°F**.

This value applies to both the instantaneous and time-averaged data channels.

The Temperature Channel Calibrator containing three fixed precision resistors of 94, 104, and 114 ohms is used to calibrate the RTD channels. The same resistor is used on all three RTD channels at each of the three simulated temperatures; therefore an exact zero differential is simulated for each pair.

This is a **random** error since the value reported may be either above or below the actual temperature. The number of readings is assumed to be **1** because calibration is performed at a single temperature (and is treated as an instantaneous observation).

(3) Test position = **N/A**.

The Temperature Channel Calibrator is not position sensitive.

b. Output tolerance = ±**0.045°F**.

This value applies to both the instantaneous and time-averaged data channels.

2.5.2 VERTICAL TEMPERATURE DIFFERENCE SYSTEM ACCURACY (continued)

The maximum allowable difference in the resistance readings of the three channels is 0.01 ohm (EPFS-6).

0.01 ohm @ 4.5°F/ohm = ±0.045°F.

Note: In this procedure each channel also produces temperatures calculated from its readings of the fixed resistors. These temperatures are not expected to be exactly the same for all channels because the channels use different equations.

Therefore, the calibration is determined based on the resistance readings and not the temperature readings.

This is a **random** error since the value reported may be either above or below the actual temperature. The number of readings is assumed to be **1** because calibration is performed at a single temperature (and is treated as an instantaneous observation).

2. Processing Hardware Drift

Drift error is for at least 184 days and ±5°C because the air temperature measurement system is re-calibrated each 184 days and the building temperature is controlled within ±5°C.

a. Data Acquisition Switch Unit

(1) Instantaneous Data Channel [All temperatures] = ±**0.027°F**.

(2) Time-Averaged Data Channel [All temperatures] = ±**0.002°F**.

For the DASU, the relays give an offset of 0.003 mV (3uV) for each RTD channel. Two channels are involved in each temperature difference measurement, so 0.006 mV is the maximum total error. Given the test current of 1 mA on the 1.00 Kohm scale, this translates into a resistance error of 0.006 ohm.

This is a **random** error since the value reported may be on either side of the actual temperature. The number of readings is assumed to be **180** because that is the number of samples used for a 15-minute data value.

Converting from ohms to degrees (using a typical scale factor):

0.006 ohm @ 4.5°F/ohm = ±0.027°F.

Temperature	Random Error	Time-adjusted Error
All Temperatures	±0.027°F	$\pm 0.027 \big/ \sqrt{180} = \pm 0.002^\circ \mathrm{F}$

2.5.2 VERTICAL TEMPERATURE DIFFERENCE SYSTEM ACCURACY (continued)

3. Software

   a. Final rounding of hourly average values = ±**0.005°F**.

      This value applies to both the instantaneous and time-averaged data channels.

      Rounding of the final data to the nearest 0.01°F causes an error of ±0.005°F.

      This is a **random** error since the value reported may be on either side of the actual temperature. The number of readings is assumed to be **1** because the calculation is performed on the single final value before it is reported.

System Accuracy Calculations (Instantaneous Data Channel)
All Temperatures: $$\left[\sqrt{(0.105)^2+(0.090)^2+(0.000)^2+(0.045)^2+(0.027)^2+(0.005)^2}\right]\pm 0.000=\pm 0.148^\circ\mathrm{F}$$
System error satisfies RG-1.23 and ANS-3.11 specifications for all temperatures.

System Accuracy Calculations (Time-Averaged Data Channel)
All Temperatures: $$\left[\sqrt{(0.008)^2+(0.007)^2+(0.000)^2+(0.045)^2+(0.002)^2+(0.005)^2}\right]\pm 0.000=\pm 0.046^\circ\mathrm{F}$$
System error satisfies RG-1.23 and ANS-3.11 specifications for all temperatures.

2.6 DEWPOINT TEMPERATURE

VARIABLE:	Dewpoint Temperature (Vaisala HMT337)
MEASUREMENT METHOD:	Capacitive humidity sensor with warmed probe head
VALID DATA RANGE:	-4.00°F to +85.00°F
CALIBRATED RANGE:	+34.00°F to +81.00°F
NUMBER OF SAMPLES ASSUMED:	720 samples in 1 hour

REQUIREMENTS SPECIFICATIONS	
ANSI/ANS-3.11-2005	• ±2.700°F for all dewpoints
RG-1.23 (Revision 1)	• ±2.700°F for all dewpoints

SOURCES OF ERROR - SENSOR		POTENTIAL ERROR (°F)
SENSOR ACCURACY	# Samples	All Dewpoints
A. Sensor Calibration	1	±2.000
1. Input		
a. Standard	---	---
b. Test position	---	---
2. Output		
a. Measurement/Readout device	---	---
b. Tolerance	---	---
B. Sensor Drift	1	±1.000
ROOT-SUM-SQUARE ERROR (with bias adjustments)		± **2.236**
Specification (°F)		±2.700
Meets Specifications?		Yes

2.6 DEWPOINT TEMPERATURE (continued)

SYSTEM ACCURACY (INSTANTANEOUS) is not calculated since instantaneous dewpoint data are not reported.

<u>SOURCES OF ERROR - TIME-AVERAGED</u>

SYSTEM ACCURACY	# Samples	POTENTIAL ERROR (°F) All Dewpoints
A. SENSOR ERROR (± 2.236°F from above)	720	±0.083
B. SAMPLING ERRORS		
C. SIGNAL CONDITIONING ERRORS		
1. Channel Calibration		
a. Input		
(1) Input signal tolerance	---	---
(2) Test meter/ transfer standard	1	±0.000
(3) Test position	---	---
b. Output tolerance	1	±0.500
2. Processing Hardware Drift		
a. Data Acquisition Switch Unit	720	±0.000
3. Software		
a. Rounding of final average value	1	±0.005
ROOT-SUM-SQUARE ERROR (with bias adjustments)		**±0.507**
Specification (°F)		±2.700
Meets Specifications?		Yes

2.6 DEWPOINT TEMPERATURE (continued)

DEWPOINT, ERROR SOURCE/VALUE EXPLANATION

Both ANSI/ANS-3.11-2005 and RG-1.23 (Revision 1) use a specification of ±2.700°F for all dewpoint values.

2.6.1 DEWPOINT TEMPERATURE SENSOR ACCURACY

A. Sensor Calibration = ±**2.000°F**.

The Vaisala HMT337 Humidity and Temperature Transmitter is calibrated an environmental chamber at 34°F, 50°F, 68°F, and 86°F, and adjusted to satisfy the conversion equation used in the data logger program. The calibration includes the 500-ohm resistor that converts the mA signal from the sensor to a voltage signal transmitted to the data logger. The calibration report assumes a dewpoint accuracy of ±2 °F.

This is a **random** error since the value reported may be on either side of the actual solar radiation. The number of readings is assumed to be **1** because calibrations are performed at a single radiation value during a specific round of tests (and is treated as an instantaneous observation).

1. Input

   Included in the laboratory calibration error.

   a. Standard = **Not Applicable (N/A)**.

   b. Test position = **N/A**.

2. Output

   Included in the laboratory calibration error.

   a. Measurement/Readout device = **N/A**.

   b. Tolerance = **N/A**.

2.6.1 DEWPOINT TEMPERATURE SENSOR ACCURACY (continued)

B. Sensor Drift = ±**1.000°F**.

Based on manufacturer literature for Relative Humidity Error, the following error limits apply for the expected operational range of the HMT337.

Air Temperature (°F)	Relative Humidity (%)	Relative Humidity Error (%)	Dewpoint Error (°F)
32	30	±1.0	0.731
	90	±1.7	0.465
	100	±1.7	0.424
50	30	±1.0	0.790
	90	±1.7	0.505
	100	±1.7	0.460
68	30	±1.0	0.850
	90	±1.7	0.547
	100	±1.7	0.498
86	30	±1.0	**0.913**
	90	±1.7	0.590
	100	±1.7	0.537

Within this range, the greatest value is ±0.913°F. This is rounded to ±1.000°F

This is a **random** error since the value reported may be either above or below the actual temperature. The number of readings is assumed to be **1** because calibrations are performed at a single temperature during a specific round of tests (and is treated as an instantaneous observation).

Sensor Accuracy Calculations	
All Dewpoints:	$\left[\sqrt{(2.000)^2 + (1.000)^2}\right] \pm 0.000 = \pm 2.236^{\circ}\mathrm{F}$
Sensor error satisfies RG-1.23 and ANS-3.11 specifications for all dewpoints.	

2.6.2 DEWPOINT TEMPERATURE SYSTEM ACCURACY

SYSTEM ACCURACY (INSTANTANEOUS) is not calculated since instantaneous data are not reported.

A. SENSOR ERROR

1. [All Dewpoints] = ±**0.083°F**.

The sensor error values used in the system error are based on the calculated sensor error and adjusted for the number of samples used to determine the final reported value.

2.6.2 DEWPOINT TEMPERATURE SYSTEM ACCURACY (continued)

This is a **random** error since the value reported may be on either side of the actual dewpoint. The number of readings is assumed to be **720** because that is the number of samples used for a 1-hour data value.

Dewpoint	Random Error	Time-adjusted Error
All Dewpoints	±2.236°F	$\pm 2.236 / \sqrt{720} = \pm 0.083^\circ \text{F}$

B. SAMPLING ERRORS

Sampling Errors = **N/A**.

The Vaisala HMT337 sensor directly samples the atmosphere and performs all processing at the sampling site. No significant sampling errors have been identified.

C. SIGNAL CONDITIONING ERRORS

1. Channel Calibration

The channel calibration is performed by instructing the sensor to send a specific electronic value and verifying that the correct corresponding dewpoint value is reported.

a. Input

(1) Input signal tolerance = **NA**.

(2) Test meter or transfer standard = ±**0.000°F**.

The sensor sends a specific electronic value.

(3) Test position = **N/A**.

b. Output tolerance = ±**0.050°F**.

This is a **random** error since the value reported may be on either side of the actual dewpoint. The number of readings is assumed to be **1** because the calibration takes place at a specific time (and is treated as an instantaneous observation)

2.6.2 DEWPOINT TEMPERATURE SYSTEM ACCURACY (continued)

2. Processing Hardware Drift

a. Data Acquisition Switch Unit = ±**0.000°F**.

For the DASU, the 1-year drift on the 10 V range has a specification of 0.0035 percent of reading plus 0.0005 percent of the range. With the maximum reading of 10.000 V (85°F dewpoint), this yields:

(10.000 V × 0.0035%) + (10 V × 0.0005%)

= 0.00035 V + 0.00005 V

= 0.0004 V.

The dewpoint calibration formula is:

$$\text{dewpoint} = (\text{voltage} * 11.125) - 26.25$$

Based on this formula, the dewpoint changes 11.125°F for each 1 volt change. Therefore, the DASU error is:

0.0004 volt × 11.125°F/volt = 0.0045°F -- rounded up to 0.005°F.

This is a **random** error since the value reported may be on either side of the actual dewpoint. The number of readings is assumed to be **720** because that is the number of samples used for a 1-hour data value.

Dewpoint	Random Error	Time-adjusted Error
All Dewpoints	±0.005°F	$\pm 0.005/\sqrt{720} = \pm 0.000^\circ \mathrm{F}$

3. Software

a. Final rounding of hourly average values = ±**0.005°F**.

Rounding of the final data to the nearest 0.01°F causes an error of ±0.005°F.

This is a **random** error since the value reported may be on either side of the actual dewpoint. The number of readings is assumed to be **1** because the calculation is performed on the single final value before it is reported.

2.6.2 DEWPOINT TEMPERATURE SYSTEM ACCURACY (continued)

SYSTEM ACCURACY (INSTANTANEOUS) is not calculated since instantaneous data are not reported.

System Accuracy Calculations (Time-Averaged Data Channel)
All Dewpoints: $\left[\sqrt{(0.083)^2+(0.000)^2+(0.500)^2+(0.000)^2+(0.005)^2}\right]\pm 0.000=\pm 0.507^\circ\,\mathrm{F}$
System error satisfies RG-1.23 and ANS-3.11 specifications for all dewpoints.

2.7 RAINFALL

VARIABLE:	Rainfall (total for 15-minutes and hour)
MEASUREMENT METHOD:	Tipping bucket
VALID DATA RANGE:	0.00 inch to 10.00 inches (software limit) *
CALIBRATED RANGE:	0.00 inch to 1.00 inch**
NUMBER OF SAMPLES ASSUMED:	1 total at end of each 15-minutes or 1-hour.

* Since the rain gauge measures precipitation as it occurs and does not accumulate a sample, there is no actual upper limit to the data range. A 10.00-inch upper limit is retained in the data logger software primarily for historical continuity and consistency with ICS limits.

