

Q-SWEAT™

QUANTITATIVE SWEAT MEASUREMENT SYSTEM, MODEL 1.0



HARDWARE USER'S GUIDE, VERSION 1.3

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Comments or Questions?

We would appreciate receiving any suggestions, comments, or questions that would help us to improve this manual. Please forward comments to the address above.

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INDICATIONS AND CONTRAINDICATIONS

Indications:

- The Q-Sweat™ Quantitative Sweat Measurement System is designed to measure the sweat output of the skin of humans. This device does not make a diagnosis or indicate by itself that any disease state exists; it simply documents sweat output.

Contraindications:

- Do not conduct the Q-Sweat™ test on fragile skin.

WARNINGS AND CAUTIONS

Cautions:

- This device is restricted to sale by or on the order of a physician.
- This device is to be serviced only by WR Medical Electronics Co. If servicing is done by any party other than WR Medical Electronics Co., the product warranty and/or safety or quality certifications could be invalid. Contact the factory for repair advice before attempting to repair.

Warnings:

- None. See Contraindications.

NOTES TO PARTICIPANTS IN CLINICAL TRIALS

- If you have any questions about the specific testing techniques and procedures that are required for using the WR TESTWORKS™ software and/or devices in a specific clinical trial, please contact the sponsor of your study.
- If it appears that any part of the WR TESTWORKS™ software and/or devices need servicing or repair, first notify the sponsor of your study. The sponsor will determine whether and how to contact WR Medical Electronics Co. for service and repair advice and instructions.

SYSTEM INFORMATION

1. System Classification (IEC601-1/EN60601-1)

- Type of protection against electric shock: Type BF
- Degree of protection against electric shock: Class I
- Degree of protection against moisture ingress (IEC529): Ordinary IPX0
- Degree of protection in the presence of a flammable anesthetic mixture with air or with oxygen or with nitrous oxide: Not protected (unsuitable)
- Mode of operation: Continuous
- Sterilization/disinfections: Not suitable

2. System Configuration

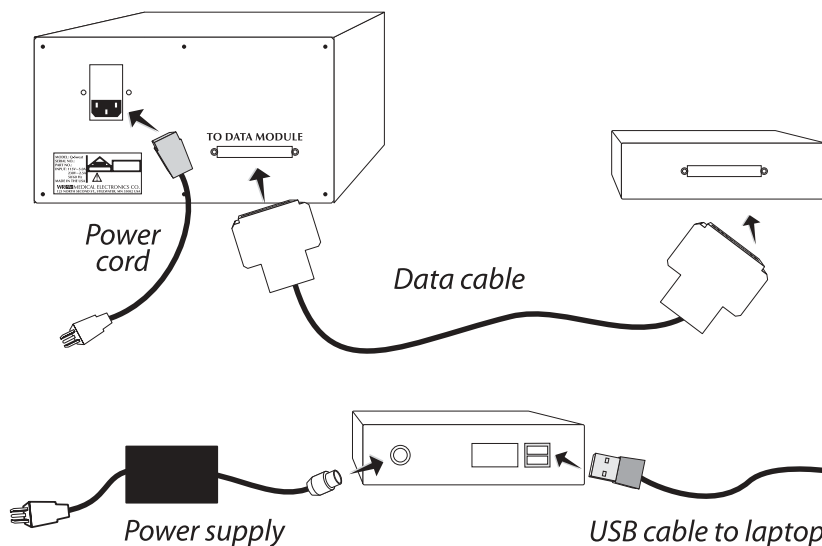
- See drawings showing equipment connections to mains voltage.

3. System Supply Mains Rating

- Supply Voltage: 100 to 240 VAC
- Supply Power: 40VA
- Supply Frequency: 50/60Hz
- Protection F 800mAL 250V (two 5x20mm IEC127)

4. Environmental Ratings

- Operating
 - Temperature: 20°C to 25.5°C
 - Relative Humidity: 0% to 70%
 - Atmospheric Pressure: 700 hPa to 1060 hPa
- Transport and Storage
 - Temperature: -10°C to 50°C
 - Relative Humidity: 0% to 90% (non-condensing)
 - Atmospheric Pressure: 500 hPa to 1060 hPa



Equipment Connections

TOP: Q-Sweat™ to DAQPad.
BOTTOM: DAQPad to laptop (not shown).

After exposure to transport and storage extremes, allow the system to acclimatize before operating. The system should not be subject to transport and storage extremes for longer than 15 weeks.

5. Preventive Maintenance Cleaning

- For preventive maintenance and servicing the user should:
 - Clean the equipment after each use and before storing. Surfaces should be cleaned using a dry cloth. Alternatively for stubborn stains, a lightly dampened cloth and a mild detergent may be used. Never wet surfaces and always ensure surfaces are dry before storing.
 - To disinfect the Q-Sweat sensor use a cloth lightly dampened with a mild solution of 5% sodium hypochlorite. Never wet surfaces and always ensure surfaces are dry before coupling to patient or storing.
 - Never immerse in water.
 - Do not sterilize.

6. Responsibility of the Supplier

- a. WR Medical Electronics Co. accepts responsibility for the effects of safety, reliability, and performance of the equipment only if:
 - i. Assembly operations, extensions, readjustments, modifications, or repairs are carried out by persons authorized by WR Medical Electronics Co.
 - ii. The electrical installation of the room complies with local regulations.
 - iii. The equipment is used in accordance with the system manual.

7. Electromagnetic Compatibility

- a. The system has been independently tested and found to comply with IEC601-1-2/EN60601-1-2.

8. Safety and Information Symbols

Symbols that appear on the equipment have the following meaning:



Attention, consult accompanying documents



Type BF Applied Part – F Type patient contact part isolated from other parts of the equipment such that patient leakage currents cannot exceed allowed limits in NORMAL and SINGLE FAULT CONDITION



On – Power connection to supply mains



Off – Power disconnection for supply mains



Replace fuselinks as marked



9. Environmental Protection

- a. Main Unit and Consumables
 - i. At the end of service consult local regulations for disposal.

10. Technical Description

- a. WR Medical Electronics Co. will make available on request circuit diagrams, component part lists, descriptions, calibration instructions, or other information which will assist an appropriately qualified technical personnel to repair or service the equipment.

DESCRIPTION OF THE SYSTEM AND ITS UNDERLYING METHODOLOGY

BACKGROUND

The Q-Sweat™ Quantitative Sweat Measurement System very accurately measures the amount of moisture emitted from skin. While the device is considered to be a simple TEWL (Trans Epidermal Water Loss) device, and is similar to TEWL devices on the market, the Q-Sweat™ device uses a unique circuit design to make the measurements and calculate the water content.

Dr. Phillip Low of Rochester, Minnesota, has published normal resting sweat values. This information is outside the scope of this document, but can be found in Low, PA. "Laboratory Evaluation of Autonomic Function." *Clinical Autonomic Disorders*, 2nd ed., 1997, Lippincott-Raven Publishers, Philadelphia, Chapter 15, pages 179–208. This information is considered to be in the public domain.

OVERVIEW

In brief, the Q-Sweat™ uses room air that is drawn across a desiccant to pick up any moisture (water) that is found in the sweat emitted from the skin. The moisture given off by the skin is captured inside a capsule, where it is transported by airflow to temperature and humidity measuring sensors. There, an accurate measure of the amount of moisture found within the moving air sample is made.

Components

The Q-Sweat™ device consists of several parts:

- a personal computer (desktop or laptop), meeting the minimum specifications outlined elsewhere in this document;
- application software to read the output signals from the Q-Sweat™ device;
- a controller box, or "main Q-Sweat™ unit";
- skin capsules (set of 4);
- a removable, disposable desiccant pack;
- a parking fixture for each channel.

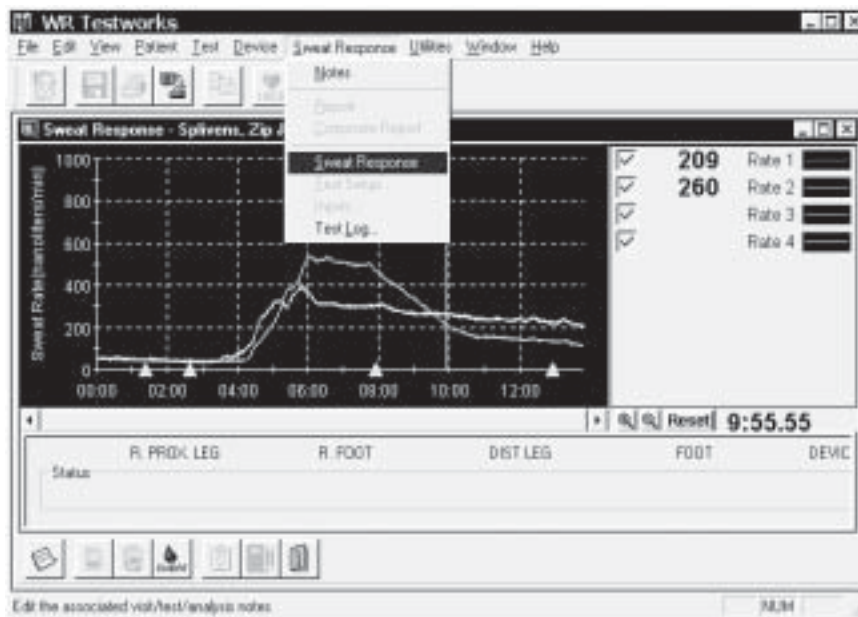
Personal Computer

The personal computer is any kind of commonly found commercial unit that meets the minimum specifications provided in the specifications section of this document. The software running on the personal computer reads the moisture measurement information (air flow, temperature, humidity, and desiccant humidity) provided by the main unit, and then it calculates the sweat rate (in nanoliters per minute) and total sweat volume (in microliters).



Application Software

The application software functions under the Microsoft Windows98® or Windows 2000® operating software and is written by WR Medical Electronics Co. Called WR TESTWORKS™, the software consists of a main framework and application submodules, which interface with medical devices. The Q-Sweat™ submodule consists of the specific code for the Q-Sweat™ device. The Q-Sweat™ device cannot be used without the PC, a Windows operating environment, or without the WR TESTWORKS™ main framework with Q-Sweat™ submodule. The main framework handles the software “housekeeping” activities, such as maintaining the database of patient demographics, visit events, database browser, historical test review, and some report generation functions. The Q-Sweat™ submodule contains the specific routines for data acquisition from the Q-Sweat™ hardware, data display, data logging, and data analysis, and some report generation functions.



