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AirNet
201, 310, 510
Operations Manual

Particle Measuring Systems, Inc.
5475 Airport Boulevard
Boulder, CO 80031
Customer Support: 1-800-557-6363

P/N 10254-5

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AirNet 201, 310, 510 Operations Manual
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First Edition, November 1997

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Declaration of Conformity

Application of Council Directive(s):	89 / 336 / EEC, 73 / 23 / EEC
Standard(s) to which Conformity is Declared:	**EMC** EN 55011, EN 50082-1
	Safety EN 61010:1993 (IEC 1010-1:1990)
Manufacturer's Name:	Particle Measuring Systems, Inc.
Manufacturer's Address:	5475 Airport Boulevard, Boulder, CO 80301 USA
Manufacturer's Telephone / FAX:	(303) 443-7100 / (303) 449-6870
Distributor's Name:	Particle Measuring Systems Europe, LTD.
Distributor's Address:	Grovewood Road, Enigma Science Park
	Malvern Worcester WR14 1XZ
	England
Distributor's Telephone / FAX:	011-44-1684-581000 / 011-44-1684-560337
Type of Equipment:	Particle Monitoring
Model No.:	AirNet

I, the undersigned, hereby declare that the equipment specified above conforms to the above Directive(s) and Standard(s).

Signature: K Urquidi	Signature: D Hall
Full Name: Kristi Urquidi	Full Name: David Hall
Position: Vice President Operations	Position: Managing Director
Place: Boulder Date: January 12, 1998	Place: Malvern Date: July 17, 1998

Warning: All I/O cables and accessories must meet current factory specifications in order for this unit to remain in compliance with CE marking requirements. Consult factory for details.

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Particle Measuring Systems, Inc., is a team of creative people who are leaders in the design and manufacture of microcontamination-detection instruments. At PMS we seek to support our valued customers by doing our job right the first time, by providing state-of-the-art products that conform to accepted specifications and standards, and by delivering our products within the committed time schedule. We rely upon our vendors for their products to conform to their specifications and invite them to join us in the commitment we have to all our customers.

Our Quality Policy is to strive to meet or exceed the needs and expectations of our customers and to align the activities of all employees with the common focus of customer satisfaction through continuous improvement in the quality of our products and services.

Manual Conventions

NOTE: **A *note* in the text is used to highlight an item that is of operational importance to the user.**

CAUTION: **A caution in the text is used to highlight an item that, if not done or incorrectly done could damage the instrument and/or any materials or devices affected by the instrument.**

WARNING: **A w*arning* in the text is used to highlight an item that, if not done or incorrectly done could result in bodily injury or death.**

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Product Support.

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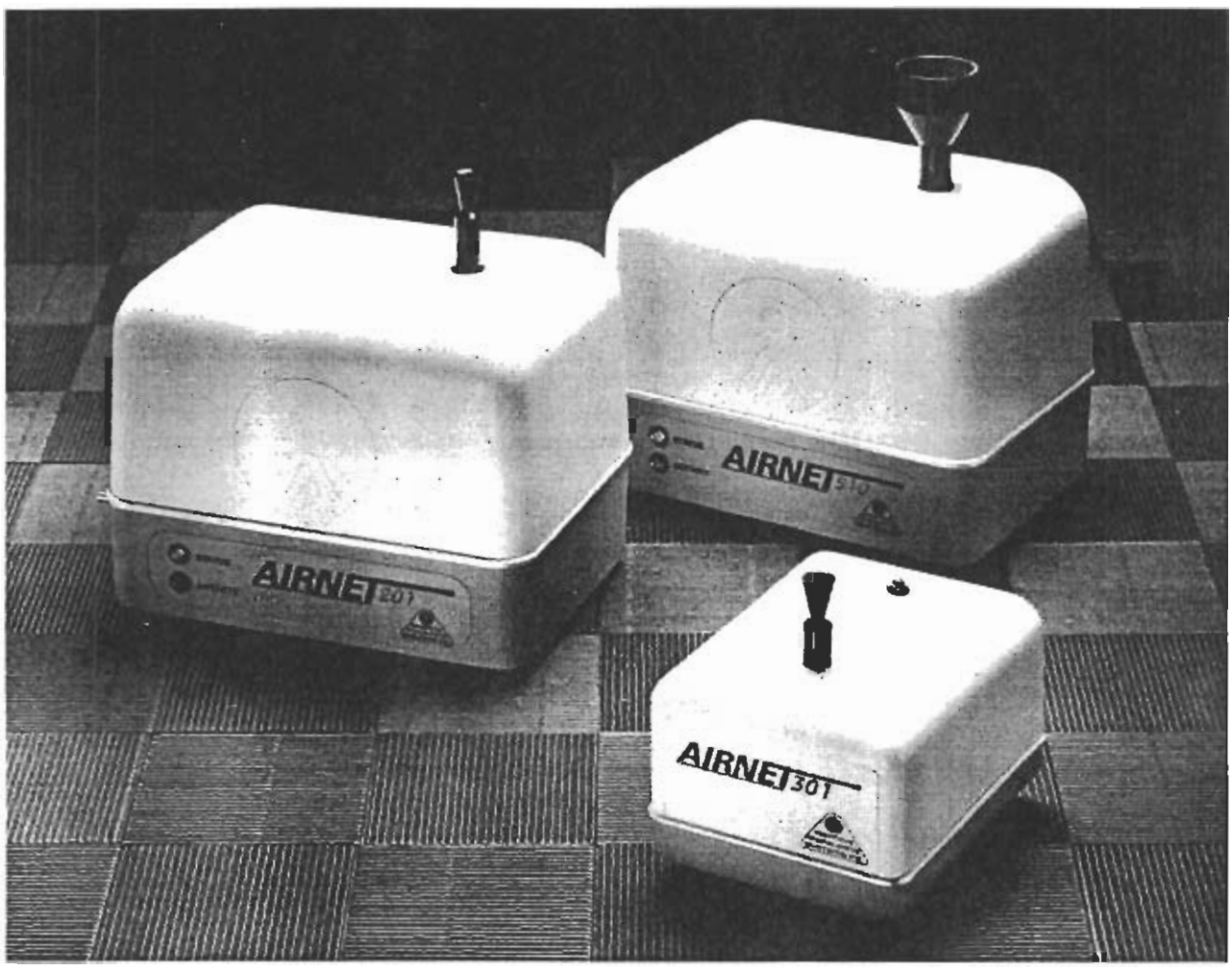
Chapter 1
Introduction

The AirNet (models 201, 310, 510) is a laser-optical based aerosol particle counter. It is designed to accurately count and measure particles suspended in air.

The AirNet offers several advantages over conventional particle sensors:

- It is small enough to be installed almost anywhere.
- It has no critical optical surfaces that require periodic cleaning and alignment.
- It requires no high voltages.
- The laser diode has a long life and constant power output.
- It has no potential for generating contamination, as do other sensors that contain pumps.