** A 1.00-inch sample is used to verify the correct number of tips is recorded. The calibration addresses the number of the individual tips associated with the sample, not the total sample size.

REQUIREMENTS SPECIFICATIONS	
ANSI/ANS-3.11-2005	• ±0.010 inch (10% of volume at 2.54 mm)
RG-1.23 (Revision 1)	• ±0.010 inch (10% of volume at 2.54 mm)

Note: Error estimates apply to a volume of 2.54 mm (0.10 inch).

<u>SOURCES OF ERROR - SENSOR</u>

ACCURACY	# Samples	POTENTIAL ERROR 0.10 inch
A. Sensor Calibration		
1. Input		
a. Standard	1	±0.001
b. Test position	---	---
2. Output		
a. Measurement/Readout device	---	---
b. Tolerance	1	±0.004
B. Sensor Drift	2	±0.006
ROOT-SUM-SQUARE ERROR (with bias adjustments)		**± 0.007**
Specification (inch)		±0.010
Meets Specifications?		Yes

2.7 RAINFALL (continued)

SOURCES OF ERROR - INSTANTANEOUS SYSTEM ACCURACY	# Samples	POTENTIAL ERROR 0.10 inch
A. SENSOR ERROR (± 0.007 inch from above)	1	±0.007
B. SAMPLING ERRORS		
• Misreporting of Rainfall Times	1	±0.005
C. SIGNAL CONDITIONING ERRORS		
1. Channel Calibration		
a. Input		
(1) Input signal tolerance	---	---
(2) Test meter/ transfer standard	---	---
(3) Test position	---	---
b. Output tolerance	1	±0.000
2. Processing Hardware Drift		
b. Data Acquisition Switch Unit	1	±0.000
3. Software		
a. Rounding of final average value	---	---
ROOT-SUM-SQUARE ERROR (with bias adjustments)		**±0.009**
Specification (inch)		±0.010
Meets Specifications?		Yes

SYSTEM ACCURACY (TIME-AVERAGED) is not calculated since only instantaneous data are reported.

2.7 RAINFALL (continued)

RAINFALL, ERROR SOURCE/VALUE EXPLANATION

Both ANSI/ANS-3.11-2005 and RG-1.23 (Revision 1) use a specification of 10% percent of volume specification for estimating rainfall accuracy at a single point (2.54 mm, 0.10 inch). All error calculations are adjusted to a 0.10-inch sample.

2.7.1 RAINFALL SENSOR ACCURACY

A. Sensor Calibration

The sensor is calibrated in-place as part of the system calibration. A known amount of water is allowed to enter the sensor at a constant rate. The sensor output is compared with the amount of water that enters the sensor.

1. Input

a. Standard = ±**0.001 inch**.

The Model 60103 Precipitation Gauge Calibrator consists of plastic bottle to hold water, a stand to set the bottle in the gauge funnel, and a constant-flow orifice assembly (to control flow rate at 2 inches/hour). The amount of water in the bottle (equivalent to 1 inch of rain) will equal 100 tips of the tipping bucket assembly (1 tip equals 0.01 inch).

The correct amount of water in the bottle is verified by weighing the bottle on a digital scale. The ±2 gram limit in EPFS-6 corresponds to 0.0025 inch (25% of 1 tip). This is rounded up to ±1 tip (±0.01 inch). When prorated to 0.1 inch this results in an error value of ±0.001 inch.

This is a **random** error since the value reported may be on either side of the actual precipitation. The number of readings is assumed to be **1** because calibrations are performed at a single time.

b. Test position = **Not Applicable (N/A)**.

The sensor is calibrated in the field by simulating rainfall falling into the rain gauge.

2. Output

Included in system calibration.

a. Measurement/Readout device = **N/A**.

The number of counts recorded exactly match the number of tips.

2.7.1 RAINFALL SENSOR ACCURACY (continued)

b. Tolerance = ±**0.004 inch**.

The maximum allowable error is ±4 tips for a 100-tip water sample. This corresponds to ±0.004 inch for a 0.10 inch sample.

This is a **random** error since the value reported may be on either side of the actual precipitation. The number of readings is assumed to be **1** because calibrations are performed at a single time.

B. Sensor Drift = ±**0.006 inch**.

The sensor drift is based on the maximum difference between two consecutive calibrations (representing the difference between the extreme positive and extreme negative error).

This is a **random** error since the value reported may be on either side of the actual precipitation. The number of readings is assumed to be **2** because it represents a difference between 2 calibrations.

Since the maximum allowable error for a calibration is ±4 tips, the maximum difference would be twice this value or 8 tips. This corresponds to ±0.008 inch.

Rainfall	Random Error	Time-adjusted Error
1.00 inch	±0.008°F	$\pm 0.008/\sqrt{2} = \pm 0.006$ inch

Sensor Accuracy Calculations	
0.10 inch:	$\left[\sqrt{(0.001)^2 + (0.004)^2 + (0.006)^2}\right] \pm 0.000 = \pm 0.007$ inch
Sensor error satisfies RG-1.23 and ANS-3.11 specifications for rainfall.	

2.7.2 RAINFALL SYSTEM ACCURACY

SYSTEM ACCURACY (TIME-AVERAGE) is not calculated since only instantaneous data are reported.

A. SENSOR ERROR

1. Instantaneous Data Channel [0.10 inch] = ±**0.007** inch.

   The sensor error values used in the system error are based on the calculated sensor error and adjusted for the number of samples used to determine the final reported value.

   This is a **random** error since the value reported may be on either side of the actual rainfall. The number of readings is assumed to be **1** because the data value is determined at the end of the sampling period.

B. SAMPLING ERRORS

Misreporting of Rainfall Times

1. Instantaneous Data Channel [0.10 inch] = ±**0.005 inch**.

   Occasionally, accumulated precipitation is not sufficient to cause the tipping mechanism to operate. In such a case, the precipitation will not be reported until additional precipitation causes the tipping mechanism to operate. Since the sensor only tips when 0.01 inches of precipitation occurs, the earlier time may be under-reported by up to 0.01 inches and the later time may be over-reported by up to 0.01 inches. Since the precipitation amount contained in a untipped bucket can be anywhere in the range 0.00-0.01 inch, the midpoint value of 0.005 inch is assumed.

   This is a **random** error since the value reported may be on either side of the actual precipitation. The number of readings is assumed to be **1** because only a single occurrence can be included in each sample (the assumed rainfall is reset to 0.00 at the start of each sampling period).

2.7.2 RAINFALL SYSTEM ACCURACY (continued)

C. SIGNAL CONDITIONING ERRORS

1. Channel Calibration

The sensor is calibrated in-place as part of the system calibration.

a. Input

(1) Input signal tolerance = **N/A**.

(2) Test meter or transfer standard = **N/A**.

(3) Test position = **N/A**.

b. Output tolerance = ±**0.000 inch**.

The number of counts exactly matches the number of tips.

2. Processing Hardware Drift

a. Data Acquisition Switch Unit = ±**0.000 inch**.

No drift applies since signal quality is not significant, only the ON/OFF state of the signal to the counter. The counter error = 0.000 inch since the number of counts exactly matches the number of rain gauge tips.

3. Software

a. Final rounding of hourly average values = N/A.

No rounding occurs since the data are recorded in fixed increments.

System Accuracy Calculations (Instantaneous Data Channel)	
0.10 inch:	$\left[\sqrt{(0.007)^2 + (0.005)^2 + (0.000)^2 + (0.000)^2}\right] \pm 0.000 = \pm 0.009 \text{ inch}$
System error satisfies RG-1.23 and ANS-3.11 specifications for rainfall.	

SYSTEM ACCURACY (TIME-AVERAGE) is not calculated since only instantaneous data are reported.

2.8 SOLAR RADIATION

VARIABLE:	Solar Radiation (hourly average)
MEASUREMENT METHOD:	Direct reading of Eppley Model 8-48 B/W Pyranometer
VALID DATA RANGE:	0.00 ly/min to 3.00 ly/min
CALIBRATED RANGE:	0.00 ly/min to 3.00 ly/min
NUMBER OF SAMPLES ASSUMED:	720 samples in 60 minutes

REQUIREMENTS SPECIFICATIONS	
ANSI/ANS-3.11-2005	• ±0.014 ly/min for solar < 0.28 ly/min • ±5% of observed for solar ≥ 0.28 ly/min
RG 1.23 (Revision 1)	• Not Specified

<u>SOURCES OF ERROR - SENSOR</u>

		POTENTIAL ERROR (mph)		
SENSOR ACCURACY	# Samples	0.28 ly/min	0.45 ly/min	1.50 ly/min
A. Sensor Calibration	1	±0.003	±0.005	±0.015
1. Input				
a. Standard	---	---	---	---
b. Test position [bias]	---	---	---	---
2. Output				
a. Measurement/Readout device	---	---	---	---
b. Tolerance	---	---	---	---
B. Sensor Drift	1	±0.005	±0.007	±0.023
ROOT-SUM-SQUARE ERROR (with bias adjustments)		**±0.006**	**±0.009**	**±0.027**
Specification (ly/min)		±0.014	±0.023	±0.075
Meets Specifications?		Yes	Yes	Yes

2.8 SOLAR RADIATION (continued)

SYSTEM ACCURACY (INSTANTANEOUS) *is not calculated since instantaneous solar radiation data are not reported.*

<u>SOURCES OF ERROR - TIME-AVERAGED</u>

SYSTEM ACCURACY	# Samples	POTENTIAL ERROR (mph) 0.28 ly/min	0.45 ly/min	1.50 ly/min
A. SENSOR ERROR (from above)				
±0.006	720	±0.000		
±0.015	720		±0.001	
±0.027	720			±0.001
B. SAMPLING ERRORS				
• Cosine response (0-70° zenith angle)	720	±0.001	±0.000	±0.001
• Temperature sensitivity	720	±0.000	±0.000	±0.001
C. SIGNAL CONDITIONING ERRORS				
1. Channel Calibration				
a. Input				
(1) Input signal tolerance	1	±0.014	±0.014	±0.014
(2) Test meter/ transfer standard	1	±0.007	±0.007	±0.007
(3) Test position	---	---	---	---
b. Output tolerance	1	±0.013	±0.015	±0.020
2. Processing Hardware Drift				
a. Data Acquisition Switch Unit	720	±0.000	±0.000	±0.000
3. Software				
a. Rounding of final average value	1	±0.005	±0.005	±0.005
ROOT-SUM-SQUARE ERROR (with bias adjustments)		**±0.021**	**±0.022**	**±0.026**
Specification (ly/min)		±0.014	±0.023	±0.075
Meets Specifications?		**No ***	Yes	Yes

* 0.45 ly/min is the lowest value at which the ANS-3.11-2005 specification is satisfied.

2.8 SOLAR RADIATION (continued)

SOLAR RADIATION, ERROR SOURCE/VALUE EXPLANATION

ANS-3.11 uses a two-part specification for solar radiation accuracy—a constant value of 10 w/m^2 (0.014 ly/min) for all measurements 200 w/m^2 (0.28 ly/min) and below, and a 5% of observed value for all measurements above 200 w/m^2 (0.28 ly/min).

RG-1.23 does not have a specification for solar radiation.

To encompass the full range of expected conditions, accuracy is calculated for 3 levels of solar radiation:

- 0.28 ly/min -- This is the breakpoint between the constant value used for low-solar ranges and the 5% value used for higher ranges.
- 0.45 ly/min -- This is the lowest value at which TVA observed accuracy satisfies the ANS-3.11 specification.
- 1.50 ly/min -- This is the maximum value that the TVA measurement system is expected to report and is the upper limit for the range over which the 5% error requirement applies.

Since the error relationship is linear over the range from 0.45 ly/min to 1.50 ly/min, all requirements within the range will be satisfied if requirements are satisfied at the upper and lower limits of the range.

2.8.1 SOLAR RADIATION SENSOR ACCURACY

A. Sensor Calibration

1. [0.28 ly/min] = ±**0.003 ly/min**.
2. [0.45 ly/min] = ±**0.005 ly/min**.
3. [1.50 ly/min] = ±**0.015 ly/min**.

   Sensor calibration is performed by the manufacturer (Eppley Laboratory). The specified linearity accuracy is ±1% (based on manufacturer specifications).

   1% x 0.28 ly/min = ±0.0028 ly/min – rounded up to 0.003 ly/min.

   1% x 0.45 ly/min = ±0.0045 ly/min – rounded up to 0.005 ly/min.

   1% x 1.50 ly/min = ±0.015 ly/min.

This is a **random** error since the value reported may be on either side of the actual solar radiation. The number of readings is assumed to be **1** because calibrations are performed at a single radiation value during a specific round of tests (and is treated as an instantaneous observation).