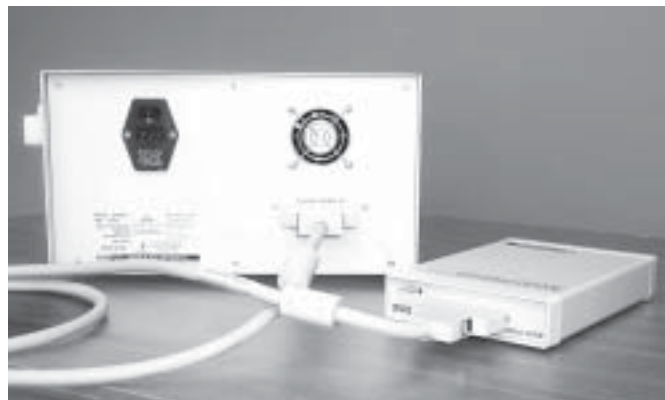
Sweat response test screen in WR TESTWORKS

The WR TESTWORKS™ main framework also has other submodules to acquire digital or analog data from the output connections of FDA-approved devices, such as the Colin Medical Model 9100 or Model 7000 devices, or simple chest expansion bellows or spirometers. Thus, the WR TESTWORKS™ software allows the presentation of both the Q-Sweat™ data and/or data acquired from other FDA-approved devices. For a more detailed description of WR TESTWORKS™, see its *Software User's Guide*.

The software itself does not control the process of airflow of sweat vapor over the measuring sensors. This function is done by the hardware itself. The data that is acquired from a Q-Sweat™ (or other device) is simply presented as a logged data plot on a graph in the same form as originally obtained by the approved device. From this data plot the physician can examine the characteristics of the plot for his own purposes.

Main Unit

The main Q-Sweat™ unit contains an internal power supply, an air pump, an airflow regulator, a voltage-sensitive proportioning orifice valve (VSO), mass air flow sensors, a source-air desiccant pack, output air connections, input air connections, and a data port. This main Q-Sweat™ unit communicates through the dataport to a National Instruments DAQPAD, which then translates the signal into a USB signal that the computer can receive. Future models of the Q-Sweat™ will have the DAQPAD eliminated and the analog to USB translation will take place inside the Q-Sweat™ main unit.



Rear of main unit and DAQPAD

Skin Capsules

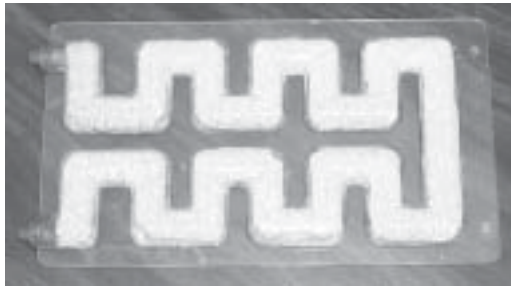
The skin capsules are round plastic devices that are open on the side that faces the skin. This opening creates a chamber in which moisture given off by the skin is captured. The moisture is drawn into the main unit where very accurate temperature and humidity measuring sensors are located, and finally exhausted into the room. Each skin capsule has a Velcro® strap attached to it so that the capsule can be firmly affixed to the skin.

Desiccant Pack

Because the skin capsules contain air that will be pumped into humidity measuring chambers inside the main Q-Sweat™ unit, the sensors will record any moisture that is found in that air sample, whether due to room humidity or water being given off by the skin. Therefore, the initial source of air is drawn across a desiccant pack to regulate the amount of ambient moisture.

Parking Fixture

The parking fixture is provided to keep the skin capsules in a dry atmosphere. The source air is pumped out to the capsules. There is no suction on the return hose. This means that when the capsule is not closed,



there will be no flow. When the capsule is on the parking fixture, there will be a flow of dried air. When the capsule is on skin, there will be a flow of moist air. The parking fixture is useful for drying out the hose/capsule assemblies prior to starting a test on a patient.



Skin capsule affixed to arm

Note:

- The Q-Sweat™ device has a built-in sensor that indicates (in the WR TESTWORKS™ software) when the desiccant pack needs to be replaced. This is accomplished by measuring the level of moisture that is detected on the output side of the desiccant pack.

Accurate readings of temperature and relative humidity are needed to calculate the amount of humidity (moisture) within the capsule. With these values (provided by the sensors), one can calculate the actual moisture according to ideal gas laws. Such calculations are too detailed to describe in this document, but are made by the software within the Q-Sweat™ application based on information provided by the sensors found within the Q-Sweat device. The sensors themselves are quite accurate, facilitating the accuracy of the actual measurement and calculation of rate and volume. Furthermore the device is calibrated to physical standards.



Note:

- The software is configured to record data for only one patient at a time, using one to four channels for that particular patient.

The Q-Sweat™ device has four built-in channels so that four individual moisture samples can be obtained simultaneously from a given patient. The entire process of taking four measurements simultaneously from a given patient can be completed in a very short time.

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HOW TO OPERATE THE Q-SWEAT™ DEVICE

OVERVIEW

Doing a Q-Sweat™ test is most efficiently done by completing steps in a certain order. This is important in order for the technician to be efficient about the time spent processing a patient.

The Q-Sweat™ test does not require the cognitive cooperation of the patient, other than to sit still during the test and to follow the technician's basic instructions (such as "roll up your sleeve," "take off your sock," etc.) For this reason the Q-Sweat™ test is considered to be an objective test, not a subjective one.

The object of testing is to obtain data that is not affected by confounding variables that are foreseeable or controllable by the technician. For example, loud or startling noises, fear of medical equipment, personnel, or institutions, or embarrassing questioning could cause a patient to sweat abnormally, or to sweat too soon before a proper resting baseline is established. Scratching the skin near the site to be tested could also evoke a premature sweat response. The patient must not be abnormally dehydrated. It is important that the patient be tested in his/her natural resting condition. Be cognizant of situations where the patient may have exerted himself/herself on the way to the examining room, such as climbing a long flight of stairs or hurrying to the exam room, which could result in some extra sweating as a result of exertion. In very hot weather make sure the patient has enough time to acclimate to room temperature before testing. In cold weather make sure the patient has warmed up to room temperature before testing. How quickly the patient acclimates to room temperature and the effect of not allowing enough time to acclimate will vary depending on whether the patient is a normal subject or an abnormal subject (either an impaired patient or an abnormally profuse sweater). The operator must be alert to any kinds of confounding variables that they can control (but which cannot be necessarily foreseen or elucidated in this particular document). Under the circumstances of variability described above, it is the user's responsibility to control these factors in order to obtain repeatable serial results.

The Q-Sweat™ test itself does not affect the patient in any significant way (in other words, it is a benign data acquisition test); but see the contraindications, warnings, and cautions provided in this manual.

Operating Parameters

For most accurate measurements, the Q-Sweat™ device should be used in the following conditions and ranges:

- The room in which the test is conducted should be at comfortable room temperatures (70 to 72 degrees F.), with no air vents or ceiling fans blowing on the patient.
- The unit requires a 1.5-hour warm-up prior to use.
- The operating ambient humidity should be less than 90 percent non-condensing.
- Finally, the technician needs to have a basic working knowledge of the how to use the Q-Sweat.™

Note:

- This document is not intended to describe how to use the operating software for the Q-Sweat™ (which is called WR TESTWORKS™). Instructions for how to use the software can be found in the WR TESTWORKS™ *Software User's Guide*.

Procedure

1) Perform a visual equipment check and be sure you have the needed components and supplies. Look for any damage to the complete system. If damage is found, DO NOT use the device.

- *Before using the equipment, make sure that both the source-air desiccant in the desiccant pack is fresh, as indicated by the color blue. If the desiccant is uniformly pink, it needs to be replaced before proceeding. This step is useful if you want to make sure that a desiccant warning does not appear part way through a test.*

2) Turn on the unit 1.5 hours prior to your testing session for most accurate measurements. The measuring sensors inside the unit need to be fully warmed up and at a stable operating temperature in order to meet the specifications provided in this manual. A shorter warm-up time will have the effect of showing more baseline moisture and more moisture during a test. However, this effect is minimized for tests that subtract out the baseline and that look only at the difference between baseline and evoked sweat response.

- *When warming up the machine or otherwise leaving it running (but not actually testing a patient), unplug all the capsule/hose assemblies from the front panel. By doing this the circulation of dry air will be stopped and thus the desiccant pack will not be consumed.*
- *When affixing the hoses to the front panel and running a test, you will notice that the hoses may have absorbed a small amount of moisture. This will result in a higher initial moisture reading. To avoid this and get a more stable baseline measurement, allow the hoses to dry out for a short time before testing.*

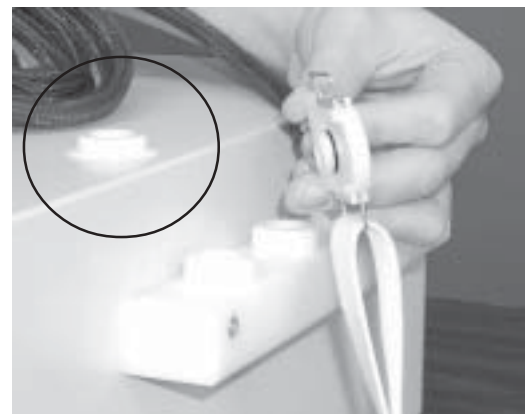
3) Decide how many channels (and thus how many sites on the patient's body) will be used. Any capsules not used should either

- a) be plugged into the Q-Sweat™ unit and also parked on the parking fixture at all times;
- b) or, preferably, be disconnected from the Q-Sweat™ device and not parked on the parking fixtures.

This ensures that the desiccant in the desiccant pack is never being consumed except during the times that you are purposefully attempting to dry out the air in capsule-hose assemblies (such as during a test or while getting ready for a test).

- *When parking the capsules on the parking fixture, remove the white doughnut-shaped spacers from the capsule assembly. Replace the spacers when using the capsules on skin.*
- *Make sure that for each of the capsule/hose assemblies plugged into the Q-Sweat™, the two associated hoses for each assembly are plugged into the same channel.*

If the hoses (for a given capsule/hose assembly) are split between channels, the software will indicate that a leak exists that must be remedied before proceeding. Under such conditions, the Q-Sweat™ device will be unable to measure sweat.