AirNet particle counters communicate via Ethernet connection with Facility-View, a software package that stores and displays particle data and allows the user to control the AirNet. They can also communicate by sending a 4-20mA signal that can be customized for many 4-20mA capable data systems.



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Chapter 2
Unpacking

1. Inspect the shipping container for any signs of damage or mishandling. If the container appears damaged, do not open it. Contact the shipper immediately.

2. If the shipping container appears undamaged, carefully open the container and remove the AirNet, inspecting each unit for damage.

3. If any components are damaged, notify the shipper and PMS, and repackage the unit in the original packing materials.

4. If the system is undamaged, store the packing materials. It is important to store packing materials, because warranties may not apply if return shipping containers are inadequate.

The AirNet is shipped with the following items:

- AirNet module
- 24VDC Power Cable
- Serial cable for initialization
- Wall mount bracket
- Isokinetic air sampler with adapter and 5' tubing (310 and 510 only) for remote mounting of sampler
- Manual

The following items are **not** included. You will need to provide them:

- Ethernet cable
- computer with Facility-View software

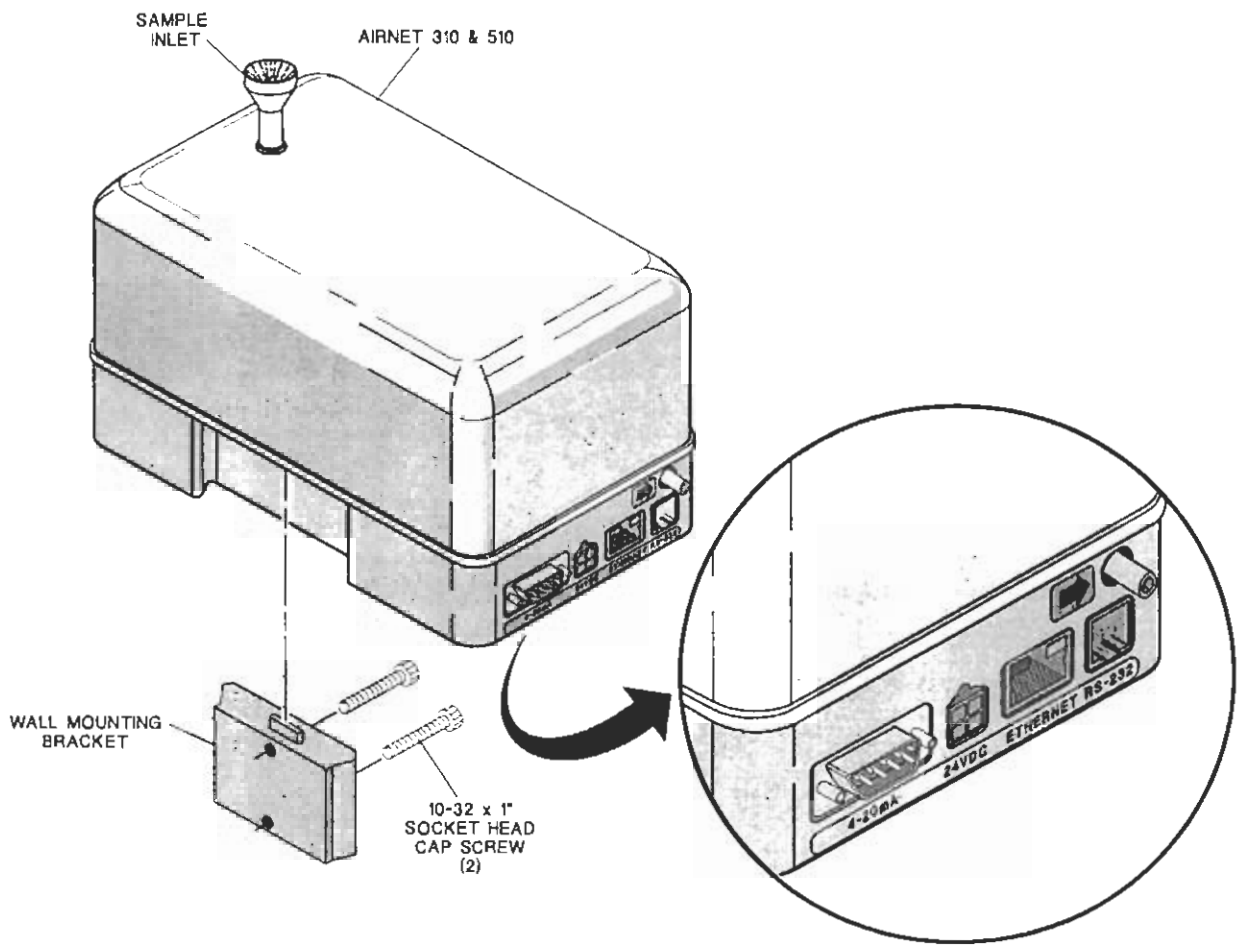
To initialize the AirNet you will need the use of a computer with a terminal program. For more information refer to the Installation section of this manual.

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Chapter 3
Description

This section contains a physical description of the AirNet sensor.



Front Panel

The front panel of the AirNet includes two LED's.

Status Light

The "Status" light indicates the operational status of the instrument. When used with Facility-View, the light is controlled by Facility-View's alarm settings. When used without Facility-View, the light is controlled by the AirNet hardware. In this instance the light will remain green except for a low flow or laser status error. A flashing red light indicates that the sensor has failed to initialize correctly.

Activity Light

The "Activity" light flashes when a particle is detected.

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Side Panel

The left side of the AirNet (viewed from the front) incorporates all electrical, electronic, and vacuum source connectors.

Electrical Power

The 24VDC power connector powers the unit.

Communications

The DB-9 4-20mA output supplies a scaled 4-20mA signal that transmits Channel 1 and 4 particle counts and instrument status messages.

The UTP Ethernet connector allows the unit to communicate with Facility-View via Ethernet.

The RS-232 RJ-11 jack is used for initializing the unit and performing limited diagnostics.

Vacuum Source

The barbed fitting allows a source of house vacuum (>15 in. Hg) to be supplied to the unit. The fitting is sized for 1/8 inch ID tubing on the AirNet 201, and ¼" on the 310 and 510 models.

Rear Panel

The rear panel incorporates a mounting bracket attachment for optional wall-mount installation.