2.8.1 SOLAR RADIATION SENSOR ACCURACY (continued)

4. Input

   Included in manufacturer's calibration error.

   a. Standard = **Not Applicable (N/A)**.

   b. Test position = **N/A**.

5. Output

   Included in manufacturer's calibration error.

   a. Measurement/Readout device = **N/A**.

   b. Tolerance = **N/A**.

B. Sensor Drift

1. [0.14 ly/min] = ±**0.005 ly/min**.

2. [0.45 ly/min] = ±**0.007 ly/min**.

3. [1.50 ly/min] = ±**0.023 ly/min**.

   Sensor changeout frequency is a maximum of 12 months (EPFS-4). Based on factory reports of sensors calibrated during 1994-1999, drift is expected to be less than 1.5%.

   1.5% x 0.28 ly/min = ±0.0042 ly/min – rounded up to 0.005 ly/min.

   1.5% x 0.45 ly/min = ±0.0068 ly/min – rounded up to 0.007 ly/min.

   1.5% x 1.50 ly/min = ±0.0225 ly/min – rounded up to 0.023 ly/min.

This is a **random** error since the value reported may be on either side of the actual solar radiation. The number of readings is assumed to be **1** because calibrations are performed at a single radiation value during a specific round of tests (and is treated as an instantaneous observation).

2.8.1 SOLAR RADIATION SENSOR ACCURACY (continued)

Sensor Accuracy Calculations	
0.28 ly/min:	$\left[\sqrt{(0.003)^2 + (0.005)^2}\right] \pm 0.000 = \pm 0.006 \text{ ly/min}$
0.45 ly/min:	$\left[\sqrt{(0.005)^2 + (0.007)^2}\right] \pm 0.000 = \pm 0.009 \text{ ly/min}$
1.50 ly/min:	$\left[\sqrt{(0.015)^2 + (0.023)^2}\right] \pm 0.000 = \pm 0.027 \text{ ly/min}$
Sensor error satisfies ANS-3.11 specification for all solar radiation values. RG-1.23 has no specification for solar radiation.	

2.8.2 SOLAR RADIATION SYSTEM ACCURACY

SYSTEM ACCURACY (INSTANTANEOUS) is not calculated since instantaneous data are not reported.

A. SENSOR ERROR

Time-Averaged Data Channel

1. [0.28 ly/min] = ±**0.000 ly/min**.
2. [0.45 ly/min] = ±**0.000 ly/min**.
3. [1.50 ly/min] = ±**0.001 ly/min**.

The sensor error values used in the system error are based on the calculated sensor errors and adjusted for the number of readings used to determine the final reported value.

This is a **random** error since the value reported may be either above or below the actual solar radiation. The number of readings is assumed to be **720** because that is the number of samples used for a 1-hour data value.

Solar Radiation	Random Error	Time-adjusted Error
0.28 ly/min	±0.006 ly/min	$\pm 0.006 / \sqrt{720} = \pm 0.000 \text{ ly/min}$
0.45 ly/min	±0.009 ly/min	$\pm 0.009 / \sqrt{720} = \pm 0.000 \text{ ly/min}$
1.50 ly/min	±0.027 ly/min	$\pm 0.027 / \sqrt{720} = \pm 0.001 \text{ ly/min}$

2.8.2 SOLAR RADIATION SYSTEM ACCURACY (continued)

B. SAMPLING ERROR

1. Cosine response

Time-Averaged Data Channel

[0.28 ly/min] = ±**0.001 ly/min**.

[0.45 ly/min] = ±**0.000 ly/min**.

[1.50 ly/min] = ±**0.001 ly/min**.

Eppley Laboratory specifies that the sensor has a cosine response ±2% from 0° to 70° and ±5% from 70° to 80° (At zenith angles greater than 80°, the sun will be close to the horizon and actual radiation levels will be too low for error contribution from cosine response to be significant).

Zenith angles 0° to 70° are assumed to apply to any solar radiation 0.30 ly/min and higher. Zenith angles 70° to 80° are assumed to apply to any solar radiation below 0.30 ly/min.

[0.28 ly/min] 5% x 0.28 ly/min = ±0.014 ly/min.

[0.45 ly/min] 2% x 0.45 ly/min = ±0.009 ly/min.

[1.50 ly/min] 2% x 1.50 ly/min = ±0.030 ly/min.

This is a **random** error since the value reported may be either above or below the actual solar radiation. The number of readings is assumed to be **720** because that is the number of samples used for a 1-hour data value.

Solar Radiation	Random Error	Time-adjusted Error
0.28 ly/min	±0.014 ly/min	$\pm 0.014/\sqrt{720} = \pm 0.001 \text{ ly/min}$
0.45 ly/min	±0.009 ly/min	$\pm 0.009/\sqrt{720} = \pm 0.000 \text{ ly/min}$
1.50 ly/min	±0.030 ly/min	$\pm 0.030/\sqrt{720} = \pm 0.001 \text{ ly/min}$

2.8.2 SOLAR RADIATION SYSTEM ACCURACY (continued)

2. Temperature sensitivity

Time-Averaged Data Channel

[0.28 ly/min] = ±**0.000 ly/min**.

[1.30 ly/min] = ±**0.000 ly/min**.

[1.50 ly/min] = ±**0.001 ly/min**.

Eppley Laboratory specifies that the sensor has a temperature dependence of ±1.5% from -20 to 40°C.

1.5% x 0.28 ly/min = ±0.0042 ly/min – rounded up to 0.005 ly/min.

1.5% x 0.45 ly/min = ±0.0068 ly/min – rounded up to 0.007 ly/min.

1.5% x 1.50 ly/min = ±0.0225 ly/min – rounded up to 0.023 ly/min.

This is a **random** error since the value reported may be either above or below the actual solar radiation. The number of readings is assumed to be **720** because that is the number of samples used for a 1-hour data value.

Solar Radiation	Random Error	Time-adjusted Error
0.28 ly/min	±0.005 ly/min	$\pm 0.005/\sqrt{720} = \pm 0.000 \text{ ly/min}$
0.45 ly/min	±0.007 ly/min	$\pm 0.007/\sqrt{720} = \pm 0.000 \text{ ly/min}$
1.50 ly/min	±0.023 ly/min	$\pm 0.023/\sqrt{720} = \pm 0.001 \text{ ly/min}$

2.8.2 SOLAR RADIATION SYSTEM ACCURACY (continued)

C. SIGNAL CONDITIONING ERRORS

1. Channel Calibration

Includes DASU and computer.

a. Input

(1) Input signal tolerance [entire range] = ±**0.014 ly/min**.

Tolerance is ±0.1 mV (EPFS-6). The nominal output of a Black/White Pyranometer at 1 ly/min is 7 mV; therefore, the nominal scale factor is 0.14 ly/min/mV.

This is a **random** error since the value reported may be on either side of the actual solar radiation. The number of readings is assumed to be **1** because calibrations are performed at a single radiation value during a specific round of tests (and is treated as an instantaneous observation).

0.1 mV x 0.14 ly/min/mV = ±0.014 ly/min.

(2) Test meter or transfer standard = ±**0.007 ly/min**.

The test DVM accuracy is ±0.05 mV or better (EPFS-6).

This is a **random** error since the value reported may be on either side of the actual solar radiation. The number of readings is assumed to be **1** because calibrations are performed at a single radiation value during a specific round of tests (and is treated as an instantaneous observation).

0.05 mV x 0.14 ly/min/mV = ±0.007 ly/min.

(3) Test position = **N/A**.

No component involved in this calibration is position sensitive.

2.8.2 SOLAR RADIATION SYSTEM ACCURACY (continued)

b. Output tolerance

Time-Averaged Data Channel

(1) [0.28 ly/min] = ±**0.013 ly/min**.

(2) [0.45 ly/min] = ±**0.015 ly/min**.

(3) [1.30 ly/min] = ±**0.020 ly/min**.

The tolerance is ±0.01 ly/min for 0.00 ly/min and ±0.02 ly/min for 1.00 ly/min and above (EPFS-6).

This is a **random** error since the value reported may be on either side of the actual solar radiation. The number of readings is assumed to be **1** because calibrations are performed at a single radiation value during a specific round of tests (and is treated as an instantaneous observation).

For 0.28 ly/min, the interpolated tolerance is ±0.0128 ly/min – rounded up to 0.013 ly/min.

For 0.45 ly/min, the interpolated tolerance is ±0.0145 ly/min – rounded up to 0.015 ly/min.

For 1.50 ly/min, the tolerance is ±0.020 ly/min.

2. Processing Hardware Drift

a. Data Acquisition Switch Unit

Time-Averaged Data Channel

(1) [0.14 ly/min] = ±**0.000 ly/min**.

(2) [0.45 ly/min] = ±**0.000 ly/min**.

(3) [1.50 ly/min] = ±**0.000 ly/min**.

For the DASU, the 1-year drift on the 100 mV range has a specification of 0.0050 percent of reading plus 0.0040 percent of the range. Assumed scale factor is 1 mV = 0.14 ly/min.

2.8.2 SOLAR RADIATION SYSTEM ACCURACY (continued)

0.28 ly/min corresponds to 2.00 mV. This yields an error value

= (2.00 mV X 0.0050%) + (100 X 0.0040%) mV

= 0.00010 mV + 0.00400 mV = 0.00410 mV.

Converting to langley/minute: 0.00410 mV X 0.14 ly/min/mV

= 0.000574 ly/min -- rounded up to 0.001 ly/min.

0.45 ly/min corresponds to 3.21 mV. This yields an error value

= (3.21 mV X 0.0050%) + (100 X 0.0040%) mV

= 0.00016 mV + 0.0040 mV = 0.00416 mV.

Converting to langley/minute: 0.00416 mV X 0.14 ly/min/mV

= 0.000582 ly/min -- rounded up to 0.001 ly/min.

1.50 ly/min corresponds to 10.71 mV. This yields error value

= (10.71 mV X 0.0050%) + (100 X 0.0040%) mV

= 0.00054 mV + 0.0040 mV = 0.00454 mV.

Converting to langley/minute: 0.00454 mV X 0.14 ly/min/mV

= 0.000636 ly/min -- rounded up to 0.001 ly/min.

This is a **random** error since the value reported may be either above or below the actual solar radiation. The number of readings is assumed to be **720** because that is the number of samples used for a 1-hour data value.

Solar Radiation	Random Error	Time-adjusted Error
0.28 ly/min	±0.001 ly/min	$\pm 0.001 / \sqrt{720} = \pm 0.000 \text{ ly/min}$
0.45 ly/min	±0.001 ly/min	$\pm 0.001 / \sqrt{720} = \pm 0.000 \text{ ly/min}$
1.50 ly/min	±0.001 ly/min	$\pm 0.001 / \sqrt{720} = \pm 0.000 \text{ ly/min}$

2.8.2 SOLAR RADIATION SYSTEM ACCURACY (continued)

3. Software

a. Final rounding of hourly average values= ±**0.005 ly/min**.

Rounding of the final data to the nearest 0.01 ly/min gives a maximum error of ±0.005 ly/min.

This is a **random** error since the value reported may be on either side of the actual solar radiation. The number of readings is assumed to be **1** because calibrations are performed at a single radiation value during a specific round of tests (and is treated as an instantaneous observation).

SYSTEM ACCURACY (INSTANTANEOUS) is not calculated since instantaneous data are not reported.

System Accuracy Calculations (Time-Averaged Data Channel)
0.28 ly/min: $\left[\sqrt{(0.000)^2+(0.001)^2+(0.000)^2+(0.014)^2+(0.007)^2+(0.013)^2+(0.000)^2+(0.005)^2}\right] \pm 0.000 = \pm 0.021\,\text{ly/min}$
0.45 ly/min: $\left[\sqrt{(0.000)^2+(0.000)^2+(0.000)^2+(0.014)^2+(0.007)^2+(0.015)^2+(0.000)^2+(0.005)^2}\right] \pm 0.000 = \pm 0.022\,\text{ly/min}$
1.50 ly/min: $\left[\sqrt{(0.001)^2+(0.001)^2+(0.001)^2+(0.014)^2+(0.007)^2+(0.020)^2+(0.000)^2+(0.005)^2}\right] \pm 0.000 = \pm 0.026\,\text{ly/min}$
System errors satisfies ANS-3.11 specification for solar radiation for all values ≥ to 0.45 ly/min. RG-1.23 has no specification for solar radiation.