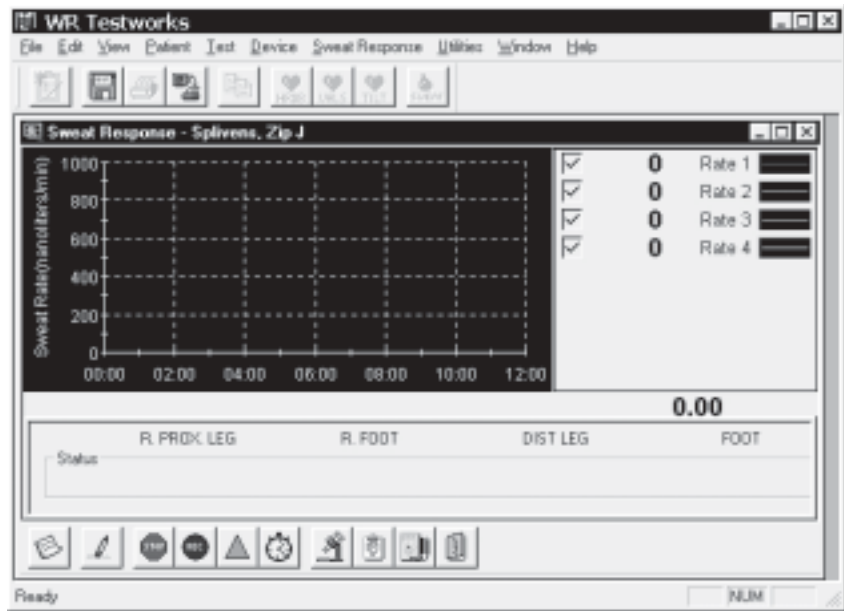


Remove the doughnut-shaped spacer when placing capsule on the parking fixture

- 4) Enter the patient's demographic data into the WR TESTWORKS™ software. Choose the Q-Sweat™ test menus to prepare the computer ready to receive data. See the WR TESTWORKS™ *Software User's Guide* for instructions on how to navigate and operate that software.
- 5) Choose the selected skin area. It is very important that the selected site be free of breaks, fissures, or any other observable abnormality in the skin. There should be no sign of inflammation. The area must be as wrinkle-free and hairless as possible. Typical sites might be:
 - the medial forearm (75 percent of the distance from the ulnar epicondyle to the pisiform bone),
 - the proximal leg (lateral aspect, 5 cm. distal to the fibular head),
 - the distal leg (medial aspect, 5 cm. proximal to the medial malleolus),
 - the proximal foot (on a flat surface over the extensor digitorum brevis muscle).
- 6) One site at a time, use each Velcro® strap to firmly affix each assembly to the skin at the desired site.

- 7) Initiate the recording of the sweat output by choosing the necessary menu item in the Q-Sweat™ application of the WR TESTWORKS™ software. Refer to the WR TESTWORKS™ *Software User's Guide* for specific instructions. Once all the capsules are placed, verify that the capsules have sealed by observing the "ON" or "AIR LEAK" indicator in the WR TESTWORKS software. Clear the recording, and start the actual test.

- 8) When the test is complete, stop the recording in the software, and disconnect the patient from the device. Remove the skin capsules from the patient and place them back onto the parking fixture or (preferably) unplug them from the Q-Sweat™ main unit.



- 9) Follow the steps outlined in the software (see WR TESTWORKS™ *Software User's Guide*) for storing the data, discarding the data, and/or analyzing the data.

CALIBRATION, MAINTENANCE, FACTORY SERVICE, AND WARRANTIES

CALIBRATION

Calibration is accomplished in several ways. At the factory, each individual sensor is calibrated to a physical standard using a traceable measurement system (temperature, flow in and out, and fractional RH). The Q-Sweat™ device and its matched sensors are then validated using a 5 microliter test with a calibrated Hamilton micro-pipette and a special test fixture.

The sensors themselves are calibrated by the original manufacturer prior to assembly at WR's factory. WR qualifies the sensors as part of WR's own system qualification. Each sensor has its own calibration constants that are provided by the original maker, and that are loaded into the Windows® registry by way of a diskette. (See the WR TESTWORKS™ *Software User's Guide* for instructions.)

A known quantity of water may be placed in a parking fixture capsule and then evaporated and totalized by the system. The totalized amount may be compared to the known quantity placed in the fixture capsule.

Notes:

- The Q-Sweat™ should be checked for calibration to physical standards as described above at least once per year (which follows the generally accepted protocol for calibrating scientific equipment). Any calibration adjustments or calibrations using specific quantities of water (as described above) should be performed by WR Medical at its factory or by trained biomedical technicians according to the WR-approved procedure.

MAINTENANCE

The Q-Sweat™ does not require any unique kinds of regular maintenance. It is the responsibility of the user to examine the equipment visually from time to time to see if there is any visible damage or other visual flaws with the equipment that might make it not work properly. For example, skin capsules should be examined to make sure that the air chamber is clear of obstructions. Such examination should be made before affixing any capsule to a patient in order to ensure that the equipment will work properly and that an accurate recording will be obtained. The cable/hose assemblies should be examined to assure that there are no nicks or cuts. Air leaks will cause the Q-Sweat™ device to malfunction or provide inaccurate recordings.

The color of the desiccant pack in the main unit should be periodically examined to make sure that it is the correct color. Blue indicates that the material is dry; pink or purple indicates that the material has absorbed as much moisture as it can. When the desiccant pack is completely purple or pink, it should be replaced. New desiccant packs (WR P/N 5190) can be obtained directly from WR Medical Electronics Co.

To remove and replace the desiccant pack, fully unscrew the cover for the desiccant pack carrier. As you unscrew the carrier, the carrier itself will begin to pull away from the main Q-Sweat™ unit. This is normal and the carrier is designed to do this. After you have finished unscrewing the carrier, it should be free to pull out all the way. Once you have done this, simply lift off the desiccant pack from the right side.

When inserting the new desiccant pack, simply place it onto the right side of the carrier. (Remove plugs on pack before inserting.) Push the carrier into the Q-Sweat™ device until it stops. Then screw in the carrier using multiple turns until the entire assembly is tightly placed into the Q-Sweat™ device. The desiccant pack has two nipples that will automatically fit into a spring loaded socket inside the Q-Sweat™ device, as the carrier is screwed onto the Q-Sweat™ device.

CAUTION:

- Do not attempt to dry out the desiccant in the desiccant pack by putting in an oven or a microwave. To do so will likely cause damage to the desiccant pack.
- The Q-Sweat™ unit should be turned on only when it is to be used, 1.5 hours prior to a testing session, and then turned off when not in use.

Notes:

- Do not leave the desiccant pack out of the Q-Sweat™ device for any longer than is necessary to check its condition. Extended removal will cause the desiccant to absorb water and become consumed.
- The Q-Sweat™ device has a built-in sensor that indicates (in the WR TESTWORKS™ software) when the desiccant pack needs to be replaced. This is accomplished by measuring the level of moisture that is detected on the output side of the desiccant pack.
- If the Q-Sweat™ device is turned on, desiccant will be consumed as room air is pumped through the desiccant pack and the hoses. You should always turn off the device when you are not using it. If for some reason you need to leave it on (but are not using the device), unclip the hose connectors from the front panel. This will prevent flow out to the hoses and save on consumption of the desiccant in the desiccant pack.



Desiccant pack in carrier, being removed from main unit.

SERVICE AND TECHNICAL SUPPORT

CAUTION:

- This device is to be serviced only by WR Medical Electronics Co. If servicing is done by any party other than WR Medical Electronics Co., the product warranty and/or safety or quality certifications could be invalid. Contact the factory for advice before returning to the factory for repair.

If you need to send the Q-Sweat™ device to WR Medical, first make sure that you have contacted the factory for any advice such as a solution that eliminates the need to return the device or particular shipping instructions. Carefully pack the unit in a well-padded carton, since it is most common for goods to be damaged on the way back to the factory due to poor packing.

For questions regarding the Q-Sweat device, the WR TESTWORKS software, or the Analog Input Device (AID), please contact:

Technical Support/Help Desk
WR Medical Electronics Co., 123 N. 2nd St., Stillwater, MN 55082 USA
Phone: 651-430-1200 (or toll-free: 800-321-6387)
Fax: 651-439-9733
E-mail: neuro@wrmed.com
Web: www.wrmed.com

Please have your serial number and module license key(s) available, which are found on the license sheet shipped with the product.

The Help Desk staff is available during normal business hours (8:00 am to 4:30 pm, Central Time).

For questions regarding the Colin Pilot® or 7000, please contact:

Colin Medical Instruments
5850 Farinon Dr., San Antonio, TX 78249
Toll-free: 800-829-NIBP (6427)
Fax: 210-696-8808
E-mail: Customer Service: custsvc@colinmedical.com
Technical Support: yvette@colinmedical.com
Web: www.colinmedical.com

For questions regarding the computer, printer, or any other hardware or software not made by WR Medical, including the Windows operating system, you may need to contact the manufacturer directly. Please consult the warranty policy.

WARRANTY POLICIES FOR THIRD-PARTY GOODS PURCHASED FROM WR MEDICAL

A) Customers are fully responsible for all computer support issues when the customer has purchased software, a personal computer (PC), printer, or any other third-party hardware item from a vendor other than WR Medical Electronics Co. Support issues that may arise include incorrect configuration or malfunction.

B) WR warrants that its own software will operate properly on a correctly configured DOS-only, Windows 98, or Windows 2000 machine, regardless of who bought the PC, as long as the WR software has been validated by WR on the operating system. WR reserves the right to decide on which operating systems it will validate its software

WR does not provide free repairs to software configuration problems that were caused by another party's software, by a malfunction of the operating system, or by a user (or another party) who may have altered any configuration or program files. Such repairs are considered for-fee repairs.

C) When WR provides a third-party item to the customer as part of a "turnkey" or integrated purchase with WR-manufactured software and/or hardware, WR will warrant that:

- 1) WR made the integration;
- 2) WR did an integrated test of the WR-manufactured software and/or hardware and third-party hardware;
- 3) WR found the software and hardware to be working properly at the time they were shipped, before shipping the product.

This is strictly an integration service for the convenience of the customer. In this capacity WR is functioning solely as a wholesaler PLUS a provider of a configuration/integration service.

D) Upon completion of the complete integration described in section C above, WR will NOT warrant that:

- 1) Any operating system, such as Windows, or any other non-WR-manufactured software will continue to operate properly when additional non-WR software is installed;
- 2) Any hardware will continue to operate or that such hardware would be repairable in the event of such a malfunction (described in D(1), above).