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Chapter 4
Specifications

	AirNet 201	AirNet 310	AirNet 510
Laser Type	*diode*	*diode*	*diode*
Sample flow rate	*0.1 CF ± 5%*	*1.0 CF ± 5%*	*1.0 CF ± 5%*
Purge flow rate	*0.01 CF ± 5%*	*N/A*	*N/A*
Vacuum source	*>15 in. Hg*	*>15 in. Hg*	*>15 in. Hg*
Background counts	*< 1 count/ft³*	*< 0.1 count/ft³*	*< 0.1 count/ft³*
Maximum particle concentration @ 10% coincidence loss	*1,000,000/ CF (10% coincidence)*	*100,000/ CF (10% coincidence)*	*300,000/ CF (10% coincidence)*
Counting efficiency	*50% ± 10% @ 0.2µ*	*50% ± 10% @ 0.3µ*	*50% ± 10% @ 0.5µ*
Viewing volume	*100% ± 10% @ 0.3µ*	*100% ± 10% @ 0.5µ*	*100% ± 10% @ 1.0µ*
Number of size channels	*4*	*4*	*4*
Channel thresholds	*0.2µ, 0.3µ, 0.5µ, and 1.0µ*	*0.3µ, 0.5µ, 1.0µ, and 5.0µ*	*0.5µ, 0.7µ, 1.0µ, and 5.0µ*
Communications	*10baseT Ethernet 4-20mA*	*10baseT Ethernet 4-20mA*	*10baseT Ethernet 4-20mA*
Environmental limits	*Temperature: 4-35C Humidity: Noncondensing*	*Temperature: 4-35C Humidity: Noncondensing*	*Temperature: 4-35C Humidity: Noncondensing*
Material	*Kydex ® thermoformed plastic*	*Kydex ® thermoformed plastic*	*Kydex ® thermoformed plastic*
Mounting	*table-top or wall mount*	*table-top or wall mount*	*table-top or wall mount*
Power	*24VDC, 300mA*	*24VDC, 300mA*	*24VDC, 300mA*
Dimensions (H x W x D)	*5" x 5" x 7"*	*5" x 5" x 7"*	*5" x 5" x 7"*
Weight	*4lb*	*4lb*	*4lb*

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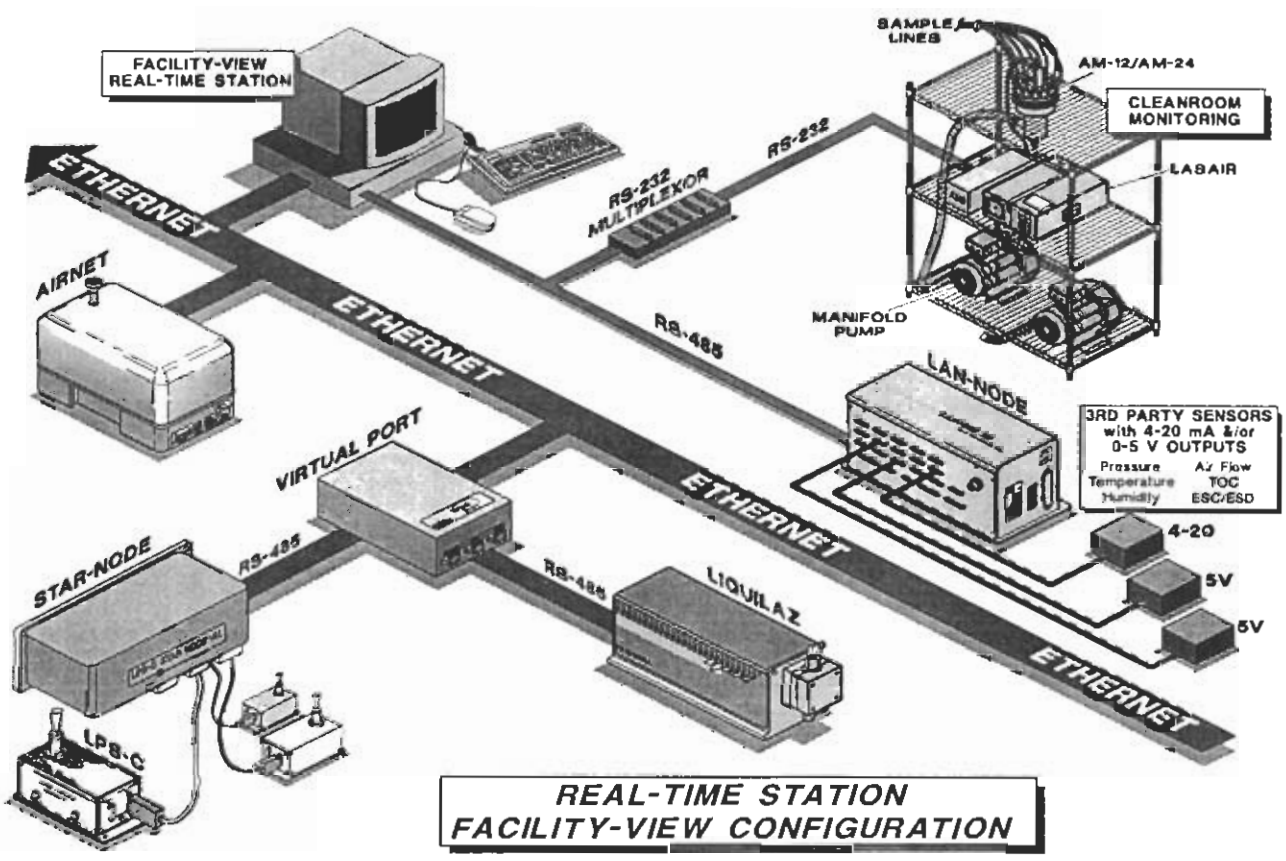
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Chapter 5
Installation and Setup

The following sections describe in detail the installation and setup of the AirNet. In general these steps consist of:

- Initializing the unit via RS-232 and a terminal program
- Selecting a location
- Connecting the power cable
- Connecting the Ethernet data cable
- Connecting the 4-20mA data cable (if desired)
- Starting Facility-View
- Configuring the unit through Facility-View

The procedures that follow are designed to help you make sound decisions about installation. Some of the items are merely guidelines — good general practices. Other items include specific details and should be followed exactly. If you have questions about these items, contact your PMS representative.



REAL-TIME STATION
FACILITY-VIEW CONFIGURATION

Overview of System Architecture showing the AirNet

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Initializing the Unit

NOTE: **It is not necessary to complete this procedure prior to mounting the unit *if it will be practical to connect a computer to the RS-232 port of the AirNet after it is installed.* If access to the AirNet is limited to the point that getting a computer to the unit for initialization is difficult or impossible, the unit should be initialized before installation.**

CAUTION: **As with *any* network-capable software, do not attempt to connect the AirNet to a network without your network administrator's cognizance and explicit permission.**

Before the AirNet can be used it must be initialized to work with your Ethernet network. Because of this it is critical that you coordinate the initialization with your network administrator. He or she will need to approve (and in most cases will issue) hardware addresses.