TVA **Environmental Data Station Manual**	**Clinch River Nuclear Plant** **Module II-c** **METEOROLOGICAL MONITORING**	**EDS-CRN** **Rev. 0001** **Page 1 of 23**
		Quality Related ☑ Yes ☐ No
		Effective Date

Level of Use: Reference Use

Prepared by: Kenneth G. Wastrack (EMA), Meteorologist

Reviewed by:	< see module II-a >	n/a Date
Concurred by:	< see module II-a >	n/a Date
Approved by:	< see module II-a >	n/a Date

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1.0 SCOPE AND FORMAT OF MODULE II

EDS Manual Module II ("Meteorological Monitoring") contains an extensive amount of information that cannot be easily presented in a single document. Therefore, this module is divided into three parts:

A. Module II-a

Introduction.

Station and Equipment Description.

Equipment Calibration and Maintenance.

Meteorological Data Processing, Validation, and Reporting.

References.

Abbreviations and Definitions.

B. Module II-b

Accuracy of Meteorological Measurements.

C. Module II-c

Site-specific Appendices.

All three parts of the Module are issued at the same time. Module II-a includes the Cover Page (with approval signatures) and the Revision Log for all three parts.

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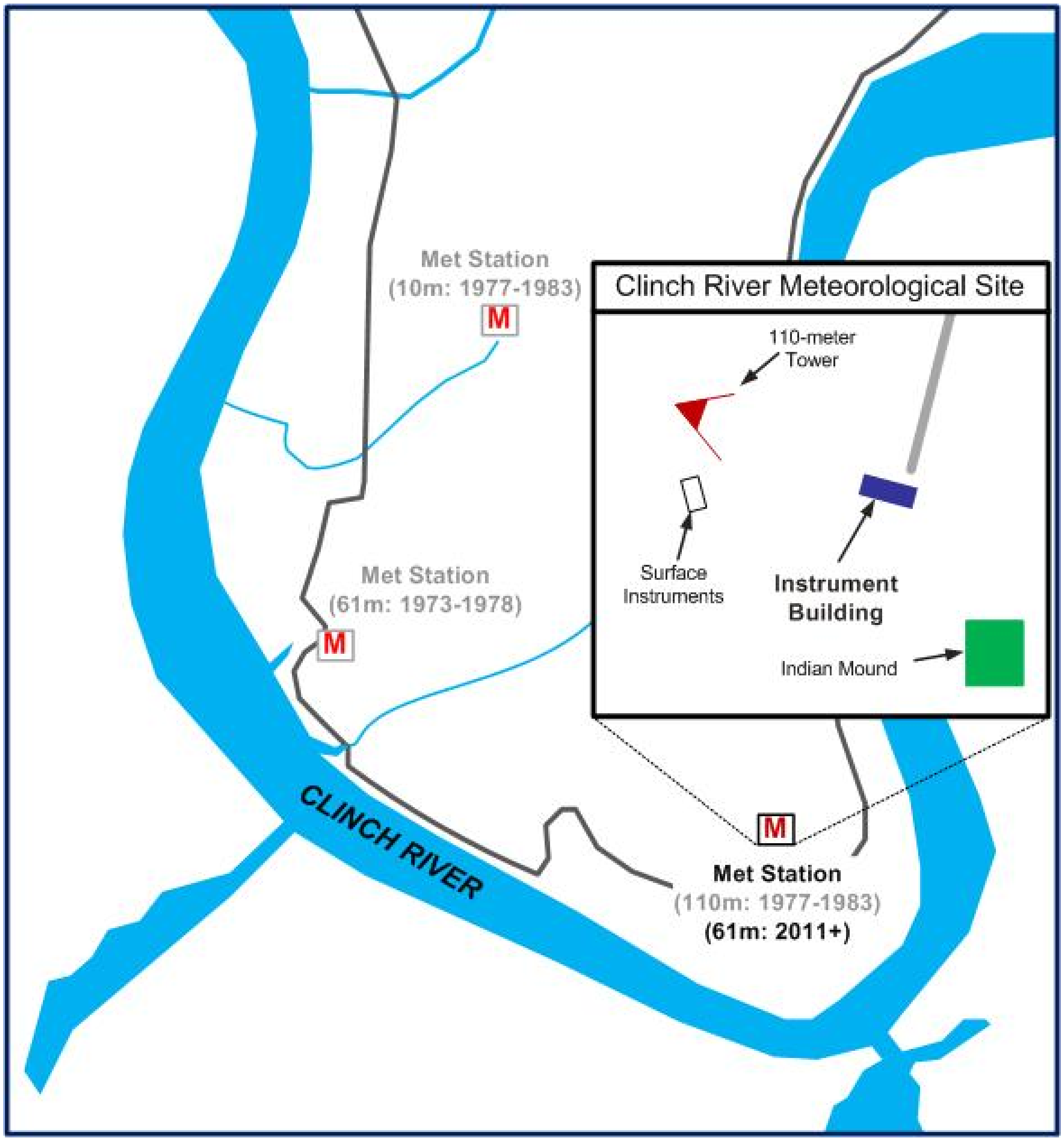
Station Description

Site Map



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Station Description

<u>Sensor Orientation</u>

The wind sensor for each level is mounted on a boom that extends towards the southeast (~140°). The orientation direction enables the maximum amount of data to be collected from directions unobstructed by the tower structure. The wind sensor mounting booms extend 100 inches from the tower, so the sensors are mounted 2.08 tower widths from the tower.

Air temperature sensors are mounted in downward pointing radiation shields that extend towards the east. The sensor inlet is 72 inches from the tower, so the sensors are mounted 1.50 tower widths from the tower. The dewpoint sensors also have downward pointing radiation shields and are mounted approximately 1 meter directly above the air temperature sensors

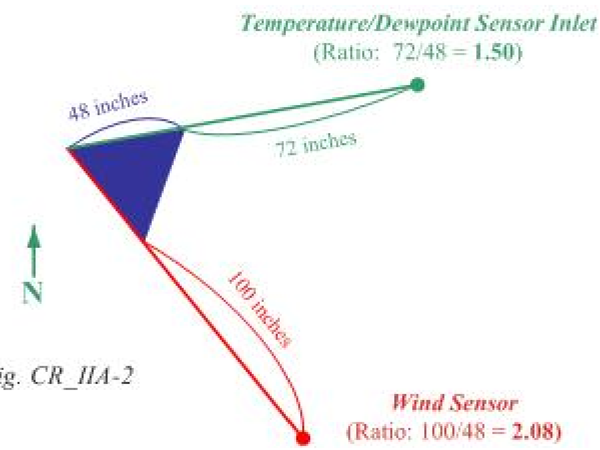

Fig. CR_IIA-2

Solar radiation and rainfall sensors are located 55 feet south of the tower with sensor inputs approximately 4 feet above ground level.

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Site Facilities

	Type	Installed
Tower - 360 feet	Advance	January 1977
Building	Portable Building	April 2011

SENSOR ELEVATIONS

	Height		
Point/Parameter	Feet	Meters	MSL Elevation (feet)
Ground at tower	-0.3	-0.09	799.6
Tower base	0.0	0.00	799.9
Rain Gauge (intake)	-2.5	-0.76	797.4
Solar Radiation	-0.4	-0.12	799.5
10 meter temperature	27.7	8.44	827.6
10 meter wind test sensor	28.5	8.69	828.4
10 meter dewpoint	31.6	9.63	831.5
10 meter wind direction/speed	32.1	9.78	832.0
60 meter temperature	194.3	59.22	994.2
60 meter wind direction/speed	197.2	60.11	997.1
60 meter dewpoint	197.8	60.29	997.7

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Site Facilities

1.0 METEOROLOGICAL MONITORING STATION HISTORY

Three meteorological towers have been operated at the Clinch River site.

A. Tower 1, which operated during 1973-1978, was a temporary tower at the plant site.

B. Tower 2, which operated during 1977-1978 and 1982-1983, was a 10-meter tower to collect supplemental wind direction/speed. It was discontinued when the Breeder Reactor project was canceled.

C. Tower 3 was operated for 2 different periods.

[Original] During 1977-1978 and 1982-1983, it was the primary tower for the site. It was discontinued (but not removed) when the Breeder Reactor project was canceled.

[Refurbished] Starting in 2011, it was refurbished to collect background data for licensing purposes.

The meteorological sensor heights and elevations for each of these towers are summarized below:

	Tower 1		Tower 2		Tower 3 (original)		Tower 3 (refurbished)	
	Height (ft -gnd)	Elevation (ft - msl)	Height (ft -gnd)	Elevation (ft - msl)	Height (ft -gnd)	Elevation (ft - msl)	Height (ft -gnd)	Elevation (ft - msl)
Tower Base	0	772	0	852	0	800	0	800
Wind Direction & Wind Speed	200 75 35	972 847 807	33	885	363 198 33	1163 998 833	197 32	997 832
Air Temperature	200 75 32	972 847 804			362 198 34	1162 998 834	194 28	994 828
Dewpoint	32	804			34	834	198 32	998 832
Precipitation					-1 *est*	799	-1	799
Solar Radiation					0 *est*	800	0	800
Atmospheric Pressure					6 *est*	806	6	806

Information is based on station descriptions and survey reports.

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Site Facilities

2.0 METEOROLOGICAL MONITORING HISTORY (TOWER 1)

Elevation = 235 meters-msl
State = Tennessee County = Roane Quad Map = Elverton (130 NW)
Latitude = 35° 53' 20" North Longitude = 84° 23' 10" West
UTM Grid = 16 Northing (km) = 3974.58 Easting (km) = 735.95

Data Type	Instrument	Height (meters)	Beginning Date	Ending Date
Wind Speed & Direction		61	04-11-1973	03-02-1978
Wind Speed & Direction		25	04-11-1973	03-02-1978
Wind Speed & Direction		10	04-03-1974	03-02-1978
Dry-bulb Temperature		61	04-11-1973	03-02-1978
Dry-bulb Temperature		25	04-11-1973	03-02-1978
Dry-bulb Temperature		10	04-03-1974	03-02-1978
Dewpoint Temperature		10	05-15-1975	03-02-1978

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Site Facilities

3.0 METEOROLOGICAL MONITORING HISTORY (TOWER 2)

Elevation = 260 meters-msl
State = Tennessee County = Roane Quad Map = Elverton (130 NW)
Latitude = 35° 53' 44" North Longitude = 84° 33' 56" West
UTM Grid = 16 Northing (km) = 3975.31 Easting (km) = 736.28

Data Type	Instrument	Height (meters)	Beginning Date	Ending Date
Wind Speed & Direction		10	05-11-1977	03-06-1978
Wind Speed & Direction		10	03-25-1982	11-04-1983

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Site Facilities

4.0 METEOROLOGICAL MONITORING HISTORY (TOWER 3)

Elevation = **244 meters-msl**

State = **Tennessee** County = **Roane** Quad Map = **Elverton (130 NW)**

Latitude = **35° 53' 07" North** Longitude = **84° 22' 33" West**

UTM Grid = **16** Northing (km) = **3974.21** Easting (km) = **736.88**

Data Type	Instrument	Height (meters)	Beginning Date	Ending Date
Wind Speed & Direction	**Vaisala 425**	**61**	**04-21-2011**	**current**
Wind Speed & Direction	**Vaisala 425**	**10**	**04-21-2011**	**current**
Wind Speed & Direction		110	03-24-1982	11-04-1983
Wind Speed & Direction		110	02-16-1977	03-06-1978
Wind Speed & Direction		61	03-24-1982	11-04-1983
Wind Speed & Direction		61	02-16-1977	03-06-1978
Wind Speed & Direction		10	03-24-1982	11-04-1983
Wind Speed & Direction		10	02-16-1977	03-06-1978
Dry-bulb Temperature		110	02-16-1977	03-06-1978
Dry-bulb Temperature		110	03-24-1982	11-04-1983
Dry-bulb Temperature	**Weed 101 (R. M. Young Shield)**	**61**	**04-21-2011**	**current**
Dry-bulb Temperature		61	02-16-1977	03-06-1978
Dry-bulb Temperature		61	03-24-1982	11-04-1983
Dry-bulb Temperature	**Weed 101 (R. M. Young Shield)**	**10**	**04-21-2011**	**current**
Dry-bulb Temperature		10	02-16-1977	03-06-1978
Dry-bulb Temperature		10	03-24-1982	11-04-1983
Dewpoint Temperature	**Viasala HMT-337**	**61**	**04-21-2011**	**current**
Dewpoint Temperature	**Viasala HMT-337**	**10**	**04-21-2011**	**current**
Dewpoint Temperature		10	02-16-1977	03-06-1978
Dewpoint Temperature		10	03-24-1982	11-04-1983
Solar Radiation	**Eppley**	**1**	**04-21-2011**	**current**
Solar Radiation		1	02-16-1977	03-06-1978
Solar Radiation		1	03-24-1982	11-04-1983
Rainfall (tipping bucket)	**Sutron 5600-420-1**	**1**	**04-21-2011**	**current**
Rainfall (weighing bucket)	Belfort 5912-12	1	02-16-1977	03-06-1978
Rainfall (weighing bucket)	Belfort 5912-12	1	03-24-1982	11-04-1983
Atmospheric Pressure	Sostman 2010-28/32 HA-1	1	02-16-1977	03-06-1978