In the case when WR provides the wholesaling and configuration/integration service, WR will provide elementary troubleshooting assistance (by phone or at the WR factory). If any problem found is the fault of a third-party manufacturer of software or hardware, WR will provide basic repair assistance that may include:

- 1) Referring the caller directly to the manufacturer;
- 2) Reshipping the goods on to a third-party authorized repair station;
- 3) Making whatever repairs or re-configuration possible at WR's factory.

In any event, such assistance for third-party goods would be considered by WR to be a for-fee repair.

E) The warranties of any third-party software or hardware (such as Microsoft or Toshiba) usually require that the customer or "end-owner" register for warranty service. If WR has acted as the wholesaler for such software or equipment, WR may assist the end-owner in obtaining registration. However, the responsibility for registration rests with the new end-owner of the goods. The end-owner is responsible for providing sales receipts to the third-party manufacturer to confirm date of purchase.

F) If WR has acted as the wholesaler for such software or equipment, and if WR opens packages and is required to use license numbers in order to configure the goods, WR will use the name and address of the purchaser (end-owner). This may be a different name/address than the actual USER (such as in a drug trial).

G) If WR has acted as the wholesaler for such software or equipment, WR will act as an ombudsman (to the best of its ability) on behalf of the end-owner in order to assist the end-owner in obtaining the third-party warranty service.

H) WR does not provide any warranty on any third-party goods for which WR has served in a simple wholesaling/resale/integration role. WR not provide any warranty on any goods which WR did not actually manufacture. Third-party goods carry their own warranties from the original manufacturers.

TECHNICAL SPECIFICATIONS FOR ACCURATE OPERATION*

Environment:

Power requirement:	100-240VAC 50/60Hz
Power consumption:	Max. 40VA (0.33A at 120VAC)
Physical dimensions:	16.0"w x 7.25"h x 13.0"d (406.0 x 184.0 x 330.0 cm)
Weight:	10.0 kg (22.0 lbs)
Operating Temperature:	68 to 78 degrees F. (20 to 25.5 degrees C.)

Minimum PC requirements:

Processor:	Pentium 266 with CD Drive
Memory:	32 Meg
Display:	800 x 600
Storage:	500 Meg
I/O Interface:	RS-232 (16550 UART)

Software description:

Operating system:	Windows 98/2000 with IE4.0
Application software:	WR TESTWORKS
Integrated features:	Patient browser and database Test browser and database Report generator and data export utility Real-time rate and volume display (with event markers)

Sweat output measurement:

Number of channels:	4
Measurement method:	direct vapor pressure calculation
Measurement area:	.781 square centimeters
Dry air flow rate:	0.0-100.0 cubic centimeters/minute

Volume calculations:

Range:	(Dependent upon rate and time)
Accuracy:	± 5 percent
Repeatability:	± 5 percent
Sensitivity:	10 nanoliters

Rate calculations:

Range:	0-1000 nanoliters/minute
Accuracy:	± 5 percent
Repeatability:	± 5 percent
Sensitivity:	10 nanoliters

Features:	Integral dry air source National Instruments A/D interface (DAQPAD)
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Benefits:	No special gasses needed to operate the system Easy to interface to personal computers Convenient to operate
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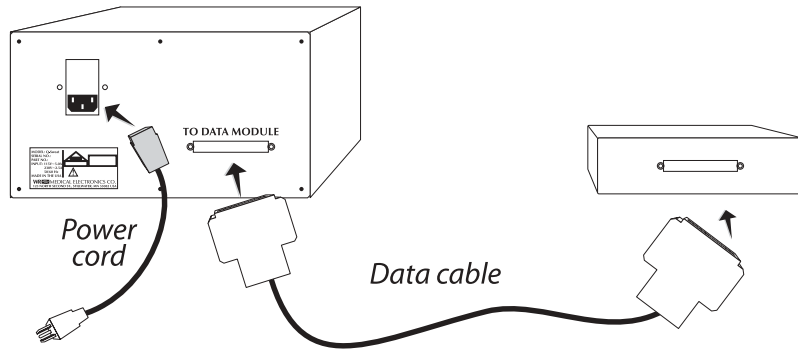
*These specifications describe tolerances for accurate operation of the Q-Sweat™ device, and may not match the safety specifications.

APPENDICES

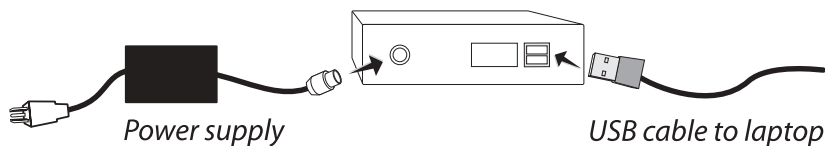
HARDWARE CONNECTIONS (LAPTOP COMPUTER SHOWN)

Main Components: Q-Sweat™ Quantitative Sweat Measurement System, WR TESTWORKS operating software version, sweat testing software module, hardware locking device, laptop or desktop computer, Iomega 250-MB Zip drive with 8 disks, laser printer, and equipment cart (not shown).

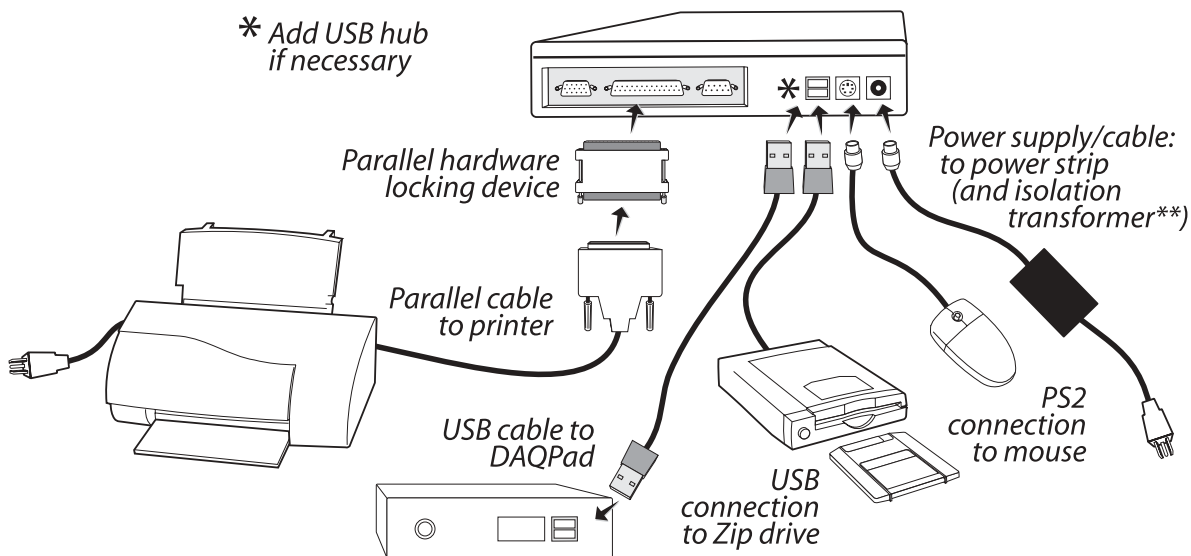
Q-Sweat to DAQPad



Back of DAQPad



Connections on Computer



Notes:

- Locations for connections on computers vary with different models. In addition, the specific items purchased by individual users may vary from the standard package offering. If necessary, please consult a computer technician.

Important Note Regarding the Hardware Locking Device:

- **DO NOT LOSE THE HARD LOCK.** A lost hard lock cannot be replaced; a new full-price copy of the WR TESTWORKS software would have to be purchased.

** Use a medical grade isolation transformer if required by local codes

SUGGESTIONS FOR USING THE Q-SWEAT™ AND CARDIAC EQUIPMENT

These hints were developed as a result of direct experience in setting up the systems and doing sweat and cardiac tests. It is possible for one person alone to set up and run the equipment. Hooking up a personal computer (PC) to a Q-Sweat™/WR TestWorks™ system, checking all connections, and running tests takes under two hours. This includes running a sweat test, a heart-rate-deep-breathing test, a Valsalva test, and a tilt test. (If one person is practicing on him/herself, the “tilt” test may be performed by sitting and standing.)

Setting Up the Equipment

National Instruments Devices

To capture the signal from the Q-Sweat™ or a Colin device in the computer, you will need one National Instruments (N.I.) device for the Q-Sweat™, and a second N.I. device for the Colin Pilot.® You may use any combination of these devices:

- PCI 6023E (PCI card that fits in the desktop computer)
- PCI-MIO-16XE-50 (PCI card that fits in the desktop computer)
- DAQCard AI-16E-4 (PCMCIA card that fits in PCMCIA slot of laptops)
- DAQCard AI-16XE-50 (PCMCIA card that fits in PCMCIA slot of laptops)
- DAQPad 6020E (external box that uses special N.I. cable and USB cable)
- DAQPad MIO-16XE-50 (external box that uses special N.I. cable and USB cable)

Check your N.I. devices for functionality first before running the WR TestWorks™ software by opening the National Instruments software, refreshing the view (this causes Windows to recognize the devices), and then running a test panel for each device. You can see whether the devices are installed by clicking on “Configuration/Devices and Interfaces.” Choose the device and then run the test panel.

When using the N.I. devices, the device that runs the cardiac application must always be “device 1” (in the National Instruments software) and the device which runs Q-Sweat™ must always be “device 2.”

When using the N.I. DAQPAD, the power switch must be in the “-” position and NOT the “O” position. Note: “-” means ON and “O” means OFF.

USB Devices

When setting up a system, first plug in the items before powering up. For systems not pre-configured by WR, USB devices require special handling. When adding a USB device to a computer, load the software first, and then — after the software installation is done — plug the USB device into the computer (with Windows already running). This is so Windows will see the new USB device.

Pre-configured systems shipped by WR are always fully tested; re-installation of software should not be required. Simply plug everything in except the USB cables; turn all items on (or make sure they are plugged into their

WARNING! A tilt test must be done in the presence of a physician and with a operable crash cart ready nearby. Although it is uncommon, people can and do crash during tilt tests.

live power supplies); turn on the PC, wait for Windows to come up, and then plug in the USB cables (from pre-powered devices). Windows should automatically “see” all the USB devices that are plugged in.

Once your system is set up for the first time and it is functioning correctly, leave everything plugged in. This assures that when the system is turned on the next time, Windows will identify all the USB devices.

Setting Up the Q-Sweat,[™] Colin, and Other Devices

Once the N.I. and USB devices are set up, make sure the Q-Sweat[™] is functioning. Launch the WR TestWorks[™] software, choose the “Default” login, choose or create a patient, click on the sweat test icon, and begin recording. Make sure your capsules are plugged in and on the parking fixture. If the capsule is not plugged in, there will be no airflow nor signal. To abort the test, close the window and choose “no” to discard the test.