The steps involved in initialization are:

- Connect the unit to a computer with terminal emulation software.
- Configure the terminal emulation software (described in the paragraph "Communicating with the AirNet" below)
- Set the IP address
- Set the multicast address
- Set the mask address
- Set the gateway address

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Connecting the RS-232 Data Cable

The RS-232 data cable is used to initialize the unit with a computer and terminal emulation software. This is usually a one-time operation. A suitable cable is provided by PMS.

Communicating with the AirNet

To communicate with the AirNet, connect a computer with a terminal emulation program to the RS-232 port. Set the program up for the following:

Baud Rate	9600
Data Bits	8
Parity	N
Stop Bits	1
Flow Control	Off
Parity Check	Off
Carrier Detect	Off
Connector	Appropriate to hardware (COM1, for example)

NOTE: **Windows includes a terminal emulator called *Terminal (Hyperterminal* in Windows95.) Other terminal emulators are widely available. Your IT administrator or microcomputer support person may be able to provide assistance.**

When you establish communications with the unit a prompt will appear. The following commands may be entered at the prompt:

?	Displays a command summary (a summary of the information in this table).
Status	Displays the current firmware version number, MAC address, IP address, Multicast address, Net mask, gateway, and connection status.
set ip *aaa.bbb.ccc.ddd*	Sets the IP address in decimal notation. The IP address is in the form *aaa.bbb.ccc.ddd* with each three character series *aaa* representing a value from 0-255 separated by period characters (.) This address is unique to the hardware it serves. For example, 192.100.100.043 would be a valid IP address.
set mask *aaa.bbb.ccc.ddd*	Sets the network mask in decimal notation. The network mask is in the form *aaa.bbb.ccc.ddd* with each three character series *aaa* representing a value from 0-255 separated by period characters (.) This address is unique to the hardware it serves. For example, 255.255.000.000 is a typical IP address.
set multicast *aaa.bbb.ccc.ddd*	Sets multicast address in decimal notation. The multicast address is in the form *aaa.bbb.ccc.ddd* with each three character series *aaa* representing a value from 0-255 separated by period characters (.) This address is unique to the hardware it serves. For example, 224.100.100.001 would be a valid multicast address.

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set gateway *aaa.bbb.ccc.ddd*	Sets the gateway address in decimal notation. The gateway address is in the form *aaa.bbb.ccc.ddd* with each three character series *aaa* representing a value from 0-255 separated by period characters (.) This address is unique to the hardware it serves. Use gateway 000.000.000.000 if no gateway is available.
write	Saves the most recent changes. You must send this command when you are finished setting up the instrument .

Typing *status* results in the following output:

>status

```
AirNet
Version:            1.1
MAC Address:        00:60:A6:FF:00:03
IP Address:         192.100.100.043
Multicast Address:  224.100.100.001
Net Mask:           255.255.000.000
Gateway:            000.000.000.000
Connected to:       Not Connected
```

If typing *status* or *?* (and then pressing the **enter** key) does not produce any kind of activity on your display screen, you may have the terminal emulator set up incorrectly or your cable may be improperly connected or faulty.

NOTE: **When you have programmed the unit, record these settings for future reference.**

TCP/IP Settings for AirNet Unit Serial Number _____

Date			
Software Version			
Set By			
MAC Address			
IP Address			
Multicast Address			
Net Mask Address			
Gateway Address			

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Selecting a Location

There are several considerations in choosing a location for the AirNet that, examined carefully, will greatly improve the overall utility of the unit. Consider the following when choosing a location for the AirNet.

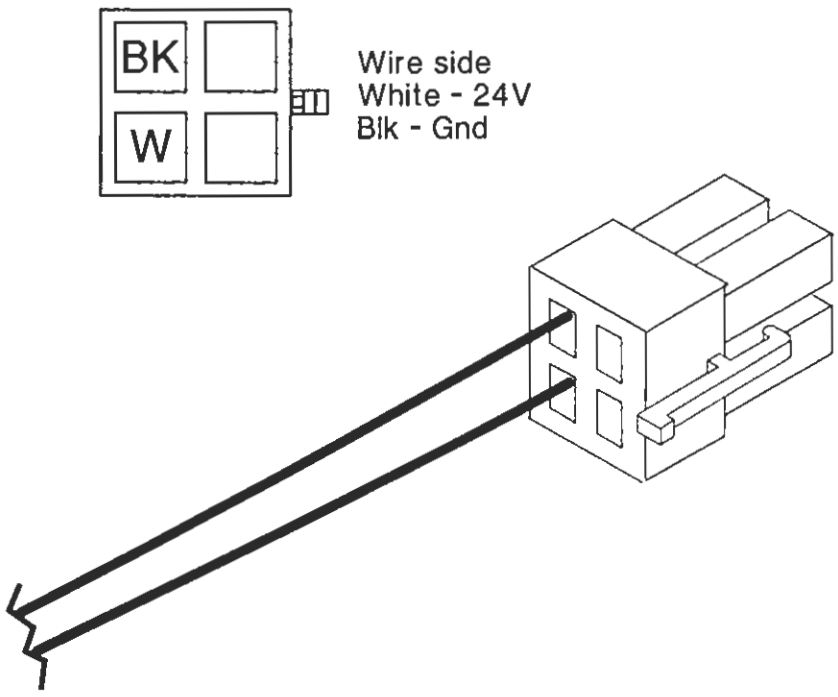
Accessibility	The unit should be readily accessible for connecting and disconnecting cables, etc.
Interference with existing equipment	The unit should not interfere with access to existing or known future equipment installations.
Visibility	The front panel of the unit should be visible from a reasonable position.
Mounting Surfaces	The proposed mounting surface should allow mounting hardware to engage properly and should be of sufficient strength to support the unit safely.
Plumbing	The unit should be located near appropriate sources of vacuum and purge gas (if necessary).
Cables	The unit should be located near a source of grounded electrical power, an Ethernet port, and any other devices it must communicate with. Cables should reach from the unit to the connector without strain.
Environmental Conditions	The unit should be located in an environment consistent with its temperature, humidity, altitude, and other relevant specifications.
Electromagnetic Interference	The unit should be located away from strong electromagnetic fields.

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Connecting The Power Cable

The AirNet requires a source of 24VDC 300mA electrical power.

The connector is a four-lead Molex 3901-2040 MiniFit 4-pin right-angle type, available as PMS part # CO533.