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Meteorological Tower Wiring Diagrams

IIC-1	EDS Site Layout
IIC-2	Block Diagram
IIC-3	Building Terminal Blocks (TB)
IIC-4	Patch Test Panel (PP)
IIC-5	Tower Base Junction Box (BP)
IIC-6	Tower 10m Panel (10m)
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IIC-8	Eppley/Rain Gauge Panel (EP/RG)
IIC-9	Air Temperature Aspirator Panel (AP)
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IIC-11	Ultrasonic Wind Sensor Rear Panel (WP)
IIC-12	Agilent Wiring List (AG)

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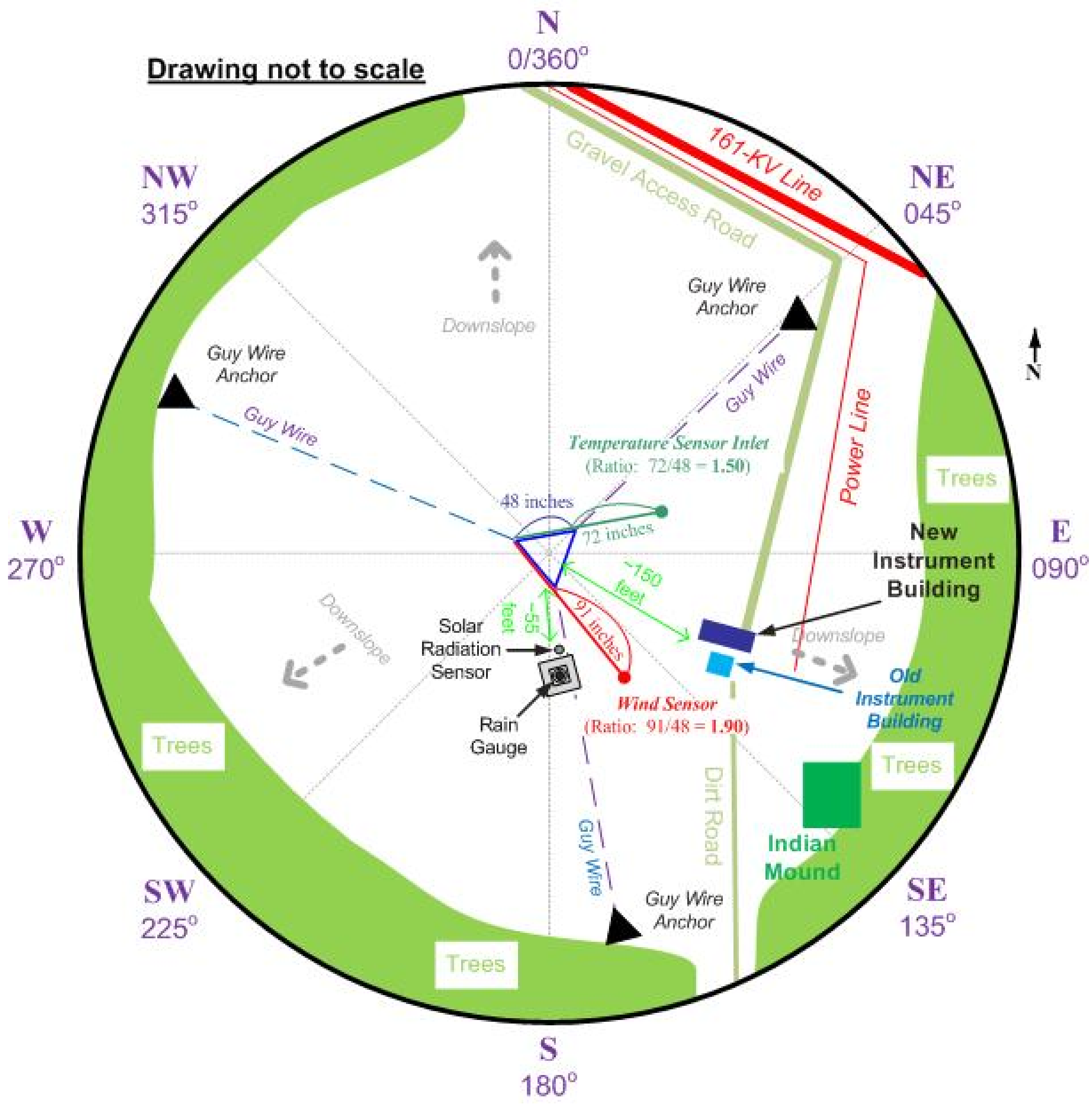
Meteorological Tower Wiring Diagrams

Figure IIC-1

EDS Site Layout



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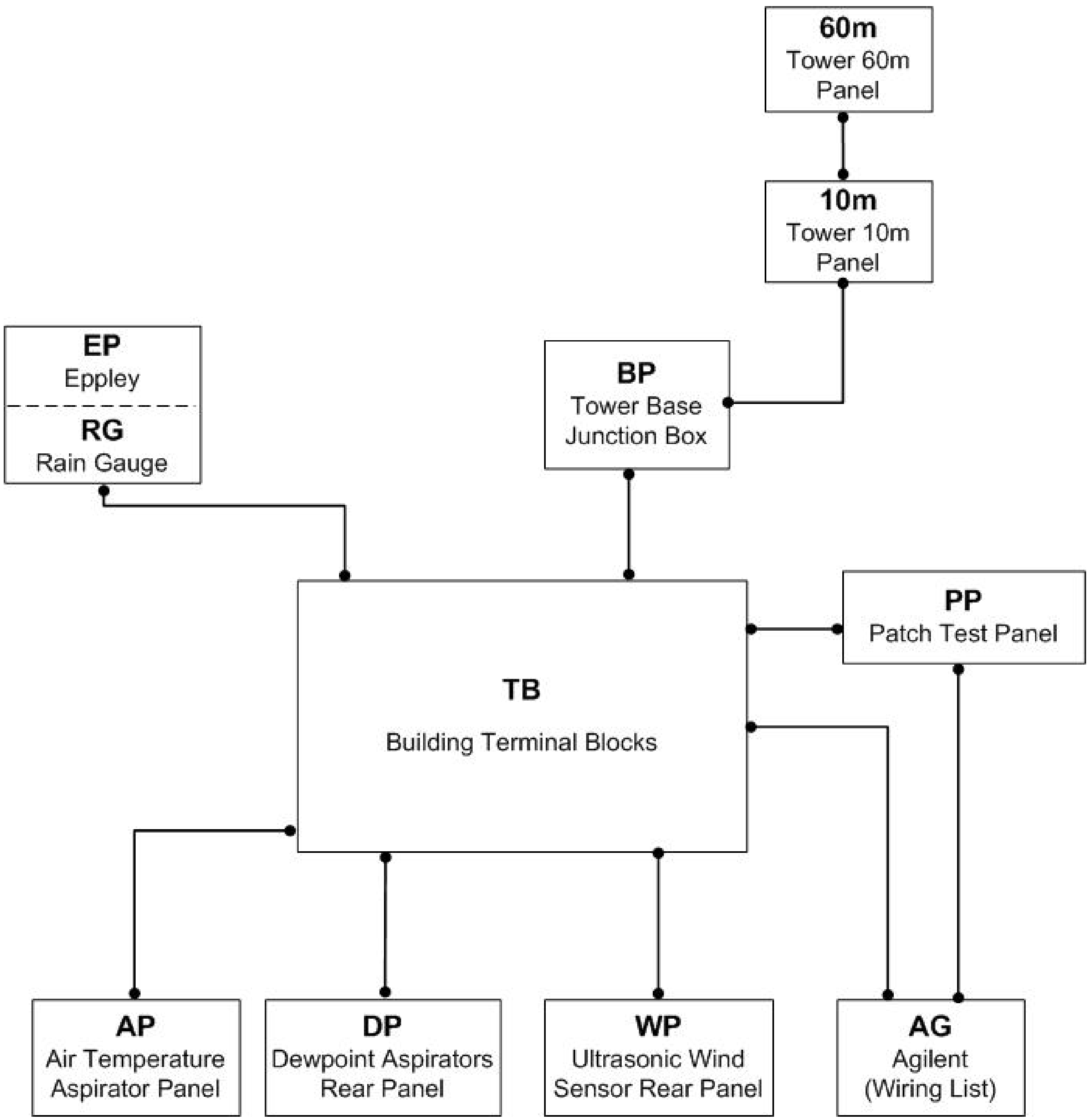
Meteorological Tower Wiring Diagrams

Figure IIC-2

Block Diagram



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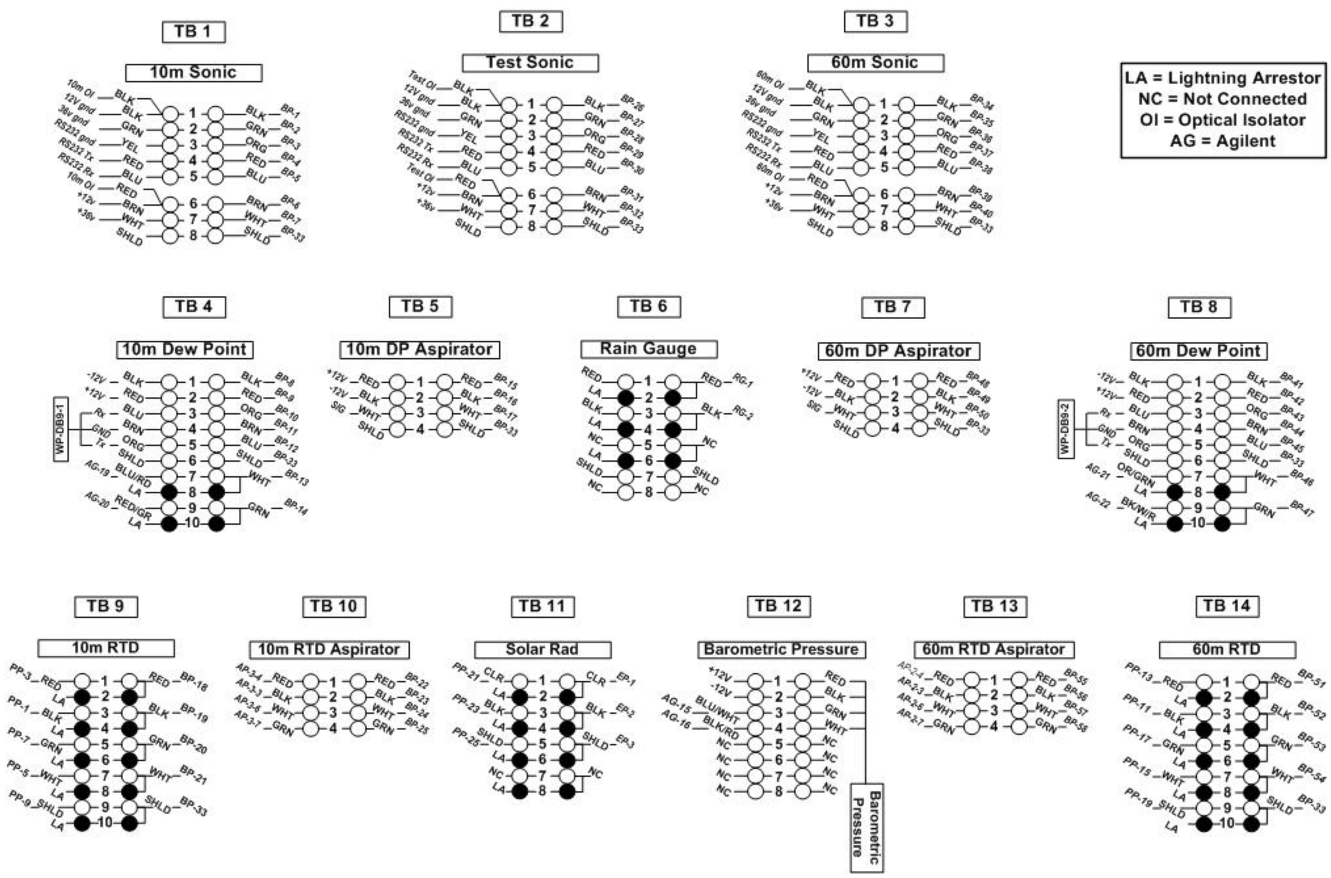
Meteorological Tower Wiring Diagrams