Next, set up the Colin Pilot[®] or 7000. First hook up the ECG cables (Pilot[®]) and get a signal on the Colin device. Then hook up the blood pressure cuff and tonometric wrist sensor and get a good tonometric signal. THEN launch an WR TestWorks[™] cardiac test and try to get a recording. Discard the recording in the same way as discarding a Q-Sweat[™] test.

Finally, hook up your air pressure devices such as a chest expansion bellows and Valsalva bugle. Make a recording to see if the traces appear as expected and then discard the recording.

The Analog Input Device (AID) takes the air inputs and also the analog signals from the Colin device and converts them to digital (using the N.I. device) so that they can be fed into the computer.

When looking for the blue chest bellows trace on the WR TestWorks[™] HRDB screen, you may choose between a fixed or variable scaling. Sometimes it’s easiest to flip the switch on the AID box to “variable” and then turn the offset and gain knobs until you see the blue trace on the lowest window. Look at the black number on the chest expansion indicator on the right side of the screen and turn the offset knob until the number is just positive above 0.00. Then you’ll see the trace on the screen as you breathe.

Remember that using WR TestWorks[™] is a two-step process: First, get a good recording. Then, analyze and re-analyze the test as often as you want. You can also create the final report on the screen without printing it.

Shutting Down the System

To turn off the system, turn off the personal computer first, and then turn off the other items. Do not use a master power buss (power strip) to shut everything off at once.

If your system uses a PCMCIA N.I. card, leave the card in the socket and the clamp untouched. This type of clamping system is not designed for frequent removal and installation. The clamp has adjustable pinching bars, which can be adjusted to clamp the ribbon cable into place and to hold the ribbon cable into the card. Frequent removal and re-installation of this ribbon cable and card can result in accidental damage to the cable or card. Remove only if necessary.

IMPORTANT PRACTICAL INFORMATION ON DOING SWEAT TESTS AND INTERPRETING RESULTS

Introduction

This document advises on important practical aspects of the Q-Sweat™ Quantitative Sweat Measurement System and clarifies analysis of the test results (once a recording has been made). It also explains the differences between a *resting* sweat and an *evoked* sweat recording (caused by exercise, psychological or noxious stimuli such as sound, or raised room temperature; in other words by some method that does not require a specific FDA clearance). This document is not intended to define specific testing protocols, which should be established by physicians or qualified researchers.

By Patrick J. Anderson,
WR Medical Electronics Co.

The author has gathered the information contained within from practical experience and from talking with device designers, engineers, users, and other interested parties. The author has also examined various journal articles and has run practical experiments in order to provide the enclosed information.

Intended Use of the Q-Sweat™

The Q-Sweat™ device was mainly designed to make sweat volume computations. While it provides rate information, this was not the main design objective. Due to limitations imposed by using desiccated room air and the device's internal sensors, some very low-level test results should only be considered relative to values obtained from normal controls (in other words, very low-level measurements may not be absolutely accurate values by themselves). The designers of the Q-Sweat™ presumed that the device would be used primarily in comparing study patients to normal patients in order to determine whether the study patients fall out of the statistically normal range. In making such a judgment one is mainly concerned with whether the patient is, or is not, within the normal range — not the exact degree to which the patient is abnormal. This distinction is important if the data obtained by Q-Sweat™ is to be used in statistical studies.

The term “normal controls” refers to a population of patients who have been carefully screened for the absence of disease or other factors that would cause their sweat production to be abnormal, and who have been tested under controlled circumstances.

Zero Sweat Rate

An evoked test is characterized by a graph that shows a stable “baseline” rate, which then increases from the baseline as a result of some sort of stimulus. (See figure 5 on page 5.) A resting test is characterized by a stable “baseline” rate, which is typically that part of the recording where no sweat is being measured, which then turns into a larger but relatively stable “resting rate.” (See figures 8 and 9 on page 8.)

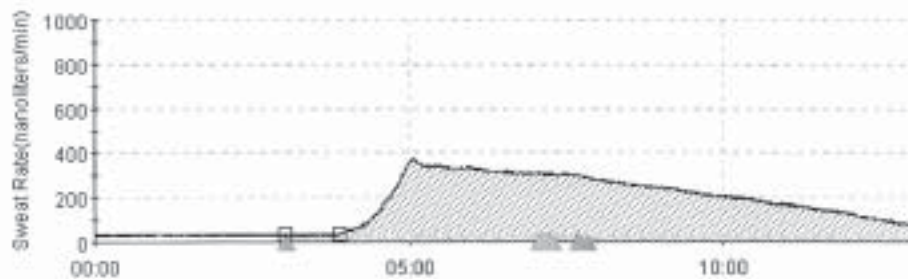


Fig. 1: Above is an example of how the volume of sweat is computed. The volume is the area under the rate curve, with the original baseline sweat rate subtracted out.

For evoked tests, the analysis tool provided in the Q-Sweat™ module of the WR TESTWORKS™ operating software was designed to make a volume computation by looking at the difference between the evoked rate curve and the baseline rate. This means that as far as the computer software is concerned, the baseline rate is the “zero” sweat rate.

In practice, using dried room air, it is difficult to quickly, accurately, and affordably measure a real sweat rate of zero moisture. Various kinds of sweat measurement devices have been marketed, including those that use nitrogen; each of these has drawbacks as far as cost, convenience, true accuracy, and speed are concerned. By eliminating the use of nitrogen as a dry gas, the Q-Sweat™ device provides an affordable, convenient, and accurate method of assessing sweat output in a clinical setting.

Because of the way the Q-Sweat™ is designed, measuring absolute or extremely near to zero moisture is challenging. Ordinary room air will always have some moisture in it, and the desiccant pack within the Q-Sweat™ device (which conditions the source air for the skin capsule) cannot remove 100 percent of the moisture from the room air. In addition, there are physical and electronic limitations of the sensors used to measure the amount of moisture flowing across these sensors. In practice it is possible to measure down to a moisture level of approximately two percent relative humidity. (Other humidity sensors are on the market but all have inherent measuring limitations, which are relative to cost.)

The following chart shows what the recording curve would look like when a relative humidity of two percent was being measured.

Relative humidity (%)	Calculated Indicated rate in nanoliters	Actual reading on sample Q-Sweat™ machine
2	20	23
5	50	48
10	100	98
20	200	195
50	500	487

Assumptions: Flow Rate = 60.0 SCCM*, Temperature = 19 deg. C.

*Standard cubic centimeters per minute

Potential Machine Sensing Error

Although the device may indicate a stable dry rate of 20 nanoliters, for example, a degree of machine error underlies the rate indication. The true dry rate may be between zero and 20 nanoliters because the humidity sensors are not able to measure below an inherent floor. This level of machine error will be present in all recordings and will remain at a fixed absolute value regardless of rate increases or sweat volume. (In other words, the error does not scale with the rate; instead it remains at a fixed amount, such as five nanoliters.)

If the device is used for the general purpose of differentiating normal from abnormal, machine error should not be a problem. However, it is not recommended that the measured resting rate values acquired by the small capsule be used by themselves when extremely small responses are obtained (see “Diameter and Volume Characteristics of Capsules”). Based upon the potential sensing error, volumes measured by rates greater than 70 nanoliters should be quite accurate. For any graphs where the curve is well below 70 nanoliters, use the rate values only to compare to normal controls.

Why Lower the Dry Rate?

When the Q-Sweat™ is recording with the skin capsules placed on the parking fixture, you should see a dry rate below 20 nanoliters. If you can make the initial rate very low *and* are able to obtain a big response, the calculation of the difference may be more accurate (please see “Factors Affecting Accuracy” for more information).

This means that on a calibrated Q-Sweat™ machine with the capsule(s) positioned on the parking fixture, a dry rate of 20 to 40 nanoliters (0.0020 to 0.0040 microliters) per minute is common. (See “Terminology,” below, for an explanation of dry rate.) WR’s standard quality control requirement is less than 20 nanoliters per minute (dry rate), and in most cases you should see a dry rate between 10 and 20 nanoliters per minute after drying out for 20 minutes. It is also common to see a dry rate of nearly zero when the capsule(s) are positioned on the parking fixture. It depends on how long the unit has been circulating desiccated air and how dry the room humidity is.

Please be aware that the hoses, if left open to the air, can absorb moisture. This means that if you attach a capsule/hose assembly and immediately begin recording, it can take some time (perhaps 15 to 60 minutes) for the air’s moisture to be taken out of the measurement system. For this reason, run the Q-Sweat™ device with the skin capsules on the parking fixture for long enough to establish a stable and low dry rate before testing a patient. (See also the sidebar, “The Dry Sweat Rate and Relative Humidity.”)

Another step that will help give you accurate measurements is to let the Q-Sweat™ unit run for about 15 to 60 minutes (to get it fully warmed up) with the hoses unplugged, and then plug in the hoses and dry them out, and then test the patient. This will warm up the electronic components so that they are working at their maximum accuracy. This is particularly important for the electronic flow sensors, humidity sensors, temperature sensors, and so forth. A Q-Sweat™ unit that was turned on when it was cold, after being brought indoors from a cold automobile or loading dock, could not be relied upon to give an accurate measurement.

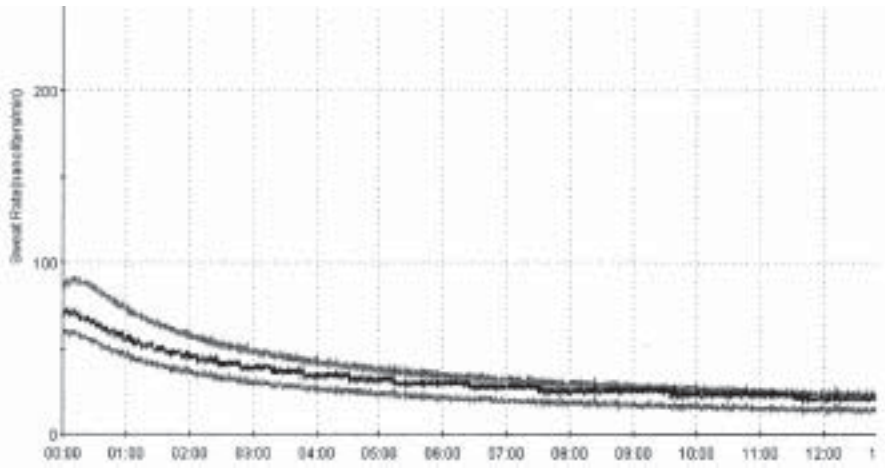


Fig. 2: This is an example of what a drying out recording looks like. The initial moisture is found in the air hoses. After a relatively short period (20 minutes), the curves flatten out as the majority of moisture in the entire closed-loop system is dried up.