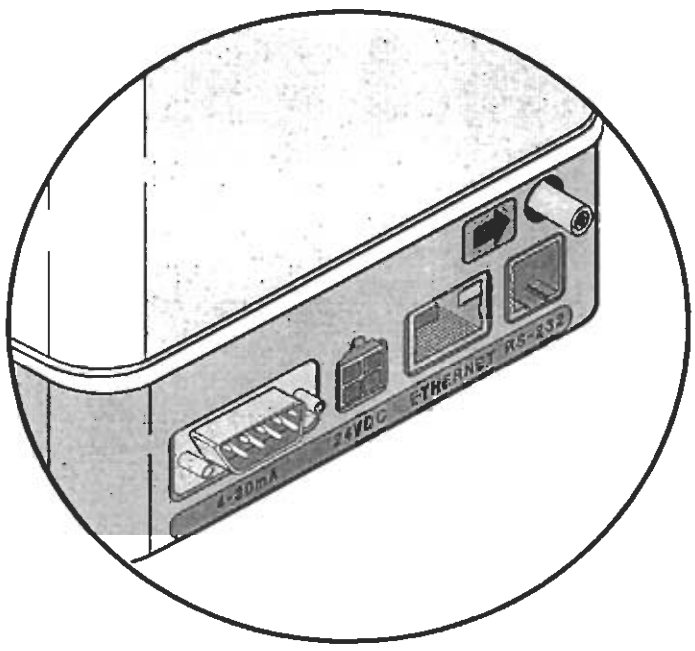


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Connecting The Plumbing

The AirNet requires the following plumbing connections:

Sample inlet	This does not require a plumbing connection, but the inlet should be correctly positioned to take accurate samples.
House vacuum source	A barbed fitting (1/8" ID on the 201, ¼" ID on the 310 and 510) on the back of the unit is provided for connection to a house vacuum source. The vacuum source should be >15 in. Hg.



Connecting the Ethernet Data Cable

The AirNet communicates with Facility-View via standard UTP Ethernet cable. Your Information Systems manager, Network Administrator, or other appropriate computer support personnel may be able to assist you in procuring a cable or fabricating a custom-length cable.

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Chapter 6
Facility-View Operations

If you are familiar with the Facility-View family of software install the AirNet driver and proceed to the next section to configure the AirNet. If you are not familiar with Facility-View, or if you need to install Facility-View, refer to the *Facility-View User's Guide To Operation* for detailed instructions.

Installing the AirNet Driver

There are two files provided for the AirNet:

PDRVLPEN.DLL	Driver file (data link library) for the AirNet (and other Ethernet-compatible PMS instruments.) You must install this file to use the AirNet.
PDRVLPEN.HLP	Help file for the driver. Installation of this file is optional, but recommended.

Insert the driver diskette into your disk drive and copy these files to your \FACILITY directory using your file management program (Windows File Manager, or the DOS *copy* command.)

NOTE: **If you install the driver while Facility-View is running, you will not be able to configure the AirNet (i.e. it will not be listed as a device under the *Configure/Instruments* option) until you re-start Facility-View. This is because drivers are loaded only during Facility-View's startup routine.**

Configuring the Unit through Facility-View

Once the driver files are copied into the \FACILITY directory and Facility-View has been started, the AirNet is configured like any other hardware item.

NOTE: **The AirNet requires that the appropriate TCP/IP address, multicast address, net mask, and gateway values be set into the device via it's serial port.**

NOTE: **The AirNet status light will continue to indicate flow and laser status errors when the device is not communicating with a host computer.**

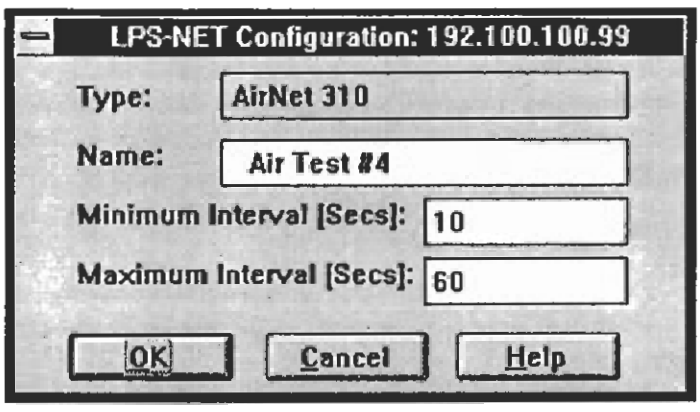
To access the configuration dialog box for the AirNet, select **Instruments** from the **Configure** menu and choose "AirNet" from the list of available items shown on the "Add Network" tab. If you do not know the address of an instrument, use the "Poll Multicast" button to detect available AirNet sensors.

Configuration Dialog

The AirNet Configuration Dialog allows the user to add any or all of the desired functionality associated with this device onto the Host Computer.

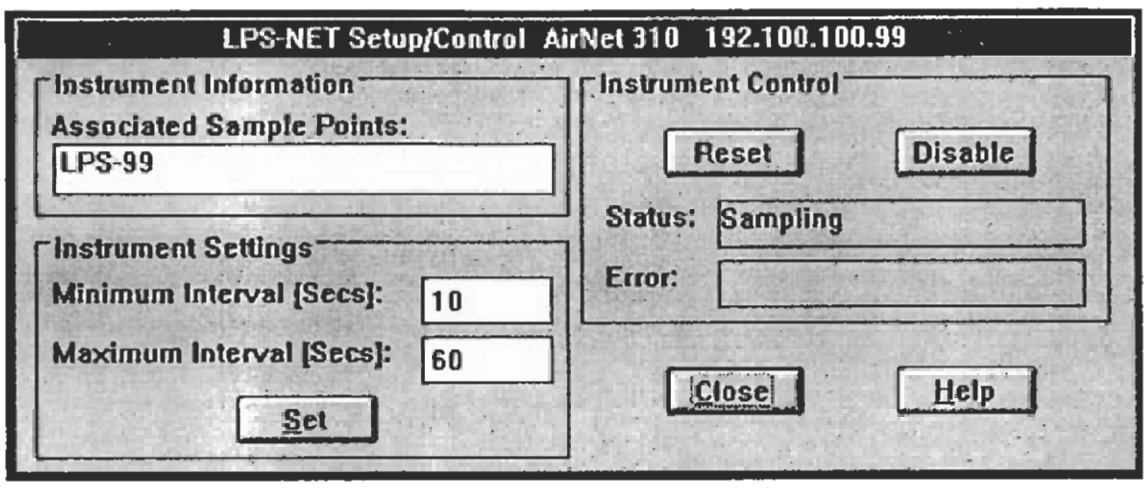
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Each AirNet instrument has a sensor type associated, which is displayed in the "Type" field (non-editable) The type will define the flow rate, number of channels, and channel sizes that are downloaded from the sensor.