Figure IIC-3

Building Terminal Blocks (TB)



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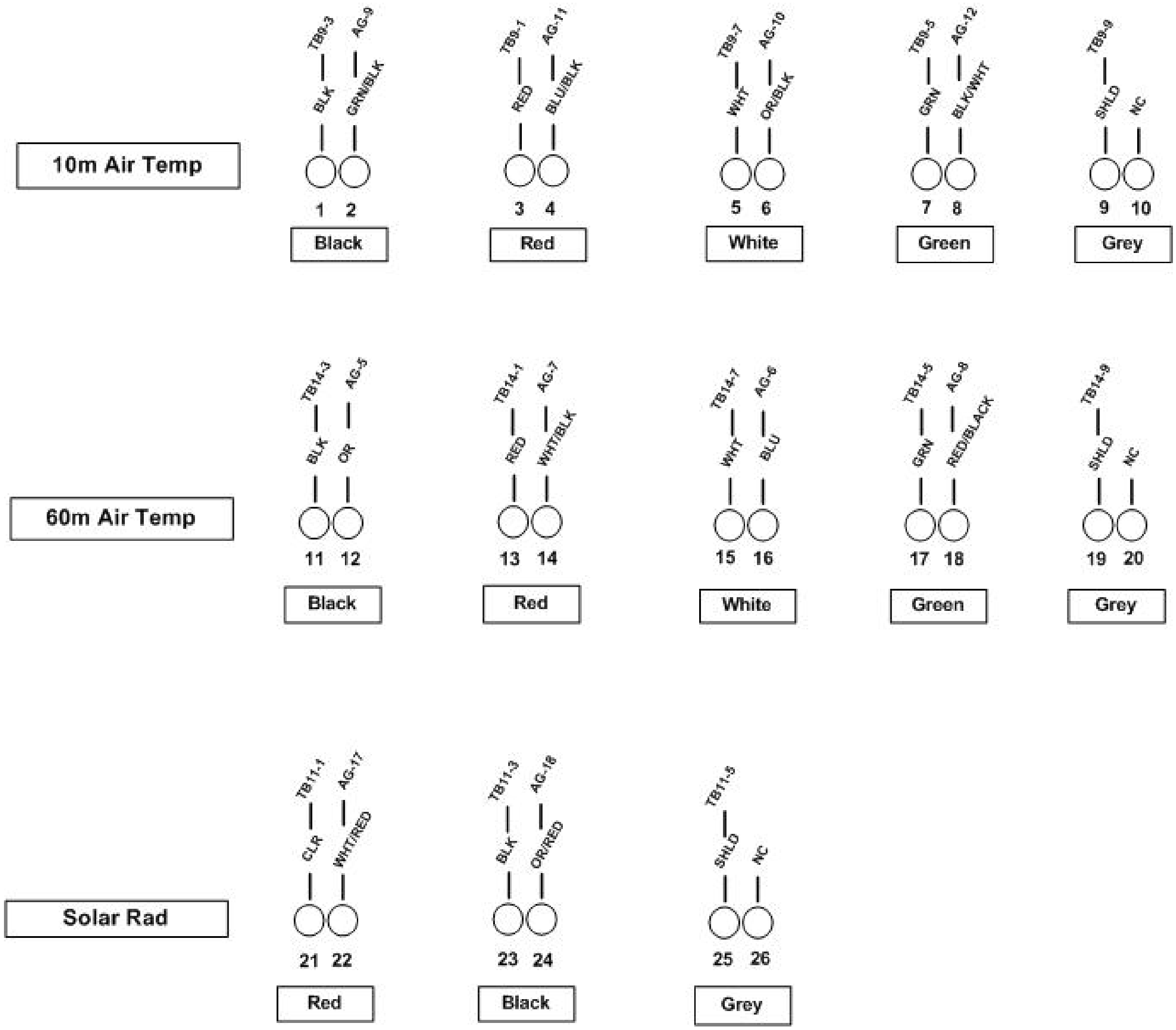
Meteorological Tower Wiring Diagrams

Figure IIC-4

Patch Test Panel (PP)



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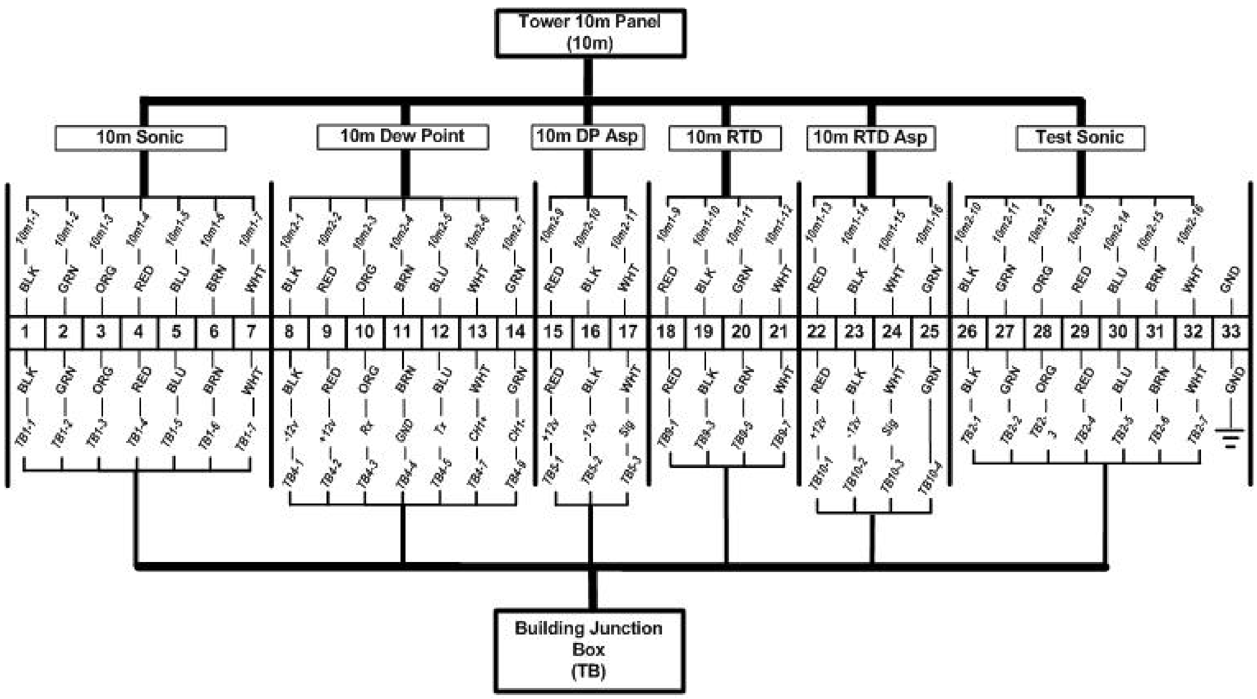
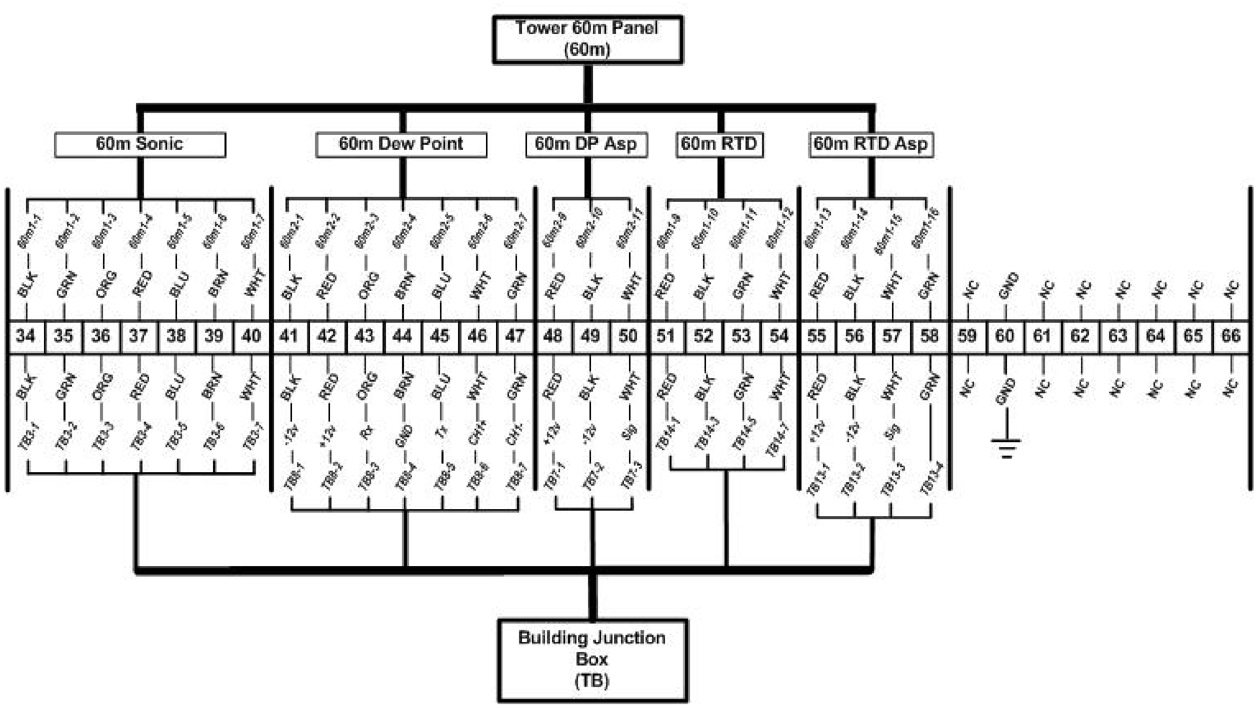
Meteorological Tower Wiring Diagrams

Figure IIC-5

Tower Base Junction Box (BP)





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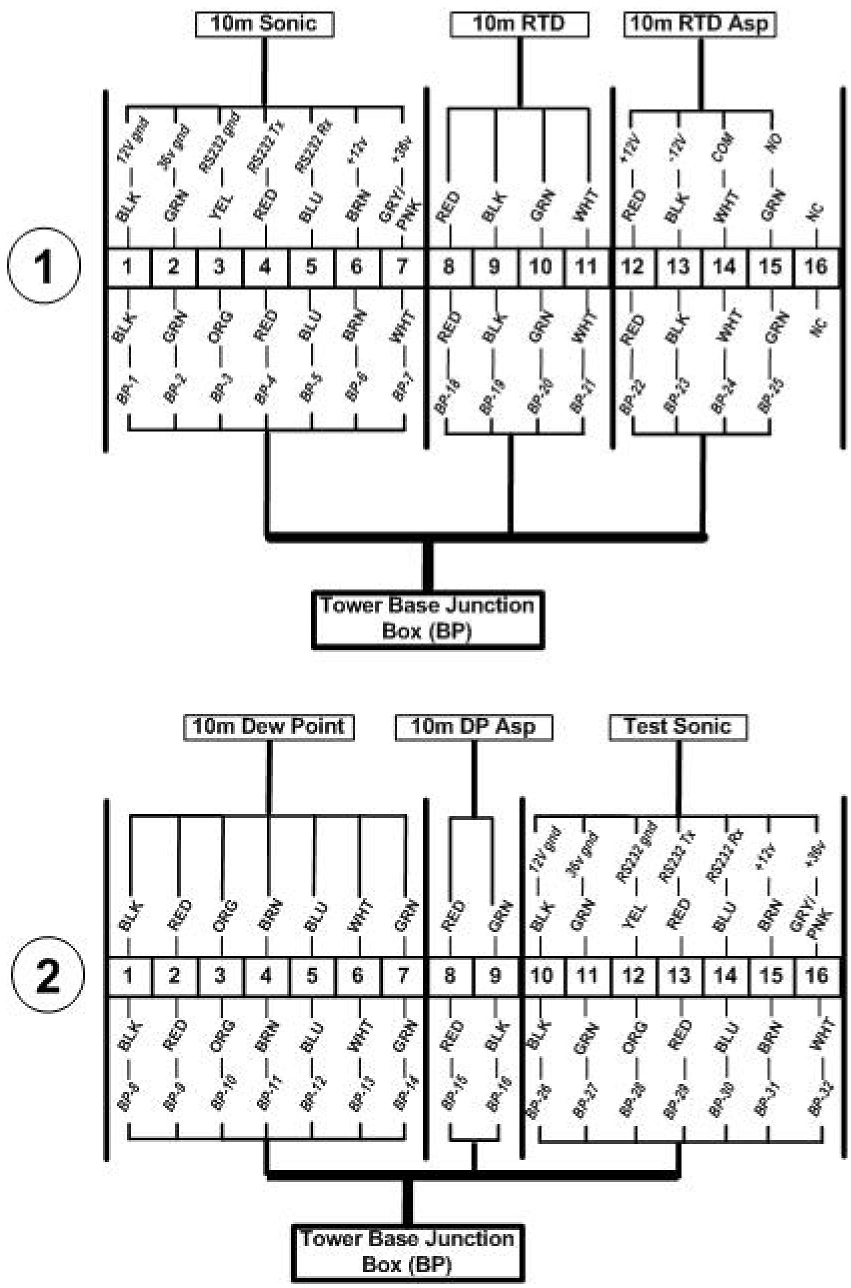
Meteorological Tower Wiring Diagrams