The Dry Sweat Rate and Relative Humidity

The amount of moisture in the room is a key factor that will determine how long it takes to establish a dry rate of approximately 20 nanoliters. If the room air is more humid, then the hoses and some of the original air-source tubing will absorb more moisture. It is only during the time that the air pump is running that the drying-out process can take place. A higher relative humidity of the room air means it may take longer to establish a suitably low initial dry rate. For example, in Minnesota in winter, it is easy to establish the rate quickly because the room air is fairly dry.

Management of the Desiccant Pack

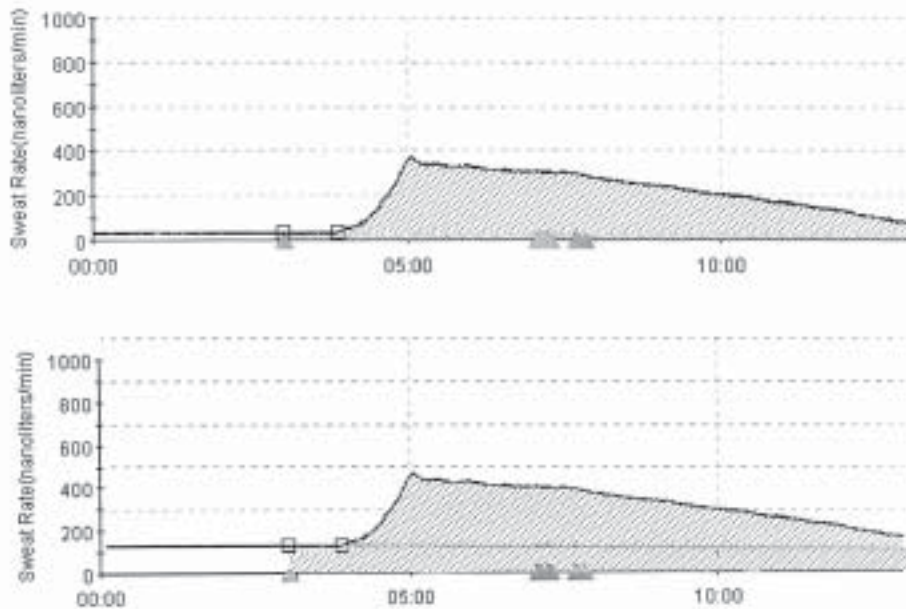
If the Q-Sweat™ device is not used for a long period of time (days or weeks), or if you intend to run the Q-Sweat™ air pump for a very long period (hours), disconnect the hoses from the front panel. This is because desiccant will be consumed for any time that room air is pushed through the desiccant pack. Thus there is a trade-off between keeping the hoses and skin capsules dry (away from contact with moist air) and conserving the material in the desiccant pack.

It makes no difference to longevity of the desiccant pack whether the capsules are parked on the parking fixture or whether the hose assemblies are unplugged. Two things consume desiccant: *room air being pumped through the pack*, and *exposure to static room air*. Always keep the capsules on the parking fixture, or the hoses unplugged, whenever possible and appropriate for the situation.

The Sweat Volume Calculation

Although the dry rate should be as low as possible, as far as the volume calculation is concerned, an initial dry rate higher than 25 nanoliters is not necessarily a problem. This is because the volume is computed by subtracting the baseline rate from the response rate. As seen in the examples to the right, both tests will provide the same volume calculation despite the fact that the baseline rates are different.

A typical recording will show a period of a very low rate, along with a period of a higher rate. It is the difference between these two levels that the software uses to determine the volume of moisture being measured.



Figs. 3 and 4: These show why the basic volume computation would not be different if the baseline rate were a little higher due to the system not being dried out enough. The volume computation is the same (and thus can be relied upon), but the baseline rate cannot be relied upon.

Terminology: Dry, Resting/Baseline, and Evoked Rates

The terms “baseline/reference rate,” “dry rate,” and “evoked/response rate” have subtle but important differences depending on test type.

For evoked tests:

- **Dry rate:** the rate during the time that the capsules are resting on the parking fixture. In this configuration, only dry, desiccated air is flowing through the system.
- **Resting/reference rate:** the rate during the time that the capsules are affixed to the patient (after the capsules are removed from the parking fixture and place on the patient). For evoked tests, this is also the baseline rate.
- **Evoked rate:** the rate caused by some kind of event or stimulus. For evoked tests, this is also the response rate.

In these tests, the volume is calculated by looking at the difference between the resting (baseline/reference) rate and the evoked (response) rate.

For resting sweat tests:

- **Dry rate:** For resting sweat tests with the capsules sitting on the parking fixture, this is considered the baseline or reference rate.
 - **Resting rate:** For resting sweat tests, this is actually the response rate, as far as the computer analysis tool is concerned.
-

Guidelines for Evoked and Resting Sweat Studies

Evoked Studies

The evoked test is a common method for measuring the sweat output of the skin. Examples of evoking that do not require special FDA authorization are exercise, psychological or noxious stimuli such as sound, or raised room temperature. In this test, the skin capsules are affixed to the patient, and a baseline of actual resting sweat is established. In most cases, the actual patient resting rate will be higher than the dry rate (in other words, the parking fixture rate) if the correctly sized measuring chamber is used. (See “Volume Values and Rate Values,” below.) In some cases, there may be no noticeable difference — for example if the patient is very diseased and completely sweat-impaired. The Q-Sweat™ equipment is somewhat like hearing test equipment in that a patient may be too diseased to be measured. Thus there is the possibility that you will not see any kind of response. In this case, there is nothing wrong with the Q-Sweat™ device.

For an evoked test, you will typically put the capsules on the skin and subsequently start your recording. After the capsules are placed correctly, your recording should be free of the spikes and blank areas described in the sidebar “Behavior of the Recording Trace.” It is important a good recording is obtained from the time a patient’s actual resting baseline is established to the time that the test is ended.

As the recording progresses, place the markers at the point where the formal test begins, such as the point where the stimulus is given. Additional markers can be placed to remind you of some other events during the recording or to mark the end of the test.

Software Analysis Logic

The evoked test depends on finding a difference between the resting baseline rate and the magnitude of the subsequently higher response rate. The analysis tool will automatically place “selection points” on the position where the first marker is added (or at the beginning of the recording if no marker is placed) and also at the place where the recording changes from a resting value to an evoked value (where the rate changes suddenly, signifying the onset of response). The operator then inputs the resting (baseline) rate and the totalized time for the volume computation into the analysis screen.

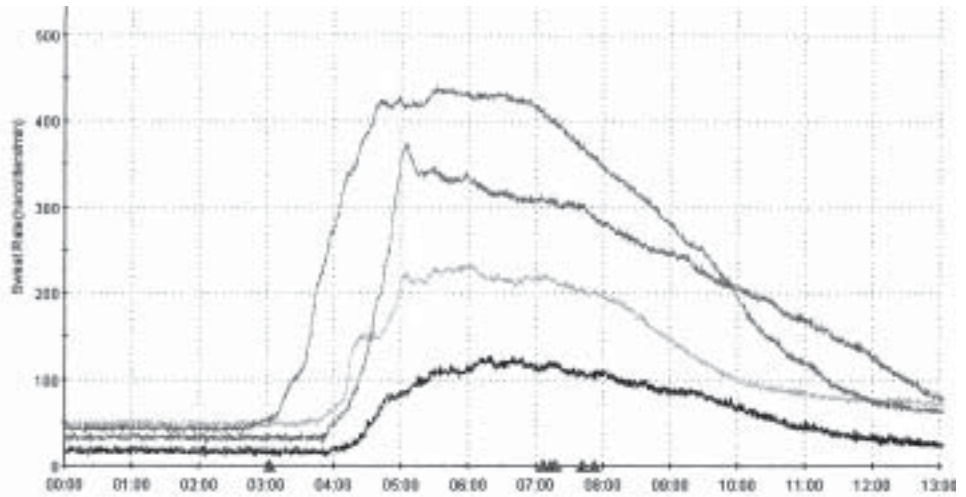


Fig. 5: This is an actual evoked recording showing simultaneous measurements of the foot, calf, thigh, and forearm. In this image the foot is the smallest line, the forearm the next larger line, the calf the second largest line, and the thigh the largest line.

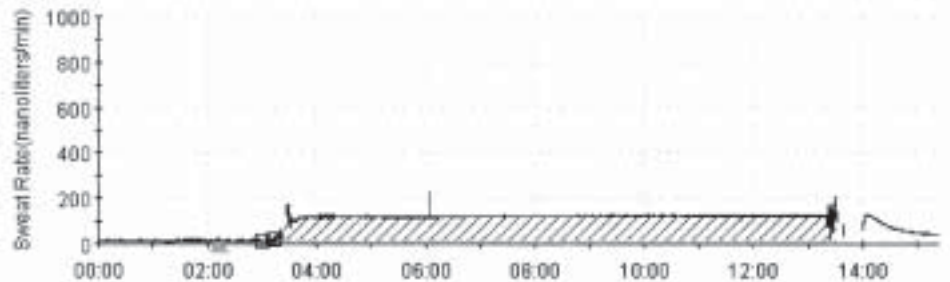


Fig. 6: This is an example of what a recording looks like where the flow was interrupted due to removal of the capsule from the skin during the time the recording was underway. The volume calculation is typically not affected by missing parts of the recording line or the spikes in the recording line.

Terminology

- **Selection points:** Also called cursors, these are the little white square boxes that the computer automatically places. These can be moved by the operator (right click to remove a selection point, and left click to place it somewhere else). These selection points are used in the mathematical volume computations.
- **Marker:** The little green triangles that the operator places along the timescale while the recording is taking place. Once placed, markers cannot be moved.