Type	This field displays the type of sensor currently connected. It is not user-editable.
Name	Enter a name for the sample point here. The name must be unique to the system. Facility-View will notify you if a chosen name is already in use.
Minimum Interval	Defines the time in seconds that the AirNet will process an individual sample. If the maximum sample interval is the same as the minimum sample interval, all samples will be processed as reported by the instrument. The volume sampled over time depends on the flow rate. AirNet uses this interval when particles are being counted. When no particles are counted, the Maximum Interval is used. This allows for reduced data storage space.
Maximum Interval	If the maximum sample interval is greater than the minimum sample interval, zero count reports from individual sensors will be accumulated (in time) up to the maximum interval. *The maximum sample interval is always a multiple of the minimum sample interval.* The volume sampled over time depends on the flow rate. This sample interval is used by the AirNet when zero particles are being counted, to reduce data storage space requirements.
TCP/IP Address	The AirNet instrument requires that the appropriate TCP/IP address, Multicast address, Net Mask, and Gateway values be set into the device via it's serial port.
Indicator Lights	The AirNet instrument has two lights. One light indicates particle activity. The other light indicates sensor status. The status light is run from the Facility-View alarm function, or if Facility-View is not present will show status messages from the AirNet.
OK	Clicking on OK accepts the changes to the settings and closes the dialog box.
Cancel	Clicking Cancel ignores the changes to the settings (if any) and closes the dialog box.
Help	Clicking Help invokes context-sensitive help.

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Run-Time Settings

The Run-Time Settings Dialog allows you to change selected instrument parameters without re-configuring the system. Limited instrument control and status/error information is also available.

Associated Sample Points	Names of sample points associated with the device selected. This field cannot be edited—it is for information only.
Set	Allows the user to process any changes made to instrument setup. If any changes to the setup are detected, all of the instrument controls except Enable/Disable button are grayed out. The Set button can then be used to process changes and re-enable instrument controls.
Reset	Resets the instrument.
Enable/Disable	Allows the user to enable or disable the instrument. It also, obliquely, indicates the current operating status of the instrument. If the instrument is disabled, all other controls are grayed out.
Status	Shows the current operational status of the instrument
Error	Shows the last detected error message from the instrument.

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Chapter 7
4-20 mA operation

The AirNet can communicate data about particle counts and operational status by generating three 4-20mA signals—one for particle size channel 1, one for particle size channel 4, and one for operational status.

This signal is provided through a 9-pin D-type connector located on the rear panel of the instrument.

To use the 4-20 mA option:

1. Build a cable that will allow you to connect the AirNet to your data collection system's 4-20 mA input.

   Connection to the 4-20 mA output option on the AirNet is made using a standard DE-9S "D" type connector. This connector mates with a DE-9P connector located on the rear of the AirNet. The following pins are used on the connector.

Pin	*Function*
1	Current output for channel 1*
2	Ground
3	Current output for channel 4*
4	Ground
5	Status
6	Ground
7	Ground

Each of the channels is capable of driving a grounded load of 400 ohms or less. All ground are common and are common to the internal analog ground of the AirNet.

*Channel thresholds are as follows:

Channel	AirNet 201	AirNet 310	AirNet 510
1	*0.2μ*	*0.3μ*	*0.5μ*
4	*1.0μ*	*5.0μ*	*5.0μ*

2. Set up your AirNet's 4-20 mA parameters using the RS-232 port and a terminal program. Refer to the list of 4-20 mA commands in the following chapter. Remember to enter the **write** command when you have entered all the 4-20 mA parameters.

3. Set up your data collection system to correctly interpret the AirNet's 4-20 mA data.

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Factory Preset Status Levels

Current	Flow Status	Laser Status
8mA	*OK*	*OK*
12mA	*OK*	*Bad*
16mA	*Bad*	*OK*
20mA	*Bad*	*Bad*

Ethernet Cable Pin Out

Pin 1 TD+
Pin 2 TD-
Pin 3 RD+
Pin 4
Pin 5
Pin 6 RD-
Pin 7
Pin 8 GND

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Chapter 8
Communicating with the AirNet for Setup

CAUTION: **As with *any* network-capable software, do not attempt to connect the AirNet to a network without your network administrator's cognizance and explicit permission.**

Before the AirNet can be used it must be initialized to work with your Ethernet network. Because of this it is critical that you coordinate the initialization with your network administrator. He or she will need to approve (and in most cases will issue) hardware addresses.

The steps involved in initialization are:

- Connect the unit to a computer with terminal emulation software.
- Configure the terminal emulation software (described in the paragraph "Communicating with the AirNet" below)
- Set the 4-20mA parameters

Connecting the RS-232 Data Cable

The RS-232 data cable is used to initialize the unit with a computer and terminal emulation software. This is usually a one-time operation.

A suitable cable is (PMS-CD1995) provided by PMS. The wiring for this cable is as follows:

RS-232 Pin Out (RJ-11 jack on AirNet)

Pin 1	DSR
Pin 2	Transmit →
Pin 3	Receive ←
Pin 4	RTS
Pin 5	CTS
Pin 6	GND

NOTE: **Pins 1, 4 and Pin 5 are shorted together.**

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To communicate with the AirNet, connect a computer with a terminal emulation program to the RS-232 port. Set the program up for the following:

Baud Rate	9600
Data Bits	8
Parity	N
Stop Bits	1
Flow Control	Off
Parity Check	Off
Carrier Detect	Off
Connector	Appropriate to hardware (COM1, for example)

NOTE: **Windows includes a terminal emulator called *Terminal (Hyperterminal* in Windows95). Other terminal emulators are widely available. Your IT administrator or microcomputer support person may be able to provide assistance.**

When you establish communications with the unit a prompt will appear. The 4-20mA option adds five new commands that setup the format of the data transmitted by the current output channels. These commands are:

?	Displays a command summary (a summary of the information in this table).
status	Displays the current firmware version number, MAX address, IP address, Multicast address, Net mask, gateway, and connection status. It will also display current 4-20mA parameters, if set.
set samp *x y*	This function sets the minimum sample interval to *x* seconds and the maximum sample interval (used when zero particles are detected) to *y* seconds. This value is used by the instrument when it first turns on and is used until the value is changed by the Ethernet interface. The value set by this function is stored in permanent memory whereas the value set by the Ethernet interface is lost when the power to the AirNet is removed.
set cumul *n*	This function selects between cumulative and differential data for the 4-20 mA channels. If *n* is equal to 1 then the data for each channel represents the number of particles detected that are larger than the sized specified for the channel. If *n* is equal to 0 then the data in each channel represents the particles detected between the size specified for the channel and the size specified for the next channel.
set eos *n*	If *n* is set to 1 then the data in each channel is updated only at the end of each sample interval and is held constant for the duration of the subsequent sample interval. If *n* is equal to 0 then the 4-20 mA channels are updated approximately every 20 milliseconds.
set raw *n*	If *n* is 1 then the data in each channel is simply the number of particles detected. If *n* is 0 then the data is divided by the volume sampled in which the particles were detected expressed in cubic-feet.
set scale *n*	This value defines the scaling of the 4-20 mA channels. This is the value that corresponds to 20 mA at the output. The lower end of the range is always defined so that 4 mA corresponds to zero particles. The units of this value are defined by the settings entered by the "cumul" and the "raw" commands.
write	Saves changes. You must send this command at the end of the setup to make your changes effective.