Figure IIC-6

Tower 10m Panel (10m)



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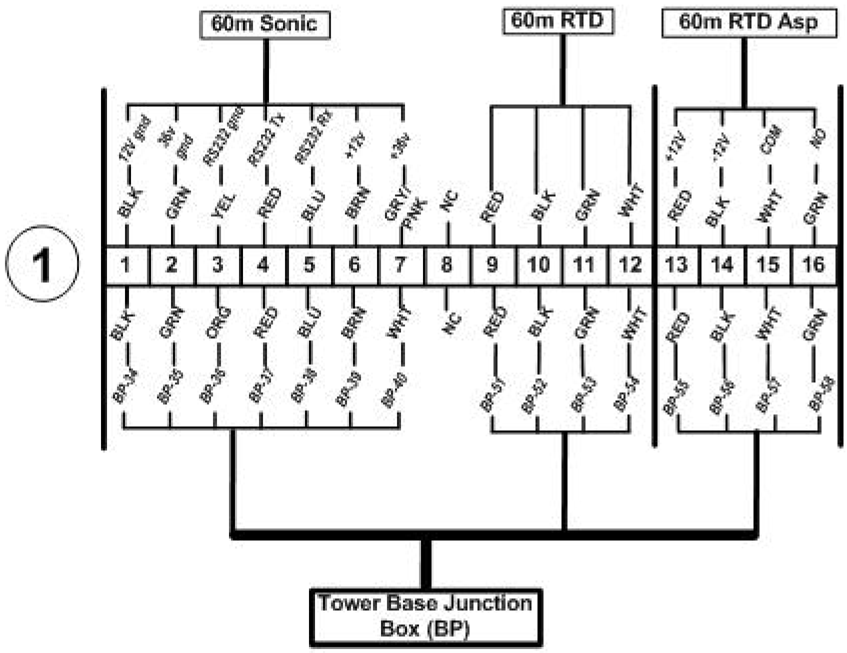
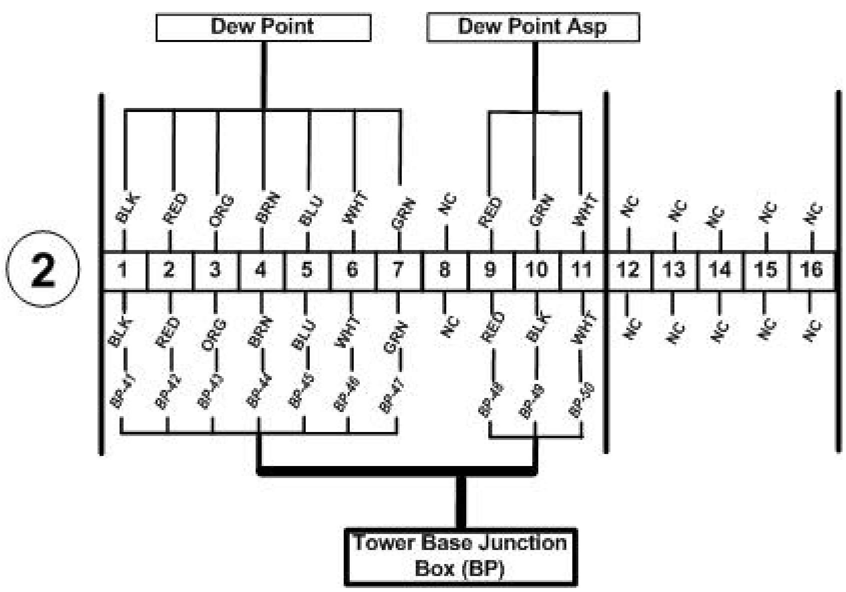
Meteorological Tower Wiring Diagrams

Figure IIC-7

Tower 60m Panel (60m)





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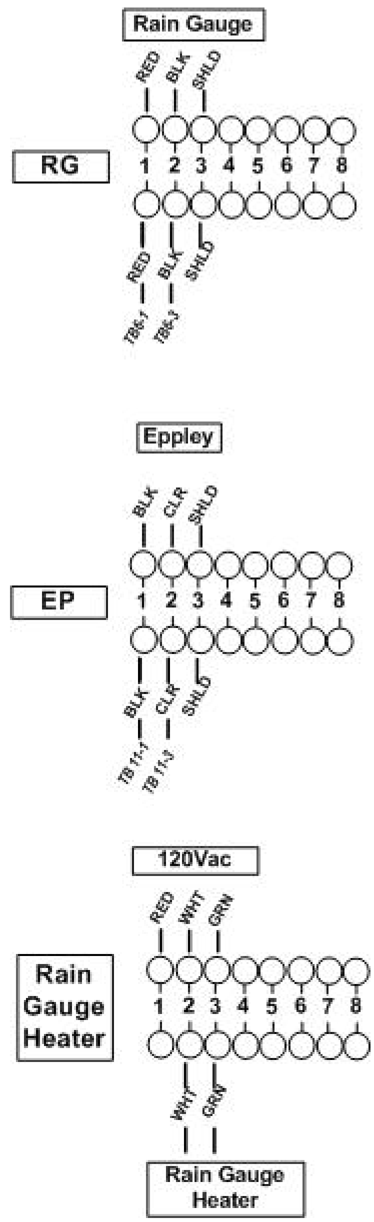
Meteorological Tower Wiring Diagrams

Figure IIC-8

Eppley/Rain Gauge Panel (EP/RG)



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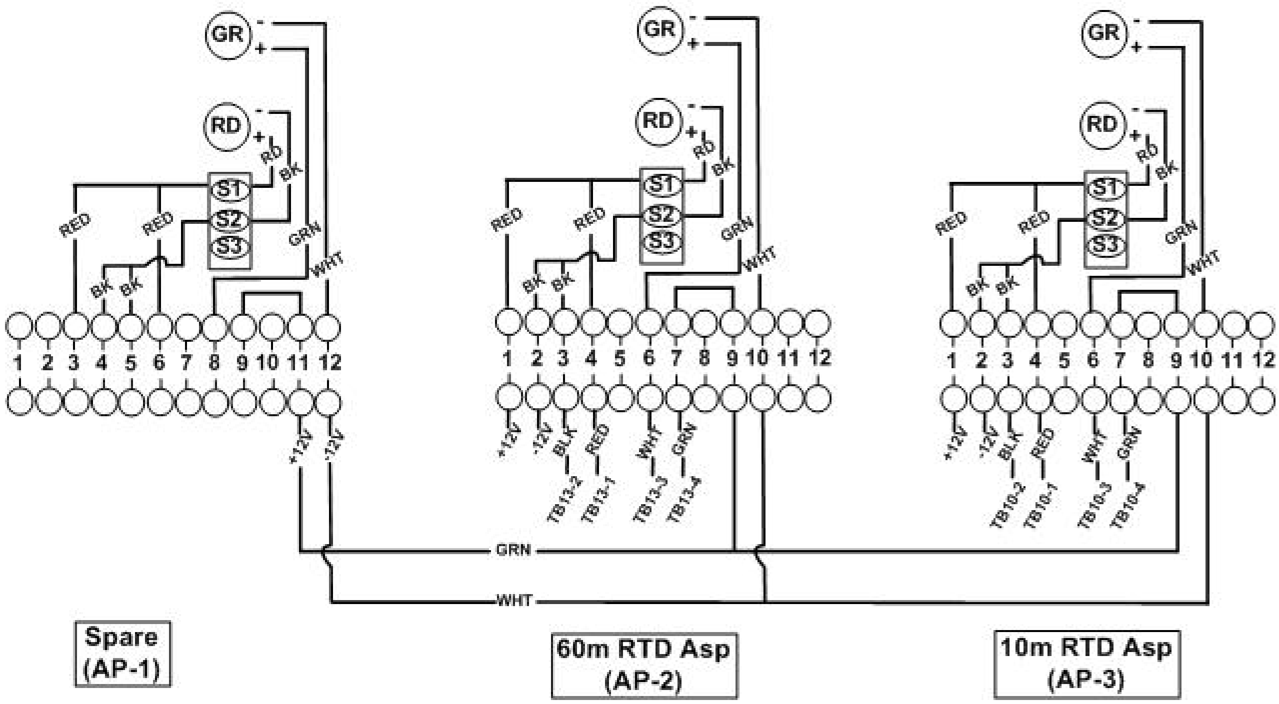
Meteorological Tower Wiring Diagrams

Figure IIC-9

Air Temperature Aspirator Panel (AP)



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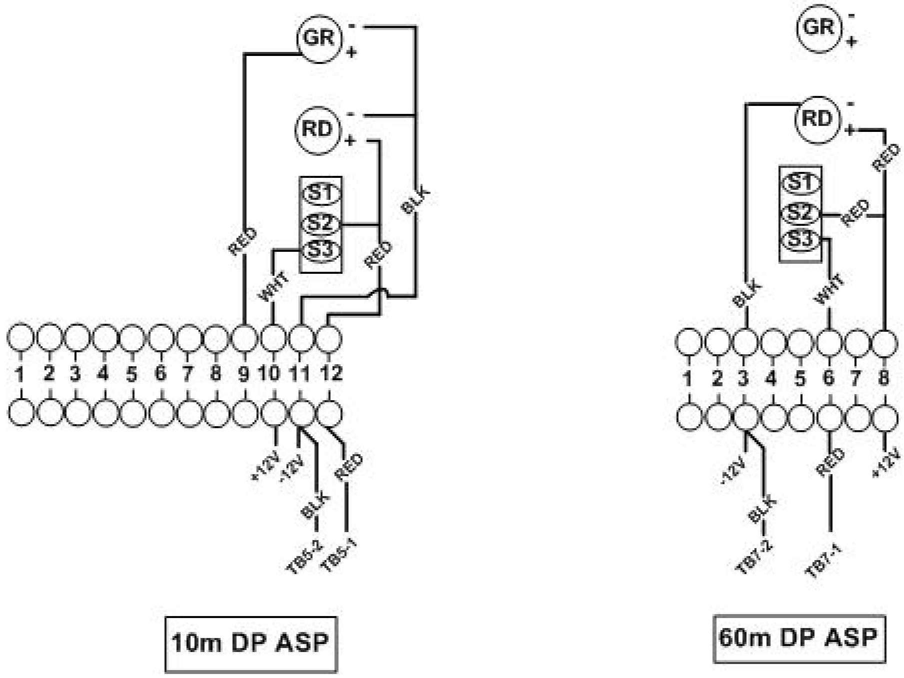
Meteorological Tower Wiring Diagrams

Figure IIC-10

Dewpoint Aspirators Rear Panel (DP)