Exact Steps of Analysis (See Fig. 7)

- The software searches forward, within the visible range on the graphical display, to find the first positive change in slope (over a 3- to 5-point average rate). This point is the response point.
- Hint: To prevent the analysis tool choosing a spike as a response point, zoom in so that the spike is not visible on the graphical display before performing the analysis.
- The software then works backward from the response point to identify a starting point, which is the immediately preceding event marker or the beginning of the visible area in the graphical display (whichever is closer to the response point).
- Next, the first selection point (“cursor”) is automatically placed at the spot of the last event marker preceding the response point. The second selection point is auto-placed based upon the change in slope rule described above. The analyst may manually move each selection point along the recording line by removing with the right mouse button and placing with the left mouse button.
- The adjustable baseline value shown in the box below the graphical line display is computed by looking at the lowest rate (using a short average) between the two selection points.
- The totalized time is computed by rolling forward from the first selection point, to be automatically defaulted to ten minutes, unless the recording is shorter than that length, in which case the totalized time is from the first selection point to the end of the recording. This value is adjustable.
- If you adjust the totalized time in the box on the first channel, then the second, third, and fourth channel totalized time will be re-set to match the time entered for the first channel.

Because of the problem of determining the true zero sweat rate (see discussion of dry rate, above), it is crucial that one measures volume based upon a difference between the baseline and the evoked rates.

Factors Affecting Accuracy

Several dynamics may enhance accuracy of the volume measurement:

- 1) The degree to which the evoked response is greater than the baseline. In other words, a large difference becomes more accurate because a bigger differential computes to more volume.
- 2) The flow rate of the air through the skin capsule. Slower air picks up more moisture but takes longer to pass through the system. The flow rate of the Q-Sweat™ is fixed at 60 standard cubic centimeters per minute (SCCM), which refers to standard pressure of one atmosphere at 21 degrees Celsius according to the manufacturers of the humidity sensors used in WR's product. A slower rate might enable one to measure moisture to a greater degree of accuracy, but doing so would increase the time it takes to complete a test, which may be a detriment in a clinical environment.

Behavior of the Recording Trace

As you are recording, and as you move the skin capsule from the parking fixture to the skin, you may notice the rate line on the computer screen jump around or show blank areas. This is a normal occurrence. The graphs will show two kinds of behaviors. The first is a spike, where the airflow is interrupted because air is not able to return to the main unit. In the Q-Sweat™, a supply pump pushes air from the main unit out to the skin capsule. If the capsule is not sealed properly against a surface, there is not enough pressure to push the air back into the return hose. The spike that you see on the recording is not a material event on the recording and may be ignored. Reposition or tighten the capsule if necessary.

You may also see the baseline rate suddenly increase due to room moisture being absorbed when the skin capsule was being moved from the parking fixture onto the skin. Then you may see the baseline start to decline until it reaches a steady state, which may be different than the original dry rate. This too is normal behavior of the recording.

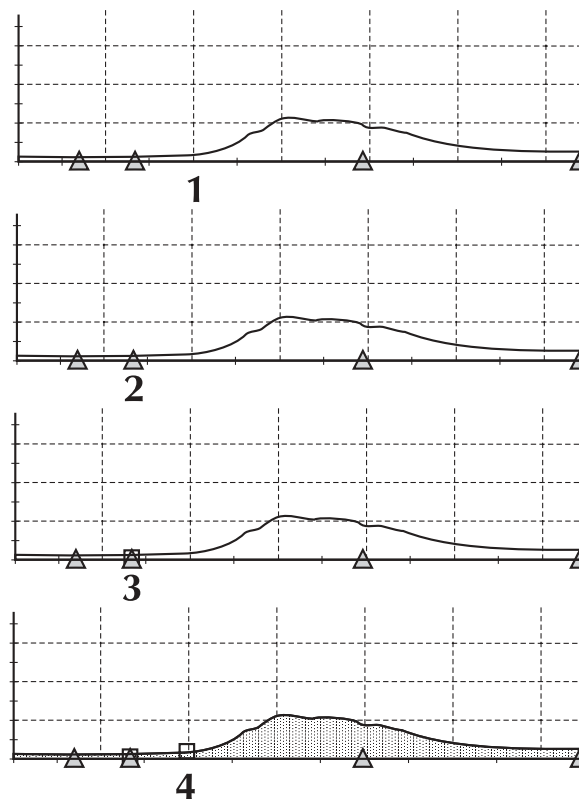


Fig. 7 (above):

- 1: Response point (first positive change in slope)
- 2: Starting point (immediately preceding event marker or beginning of visible area in display)
- 3: Software places selection point (“cursor”) at starting point
- 4: Software places selection point at response point

A faster rate would shorten the time needed for the test, but the test would be much less accurate.

- 3) The diameter and depth of the skin capsule. A capsule of larger diameter picks up more moisture from more sweat glands than does a smaller diameter capsule. Furthermore, a capsule of a large volume will take longer to exchange the air than would a small volume capsule, at least as the flow initially begins (in other words, it takes a little longer drying time before the test).

For purposes of the evoked skin test, the key thing to remember is that the bigger the size of the response, the more accurate the volume calculation would be.

Starting point, response point, baseline, and total time functions in the analysis tool are designed to be adapted to the particular testing protocol used. Descriptions of various kinds of sweat tests have been described in many medical publications. It is up to users to determine their own protocols, and to decide if they wish to replicate the tests described in the public domain literature.

Resting Studies

A resting sweat test procedure is a little different from the evoked test procedure, but it is similar in that the analysis tool looks at the difference between baseline and response in order to compute a volume. At first glance, it might seem as though it will be difficult to find a difference between the dry rate (baseline) and the measured resting rate (response). (See “Terminology,” above.) However, some tricks of the trade make this job easier.

As mentioned above (see “Zero Sweat Rate”), a truly dry rate of exactly zero may not be achieved. Still, using the standard skin capsule, most normal studies will show some difference between the dry rate and the resting rate (when the skin capsule is placed on the skin). This difference will probably be small, and could be perhaps difficult to see if a patient had very low resting sweat rates. As discussed above (see “Factors Affecting Accuracy”), the amount of skin surface area sampled and the size of the response have an impact on the accuracy of the measurement. The tricks are to use a skin capsule that has a much larger surface area to amplify the recording (WR part number 5194). The net effect is that the recording will show a much greater response, making the measurement more accurate.

For resting sweat studies, compute the volume by placing the selection points at the appropriate place on the recording line (see “Protocol Observations: Resting Studies”), and then type in the dry rate and totalized time where prompted. Make sure the patient is still during the time the recording is made. The patient should be measured in their natural state, and should not be affected by residual sweat caused by any kind of physical exertion (such as climbing stairs, walking, or by other causal factors).

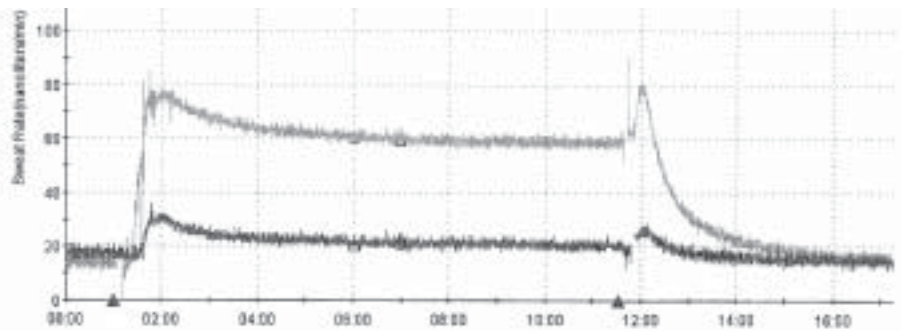
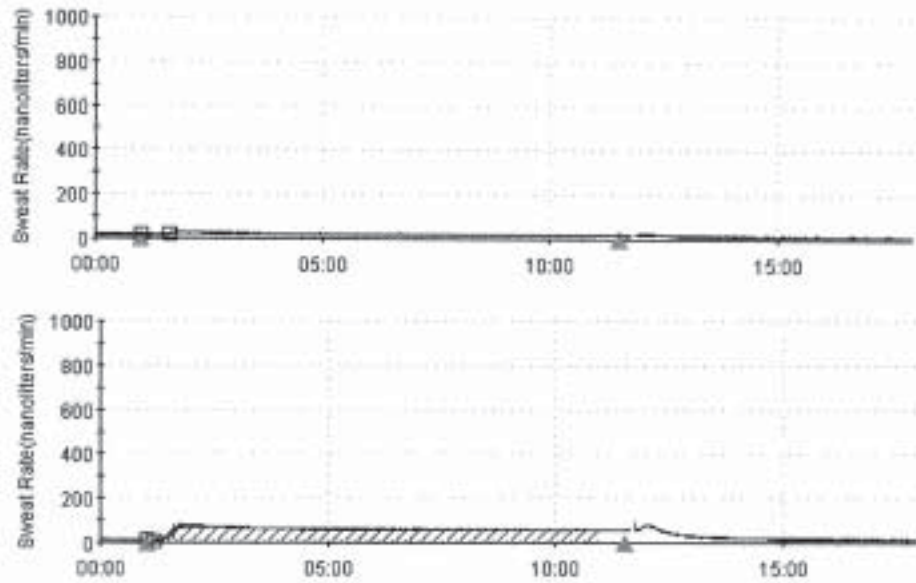


Fig. 8: This is an example of a simultaneous resting sweat recording made with a smaller and larger capsule, where the two capsules were placed directly adjacent to each other on the patient's calf. Note that the larger capsule amplifies the measurement to approximately three times the original.

In the resting sweat test, begin by starting the recording and establishing a baseline by leaving the capsules on the parking fixture. Next, while still recording, move the skin capsules to the skin, and record the patient's resting (response) rate. Note: Transfer the skin capsules promptly from the parking fixture to the skin, so that excess room moisture is not picked up. (A small amount of room air moisture should not degrade the volume computation if the size of the response and length of the test are adequate.) Using a larger chamber also makes a big positive difference in accuracy since many more sweat glands are sampled. Please see "Protocol Observations: Resting Studies" for more on what a resting recording should look like and how to analyze it.



Figs. 9 and 10: At top is an example of a resting recording made using a small capsule. Compare the volume of moisture shown on this recording (which is barely visible on the image) with the second recording directly (at bottom), made using the five-centimeter capsule. The recordings were made simultaneously on the calf, with the capsules placed adjacent to each other. Notice how the recording made with the larger capsule amplifies the measurement of resting sweat because a larger surface area of the skin is sampled.

Diameter and Volume Characteristics of Capsules

This chart of capsule sampling areas and volumes will be helpful in making correct sweat output calculations. These values were obtained by carefully measuring physical examples of capsules made by WR Medical and Dr. Phillip A. Low's lab.