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Chapter 9
Troubleshooting

Problem	Symptoms	Possible Cause	Try...
No power	No lights No communications	Power cable not connected at one or both ends	Check the seating of the power cable in the unit. Verify that the power cable is plugged in.
		Electrical power source fault	Check the electrical outlet for power, including any power strips or surge protectors.
		Power cable faulty	Try a different power cable.
Communications not established	Unable to view data from working sensor .	Unit not initialized correctly	Re-initialize the unit
		Ethernet cable problem	Replace the Ethernet cable
		Computer hardware or software problem	Substitute a computer with known good Ethernet capability. Refer to your computer/Ethernet card documentation to correct the fault.

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Chapter 10
Maintenance

The AirNet is housed in a sturdy Kydex™ housing and should provide many years of trouble-free performance. Periodically it may be helpful to wipe the case with a clean, lint-free cloth moistened with deionized water or a mild cleanser.

Connectors — Occasionally a connector may be damaged through an accident (such as someone stepping on a connector cable.) The RS-232 and UTP Ethernet connections are somewhat more fragile than the D-type connectors. If a connector is damaged, be careful not to aggravate the problem by forcing a cable into a damaged connector. Your PMS Service Representative can repair or replace damaged connectors.

Ethernet Cable

Pin 1	TD+
Pin 2	TD-
Pin 3	RD+
Pin 4	
Pin 5	
Pin 6	RD-
Pin 7	
Pin 8	

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Chapter 11
TCP/IP Protocol: A Brief Overview

NOTE: **This information is provided to help AirNet users who are not familiar with TCP/IP protocol understand more about the AirNet initialization process. It is not a substitute for the guidance of your network administrator.**

On small networks (such as that used for a workgroup in a small office) a simple, fast protocol like NetBEUI can be completely reliable. However, when multiple networks are connected together it becomes necessary to use routers or bridges to send communication packets from one network to another. If there are so many routers that it is physically possible for message packets to take different routes between two computers, the protocol must be able to handle the possibility of packets showing up out-of-order. A more complex protocol such as TCP/IP becomes necessary when multiple networks are interconnected to form an "internet".

TCP/IP is an "open system", and as such is in the public domain and is not proprietary to any one vendor. Its early versions were invented by researchers working for the US. Department of Defense Advanced Research Projects Agency (ARPA) and were the protocol used for the ARPANET—the government/university precursor of today's global Internet.

The protocol is governed by the Internet Activities Board's Engineering Task Force. Documents knows as *Request for Comments* (RFCs) include definitions for the processing functions of the TCP/IP protocol. Anyone wishing to design a network system to use TCP/IP is free to do so, and will be able to learn everything necessary from the RFCs. RFCs are available from the Network Information Center (or *NIC*), 14200 Park Meadow Drive, Suite 200, Chantilly VA 22021, phone (703) 802-4535.

Note that TCP/IP does not require connection to the global Internet to function. A network of only two computers, or a small company's internet connecting several buildings with routers could also use it. However, if the company's network is connected to the global Internet, the company must contact the NIC for Internet Protocol (IP) address assignments.
TCP/IP's Network Layer

TCP/IP's **Internet Protocol** or IP is designed to interconnect packet-switched communication networks to form an internet. (Note: internet with a lower-case "I" means any two or more networks, for example: in a small company with two buildings. Internet (with a capital I) means the global Internet that was an outgrowth of the ARPANET).

IP transmits blocks of data called *datagrams*. It provides a "best effort" or "connectionless" delivery service between the source and destination. It is said to be "connectionless" as the source does *not* establish a session with the destination before transmission. This layer is also responsible for the protocol addressing.

In summary, the IP protocol's main functions are:

- provide the basic unit for data transfer
- addressing
- routing
- fragmentation of datagrams

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Internet Control Message Protocol, or ICMP, is not part of the IP layer; rather it works with the IP layer so that routers can report certain error or test conditions on the network. The *PING* utility (explained later) uses ICMP.

Address Resolution Protocol or ARP is not truly part of the network layer, as it resides in-between the IP and datalink layers. It translates between the 32-bit IP address and a 48-bit physical LAN address.

TCP/IP's Transport Layer

Transmission Control Protocol (TCP). Whereas IP is a connectionless delivery service; *TCP* provides network access to application programs with a reliable connection-oriented transport layer service. TCP establishes sessions between applications, and ensures reliable communications between two or more processes.

TCP:

- monitors incoming session establishment requests
- requests session from other network stations
- sends and receives data reliably
- closes sessions

User Datagram Protocol (UDP) provides an unreliable connectionless transport-layer service to application programs. It allows the transfer of data between source and destination stations without having to establish a session before data is transferred. UDP does not use the end-to-end error checking used by TCP. So, UDP is a low-overhead, faster protocol; it is used for applications that do not require the robustness of TCP. E-mail, broadcast messages, naming service, and network management functions are examples of common uses of UDP.
IP Structure

A discussion of the complete structural design of an IP packet goes beyond the scope of this manual. This discussion will be confined to those aspects that might be most useful in system operation and troubleshooting efforts.

A portion of an IP packet is the 32-bit-long IP address. The address is separated into four fields of one byte each, and are typically expressed using *dotted decimal notation*, like this:

192.100.100.5

The first bits indicate the "network number"; the later bits indicate the "host number" (the division between network and host bits will be explained later). The bytes are sometimes called *octets* when they are expressed in decimal.

If the network is to be connected to the global Internet, the network portion of the IP address will be assigned by the Network Information Center (NIC) mentioned earlier. If the TCP/IP network does not have an Internet connection the system's LAN administrator can assign any numbers (within the limits imposed by TCP/IP: 0 to 255, with some values reserved). Individual hosts' IP address values are never assigned by the NIC, they are assigned by the system LAN administrator.

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IP Address Classes

The NIC assigns five different Internet IP address classes: A, B, and C are used to represent host and network addresses. Class D is a special type of address used for multicasting. Class E is reserved.