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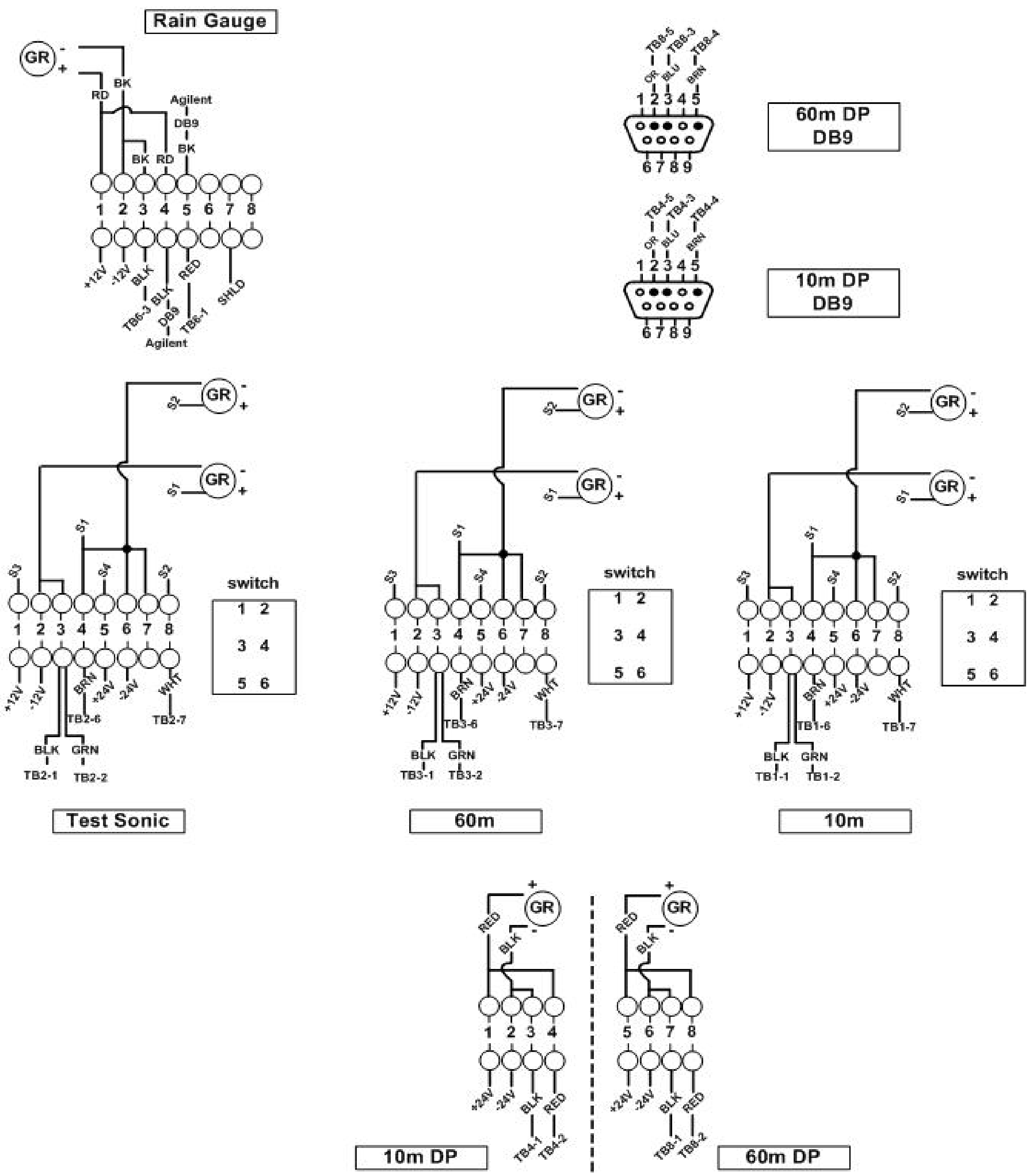
Meteorological Tower Wiring Diagrams

Figure IIC-11

Ultrasonic Wind Sensor Rear Panel (WP)



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Meteorological Tower Wiring Diagrams

Figure IIC-12

Agilent Wiring List (AG)

Connection	Conductor	Color	Use	Channel
	~~1~~	~~Black~~		
	~~2~~	~~White~~		
	~~3~~	~~Red~~		
	~~4~~	~~Green~~		
PP-12	5	Orange	60m Air Temp Low Sense	12 L
PP-16	6	Blue	60m Air Temp High Sense	12 H
PP-14	7	White/Black	60m Air Temp Low Source	02 L
PP-18	8	Red/Black	60m Air Temp High Source	02 H
PP-2	9	Green/Black	10m Air Temp Low Sense	13 L
PP-6	10	Orange/Black	10m Air Temp High Sense	13 H
PP-4	11	Blue/Black	10m Air Temp Low Source	03 L
PP-8	12	Black/White	10m Air Temp High Source	03 H
	~~13~~	~~Red/White~~		
	~~14~~	~~Green/White~~		
TB12-3	15	Blue/White	Barometric Pressure	07 L
TB12-4	16	Black/Red	Barometric Pressure	07 H
PP-22	17	White/Red	Solar Radiation High (+)	06 H
PP-24	18	Orange/Red	Solar Radiation Low (-)	06 L
TB4-7	19	Blue/Red	10m Dew Point High (+)	05 H
TB4-9	20	Red/Green	10m Dew Point Low (-)	05 L
TB8-7	21	Orange/Green	60m Dew Point High (+)	08 H
TB8-9	22	Black/White/R	60m Dew Point Low (-)	08 L
	~~23~~	~~White/Black/Red~~		
	~~24~~	~~Red/Black/White~~		
	~~25~~	~~Gree/Black/White~~		

Note: Multiplexer channels are SCC, where S is the slot and CC is the 2-digit channel number. Met multiplexer is installed in slot 1, so all channels above are accessed by adding 100. e.g. 60m Air Temp Low Sense is channel 112.

Environmental Data Station Manual	**Clinch River Nuclear Plant** **Module III** **<< Reserved for Future Use >>**	**EDS-CRN** **Rev. 0001** **Page 1 of 3**
		Quality Related ☑ Yes ☐ No
		Effective Date

Level of Use: Reference Use

Prepared by: Kenneth G. Wastrack (EMA), Meteorologist

Reviewed by: < not applicable > ________ Date

Concurred by: < not applicable > ________ Date

Approved by: < not applicable > ________ Date

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1.0 RESERVED FOR FUTURE USE

TVA **Environmental Data Station Manual**	**Clinch River Nuclear Plant** **Module IV** **STATION SCAN LISTS**	**EDS-CRN** **Rev. 0001** **Page 1 of 6** Quality Related ☑ Yes ☐ No Effective Date

Level of Use: Reference Use

Prepared by: Kenneth G. Wastrack (EMA), Meteorologist

Reviewed by: ______________________ ____________

Robert D. Stone (NPG), I&C Engineer, Computer Process Engineering — Date

Concurred by: ______________________ ____________

Jeffery N. Perry (P&O) Senior Project Manager, SMR Technology — Date

Approved by: ______________________ ____________

Walter H. Lee III (NPG), Manager, Emergency Preparedness--REMIC Chairman — Date

Revision Log

Revision or Change Number	Effective Date	Affected Page Numbers	Description of Revision/Change
0		All Pages	Initial Release.

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1.0 OVERVIEW

The Clinch River Nuclear Plant (CRN) Environmental Data Station (EDS) computer encodes and formats meteorological data in real time as it is collected. The data are recorded to disk files and are periodically sent to an offsite computer. The station scan lists (section 3) provide the keys for interpreting the encoded data.

This module of the EDS Station Manual describes where the data is sent and what the data represent.

2.0 EDS INTERFACE (EDS-TO-RAC)

The Remote Access Computer (RAC) permits users to access data from Environmental Data Stations in near real-time, without accessing the EDS computers directly. The RAC is located in the Central Emergency Control Center (CECC) computer room.

For CRN, data files written to the RAC include:

- Hourly average meteorological data
- 15-minute average meteorological data

Unlike the meteorological programs for other TVA nuclear plants, CRN is not on the TVA computer network. Therefore, a two-part process is used to communicate the data to the RAC.

A. Hourly and 15-minute observations, are copied to TVA's external FTP server (info.tva.gov). The FTP site maintains the data received from the EDS Computer.

B. The RAC obtains the data from the FTP server, posts it on the EDS website, and saves the data for later FTP access (for data validation).

3.0 SCAN LISTS - METEOROLOGICAL

3.1 Hourly Meteorological (Archive)

Station:	**Clinch River**	Date:
Station Type:	**Meteorological - Hourly**	Program Installation Date:
Station Code:	**9601**	Program No.:
Scan Sheet ID:		Previous Program No.:

Sample Printout

```
<SOH><ETX>*96,12,114,0300,D<ETX>
<SOH><ETX>1,@D24.07,=D26.82,)D287.04,>D5.23,ED5.80,@I35.05,=I39.25,)I285.35,>I2.34,EI2.95,@
Q34.56,=Q38.51,)Q285.77,>Q2.50,EQ3.12,FD43.24,FI43.05,GD30.26,GI32.09,HK0.00,JK0.00,KK28.94
<ETX><SOH><CR><LF><EOT>
```

Sample Data	Actual Decimal	Description	Units	Collection Frequency	Instrument Code (Channel No.)
@D24.07	0	61M HORIZONTAL WIND DIRECTION SIGMA-THETA 15 MIN. AVG.	° (azimuth)	5 SEC	N/A
=D26.82	0	61M HORIZONTAL WIND DIRECTION SIGMA-THETA HRLY. AVG.	° (azimuth)	5 SEC	N/A
)D287.04	0	61M VECTOR WIND DIRECTION	° (azimuth)	5 SEC	N/A
>D5.23	1	61M VECTOR WIND SPEED	MPH	5 SEC	N/A
ED5.80	1	61M AVERAGE WIND SPEED	MPH	5 SEC	N/A
@I35.05	0	10M HORIZONTAL WIND DIRECTION SIGMA-THETA 15 MIN. AVG.	° (azimuth)	5 SEC	N/A
=I39.25	0	10M HORIZONTAL WIND DIRECTION SIGMA-THETA HRLY. AVG.	° (azimuth)	5 SEC	N/A
)I285.35	0	10M VECTOR WIND DIRECTION	° (azimuth)	5 SEC	N/A
>I2.34	1	10M VECTOR WIND SPEED	MPH	5 SEC	N/A
EI2.95	1	10M AVERAGE WIND SPEED	MPH	5 SEC	N/A
@Q34.56	0	TEST HORIZONTAL WIND DIRECTION SIGMA-THETA 15 MIN. AVG.	° (azimuth)	5 SEC	N/A
=Q38.51	0	TEST HORIZONTAL WIND DIRECTION SIGMA-THETA HRLY. AVG.	° (azimuth)	5 SEC	N/A
)Q287.77	0	TEST VECTOR WIND DIRECTION	° (azimuth)	5 SEC	N/A
>Q2.50	1	TEST VECTOR WIND SPEED	MPH	5 SEC	N/A
EQ3.12	1	TEST AVERAGE WIND SPEED	MPH	5 SEC	N/A
FD43.24	2	61M AIR TEMPERATURE	°F	5 SEC	102
FI43.05	2	10M AIR TEMPERATURE	°F	5 SEC	103
GD30.26	2	61M DEW POINT	°F	5 SEC	108
GI32.09	2	10M DEW POINT	°F	5 SEC	105
HK0.00	2	1M SOLAR RADIATION	GM-CAL/ CM^2-MIN	5 SEC	106
JK0.00	2	1M RAINFALL	INCHES	HOURLY	303
KK29.84	2	2M ATMOSPHERIC PRESSURE	inchesHg	5 SEC	107

3.2 15-Minute Meteorological

Station: **Clinch River**
Station Type: **Meteorological - 15-Minute**
Station Code: **9677**
Scan Sheet ID:

Date:
Program Installation Date:
Program No.:
Previous Program No.:

Sample Printout

```
<SOH><ETX>*96,12,114,0245,D<ETX>
<SOH><ETX>77,:D284.69,:I270.68,:Q271.58,;D5.03,;I2.77,;Q3.06,ED5.50,EI3.07,EQ3.33,FD43.14,F
I43.16,&D25.61,&I25.36,&Q23.09,JK0.00,KK28.94<ETX><SOH><CR><LF><EOT>
```

Sample Data	Actual Decimal	Description	Units	Collection Frequency	Instrument Code (Channel No.)
:D284.69	0	61M VECTOR WIND DIRECTION	° (azimuth)	5 SEC	N/A
:I270.68	0	10M VECTOR WIND DIRECTION	° (azimuth)	5 SEC	N/A
:Q271.58	0	TEST VECTOR WIND DIRECTION	° (azimuth)	5 SEC	N/A
;D5.03	1	61M VECTOR WIND SPEED	MPH	5 SEC	N/A
;I2.77	1	10M VECTOR WIND SPEED	MPH	5 SEC	N/A
;Q3.06	1	TEST VECTOR WIND SPEED	MPH	5 SEC	N/A
ED5.50	1	61M AVERAGE WIND SPEED	MPH	5 SEC	N/A
EI3.07	1	10M AVERAGE WIND SPEED	MPH	5 SEC	N/A
EQ3.33	1	TEST AVERAGE WIND SPEED	MPH	5 SEC	N/A
FD43.14	2	61M AIR TEMPERATURE	°F	5 SEC	102
FI43.16	2	10M AIR TEMPERATURE	°F	5 SEC	103
&D25.61	0	61M HORIZONTAL WIND DIRECTION SIGMA-THETA 15 MIN.	° (azimuth)	5 SEC	N/A
&I25.36	0	10M HORIZONTAL WIND DIRECTION SIGMA-THETA 15 MIN. AVG.	° (azimuth)	5 SEC	N/A
&Q23.09	0	TEST HORIZONTAL WIND DIRECTION SIGMA-THETA 15 MIN. AVG.	° (azimuth)	5 SEC	N/A
JK0.00	2	1M RAINFALL	INCHES	15 MIN	303
KK28.94	2	2M ATMOSPHERIC PRESSURE	inchesHg	5 SEC	107