Although IP addresses are usually shown in dotted decimal notation, sometimes they are written in hexadecimal (in the field, it might be handy to have access to a calculator that can convert from hex to decimal—note that the "calculator" in *Microsoft Windows* can do this). Converting the IP address to binary and examining the first bits can help you determine the IP address class:

Class A IP Address: 0xxxxxxx.xxxxxxxx.xxxxxxxx.xxxxxxxx
Class B IP Address: 10xxxxxx.xxxxxxxx.xxxxxxxx.xxxxxxxx
Class C IP Address: 110xxxxx.xxxxxxxx.xxxxxxxx.xxxxxxxx
Class D IP Address: 111xxxxx.xxxxxxxx.xxxxxxxx.xxxxxxxx
Class E IP Address: 1111xxxx.xxxxxxxx.xxxxxxxx.xxxxxxxx

In Class A addresses the first byte represents the network number and the last three bytes identify the host number. Since the first bit of a Class A address must be a 0, only 127 Class A network addresses are available—worldwide. Actually, only 126 are available as 127.xxx.xxx.xxx is reserved for loop-back functions, and cannot be assigned to a network. This leaves the last three bytes available to represent host numbers: 256^3 (16,777,216) individual hosts on each of the 126 Class A networks. Note that the NIC almost never assigns a Class A license. Loop-back functions may be used by multiple applications running on the same host that use TCP to communicate with each other. Packets with the loop-back address will be discarded by a router.

Class B addresses use the first two IP address bytes for the network number, and the last two for the host number. This allows a potential of 16,384 network numbers (10000000.00000000.xxx.xxx through 10111111.11111111.xxx.xxx) with each Class B network having as many as 65,536 hosts (256^2). Class B licenses are popular with universities and corporations.

Class C addresses use the first three bytes to identify the network, and the last byte to identify the host. Since the first three bits in the first byte are 110xxxxx, the allowable range of the first byte for a Class C address is 192 to 223. This scheme allows about 2 million Class C networks, each with 254 hosts. Class C addresses are the type most commonly assigned by the NIC—however if you (or your organization) can justify a need for a Class B license, one will be assigned to you.

In sum:
Class A addresses range from (1-126).<host>.<host>.<host>
Class B addresses range from (128-191).(1-255).<host>.<host>
Class C addresses range from (192-223).(1-255).(1-255).<host>

Note: IP addresses written with zeros in the host fields are used to express a network. For example 112.0.0.0 would indicate a Class A network. 192.100.100.0 indicates a Class C network.
Broadcast Message Addressing

If each bit of the IP address is a 1 (if the bytes equal 255 in decimal) the packet is defined as a *limited broadcast*. This is a message that is received by all network stations on the local network. Limited broadcasts are used by routers to update other routers' network numbers and hop-counts; limited broadcasts are not forwarded by routers.

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A *directed broadcast* is used to send information to all hosts on a particular network. Packets with IP address 192.100.255.255 will be forwarded by routers (if routers are used) to *all* hosts on network 192.100.0.0

A packet with zeros in the network portion of the IP address such as 0.0.112.5 is an indication that the packet is intended for host 112.5 on "this" network (whatever is the network number of the host originating the message).

Multicast (Class D) Messages

Multicasting is used to send identical packets to groups of hosts. Routers update their neighboring routers using these messages; PMS *Facility View* uses multicasting to send several types of messages and data. For example, *Facility View* Real Time Stations transmit sample point data to *Facility View* Network Stations using multicasting. Multicasting is more efficient than broadcasting, as multicast packets are passed by the transport layer software only if the packet is needed by that particular host. However, all broadcast packets are passed to upper-layer software.

Subnet Masking

When the NIC assigns an IP network license number to a site, it may be awkward to use all the host numbers in one network. For example, if a company has a Class B license there could be 65534 hosts on one network—a potential management and troubleshooting problem. A scheme known as *subnet masking* can be used to reassign some of the host bits to the network bit function, allowing more logical networks under the one Class B network number.

A typical network management choice would be to segment a single Class B network into 256 subnets, each with 256 hosts (minus the reserved network and host address numbers). However, the quantity of host bits that can be reassigned as subnet bits is variable—so the network administrator could decide to divide the Class B network into more than 256 subnets (each with less than 256 potential hosts) or less than 256 subnets (each with more than 256 potential hosts).

NOTE: ***All devices on the same subnetwork must have the same subnet mask number, or they will not actually be on the same network (and may not be able to communicate with each other, depending on how the software and routers work at the facility).***

Default Subnet Masks

TCP/IP networks use subnet masks even if the network is not subnetted. In that case, standard default mask numbers are used. Some software automatically enters the correct default subnet mask when you enter the IP address (although you have to alter the mask if your facility doesn't use the default number).

Class A	255.	0.	0.	0.
(binary)	(11111111)	(00000000)	(00000000)	(00000000)

Class B	255.	255.	0.	0.
(binary)	(11111111)	(11111111)	(00000000)	(00000000)

Class C	255.	255.	255.	0.
(binary)	(11111111)	(11111111)	(11111111)	(00000000)

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Like an IP address, a subnet mask is 32 bits (4 bytes) long. The subnet mask is used in an Boolean *AND* operation to define which IP address bits are "borrowed" from the host section to be used as subnet bits. In the following example, network 192.9.202.0 will be split into two subnets, one with hosts 0-127, the other with hosts 128-255. The subnet mask 255.255.255.128 is used; in the example the decimal values are converted to binary so as to show each bit:

IP Address 192.9.202.15	11000000	00001001	11001010	00001111
Subnet Mask 255.255.255.128	11111111	11111111	11111111	10000000
AND Result	11000000	00001001	11001010	00000000

The AND function preserves the value of the IP address bit *only if* the mask bit value is a 1. In the example shown above, the most-significant bit of the fourth byte has been borrowed from the host numbers and lent to the network numbers. In the following example, a host number higher than 128 is used, so the subnet mask passes that bit along in the AND result:

IP Address 192.9.202.130	11000000	00001001	11001010	10000010
Subnet Mask 255.255.255.128	11111111	11111111	11111111	10000000
AND Result	11000000	00001001	11001010	10000000

Ports and Sockets

Sometimes there will be many TCP/IP applications (programs) running on one host (computer) at the same time. To avoid having to assign an IP address to each application, a scheme exists wherein each application on a particular host will have an assigned *port number*. There are some port numbers that are predefined ("static") for internal TCP/IP functions. "Dynamic" port numbers (of which there are about 65000) can be assigned by application writers.

The whole combination of IP number (network and host numbers) and port number is called a *socket* and must not be duplicated on any TCP/IP network.

[Adapted from the **PMS SERIAL COMMUNICATIONS & NETWORKING MANUAL** Revised 18 July 1996. ©1995, 1996 Particle Measuring Systems, Inc.]

Ping

TCP/IP systems can use a utility named *PING* (Packet InterNet Groper) to test station and network integrity. The TCP/IP-32 add-on protocol for *Microsoft Windows for Workgroups 3.11* includes a *PING* function that must be run from a *Windows* DOS window.

To use the *Windows for Workgroups* TCP/IP PING:

With Windows running, open a DOS window by double-clicking on the MS-DOS Prompt icon. At the DOS prompt, type **PING <IP ADDRESS>** (using the address of the device for which you wish to test your computer's LAN communications).

The *PING* utility will report whether or not the other device responded, and what the response time was.

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