Version of Capsule	Sampling Area		Volume	
	Sq. Cm.	Sq. In.	Cu. Cm.	Cu. In.
WR part number 5189	0.7871	0.122	0.1229	0.0075
Original Low capsule	0.7677	0.119	0.4228	0.0258
WR part number 5194 resting	5.06	0.785	3.614	0.2206
Original Low resting	5.05	0.782	4.801	0.293
WR experimental resting	6.41 ²	0.994	4.521	0.2759 ¹

(¹25 percent larger by volume)

(²26.668 percent larger by surface area)

Knowing the sampling area and volumes of the capsules used for a particular test is important, because it is common in the literature to characterize sweat output in terms of microliters-per-square-centimeter-per-minute, or some other combination of volume-per-area-per-time. Thus, in order to determine what was actually measured, the size of the surface area from which the sample was obtained, the volume of sweat, and the length of the test must be known.

Current Q-Sweat™ device users may have capsules that don't exactly match the sizes shown on the chart. By knowing the measurement surface area of the capsule used, it is easy to compute the correct unit of measure for any tests you've done in the past or any tests you will do in the future. In addition, it is possible to make your own special capsules of dimensions different than what is listed above. Ultimately the computation to derive the volume-per-area-per-time should be the same.

Protocol Observations

The Q-Sweat™ module of the WR TESTWORKS™ operating software has not been programmed to enforce a certain, specific protocol. Rather, it permits the researcher to establish customized protocols depending on the needs of the medical specialty or study. Below are a few observations of past studies.

Evoked Studies

A common protocol found in the literature for evoked studies is to use a 0.767-square-centimeter skin capsule for a total response recording time of ten minutes for forearms, and 15 minutes for feet. A variation of this protocol is a standard ten-minute recording time regardless of body location. In the case of these two different protocols, the methods and duration of evoking are a little different from each other.

Published sweat data is usually given in microliters-per-square-centimeter-per-minute. Because variations in methods exist among published protocols, carefully scrutinize those methods to make sure that any comparisons you might make between your data and the published data have taken into account the differences in protocols. The Q-Sweat™ software allows you to place the selection points at the correct place in the recording and to type in the correct baseline observation and totalized time (in minutes) in order to compute a volume number. The volume number must then be manually calculated against the capsule diameter and time in order to convert to the units that have been published in public domain literature.

Example:

Baseline rate nL/min	Total totalized time	Volume (μL)	Baseline rate in standard units (μL/min)	Resting volume in μL-per-sq-cm-per-min
16	10.5	1.08	0.0160	0.0206

Take into account the size of the skin sampling area (capsule measuring area) and the time duration of the measurement in order to get a meaningful number.

Conversion Values:

Microliter to nanoliter:	1 μL = 1000 nL
Micromole to nanoliter:	μM/minute x 18.1818 = nL/minute
Nanoliter to micromole:	nL/minute / 18.1818 = μM/minute
Microliter to micromoles:	1 μL = 55 μM
Nanoliters to micromoles:	1000 nL = 55 μM
Microliter to moles:	1 μL = 0.00055 M
Area of a circle:	3.141 x (r) ²
Volume of cylinder:	3.141 x (r) ² x h
Square inches to square centimeters:	inches x 6.4516
Square centimeters to square inches:	centimeters x 0.1550003
Cubic inches to cubic centimeters:	inches x 16.38706
Cubic centimeters to cubic inches:	centimeters x 0.06102376

Abbreviations: microliter (μL); nanoliter (nL); micromole (μM); mole (M)

Resting Studies

A common protocol found in the literature for resting studies is to use a 5.30-square-centimeter skin capsule and a computation time of one minute, starting at the fourth and ending at the fifth minute of the resting sweat recording. The Q-Sweat™ software allows you to place the selection points at the correct place in the recording and to type in the correct baseline observation and totalized time (in minutes) in order to compute a volume number. To do this, make the recording where a smooth, stable resting rate is obtained. Then, in the analysis tool, place the first selection point on the fourth minute. Place the second selection point at the fifth minute. Then use the crosshairs to drive back on the recording to the original dry (baseline) rate (when the capsule was on the parking fixture before it was placed on the skin). Read the moisture rate in the upper right hand corner of the screen. Enter that number into the baseline sweat rate box below the graph. Then input the totalized time as one minute. The analysis tool will compute the volume for the period between the fourth and fifth minutes (using the first and second selection points). Note that you can read the rate at any point on the recording by navigating with the crosshairs and reading the numeric rate directly on the screen. The volume number must then be manually calculated against the capsule diameter and time in order to convert to the units that have been published in public domain literature.

Laboratory Issues

Resting sweat rate is greatly dependent on ambient temperature and the emotional state of the subject. Essential to sweat studies are standardized room temperature and a patient who is at a steady emotional and physiological state. This translates to:

- 1) Standardized room temperature;
- 2) Patient should be rested and supine for about 20 minutes;
- 3) Patient should be comfortable (including emptying the bladder) and relaxed.

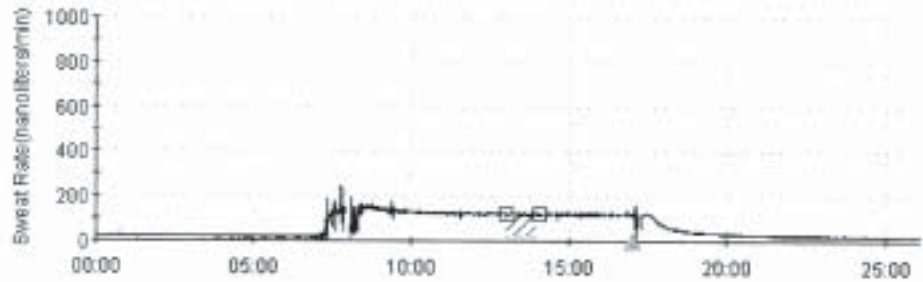
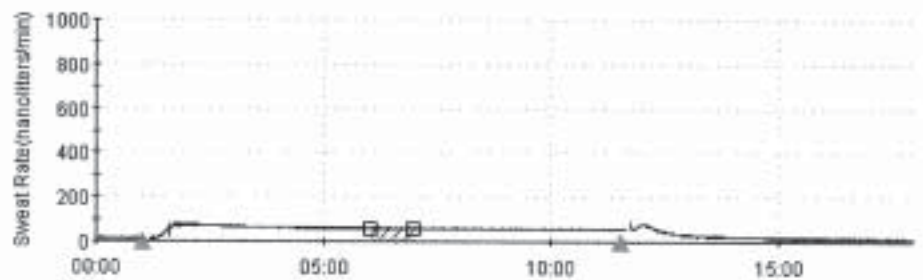
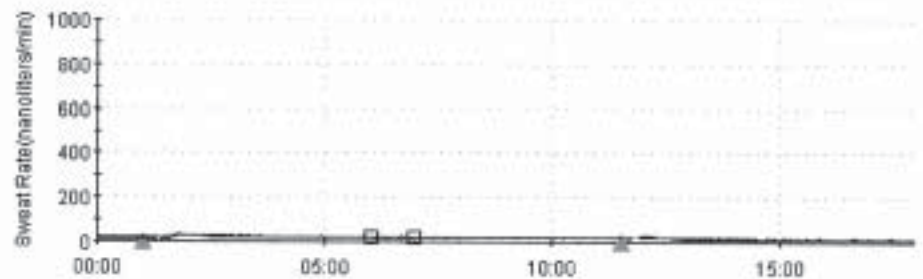


Fig. 11: Above is an example of a volume computation made for the time period between the fourth and fifth minutes, but using the initial dry parking fixture rate as the baseline. Note that there are spikes and missing parts of the recording line due to moving the capsule from the parking fixture to the skin, during the time the recording was underway. As can be seen from this example, the volume computation is not affected.

Figs. 12 and 13: The two images directly below show the difference between a small and large capsule on a simultaneous recording for a measurement of volume between the fourth and fifth minutes.



Volume Values and Rate Values: Which Measurements to Use?

You will need to use a particular capsule size depending on what measurement value you intend to use as a meaningful datapoint in your study. If you want to obtain both resting sweat rate values and evoked sweat volume values from the same patient, you will need conduct two distinct, separate tests.

Evoked Studies

For the evoked volume study, use the small capsule (0.7871 square centimeter, WR part number 5189), but use only the volume computation as a valid datapoint; do not expect the baseline rate information to be meaningful, accurate, or traceable. The reason for this is that the capsule size is too small to derive an accurate resting sweat reading, which is used as the baseline. This is due to the problem of sensor limitations that leads into further problems of defining and validating the measurement of absolute zero moisture to a National Institute of Standards and Technology (NIST) traceable or physical standard.

To compare results to those that have been published in medical literature, manually convert the Q-Sweat™ measurements into units of measure published (such as microliters-per-square-centimeter-per-minute). See “Conversion Values,” above.

Resting Studies

For resting sweat studies only, use the larger capsule (5.06 square centimeters, WR part number 5194); from this you can obtain meaningful resting (in this case, response) sweat rate and also resting sweat volume. The volume computation is most accurate when you establish a smooth resting sweat rate and then record for a long period (such as ten minutes), and then make the volume computation upon one to three minutes' worth of stable recording time. Because all volume values must be converted to standard units of quantity-per-area-per-time, a larger capsule, a longer recording, and a longer computation period are to your advantage (as far as accuracy is concerned).

To compare results with those that have been published in medical literature, manually convert the Q-Sweat™ measurements into units of measure published (such as microliters-per-square-centimeters-per-minute). See “Conversion Values,” above. Resting sweat values can be found in table 16, page 193, chapter 15, *Clinical Autonomic Disorders*, second edition, published by Lippincott-Raven, Philadelphia, PA, 1997.

Calibration Method

In order to show that the Q-Sweat™ measures the correct amount of volume of moisture, a calibrated Hamilton® pipette is used to inject five microliters of water into a sealed chamber upon which the skin capsule has been pre-positioned. With the Q-Sweat™ device in recording mode, one can quickly and easily see the resulting recorded graph and then follow the steps of the regular analysis tool to verify that a volume of five microliters is computed. Such kinds of tests can be done for other volumes also, such as ten or 50 microliters.

The resulting recorded curves (stored on the computer and shown on the test reports) are remarkably consistent in their shapes. The magnitude of the recorded response and the length of time the response is seen are consistent among the four channels of a given Q-Sweat™ device, and also consistent from device to device. Using injections of various sizes, one can also determine the linearity of the computed volume measurements.

Additional questions about the accuracy of the device must be investigated in a manner depending on which part of the recording curve one is talking about, and whether one is talking about rate or volume.

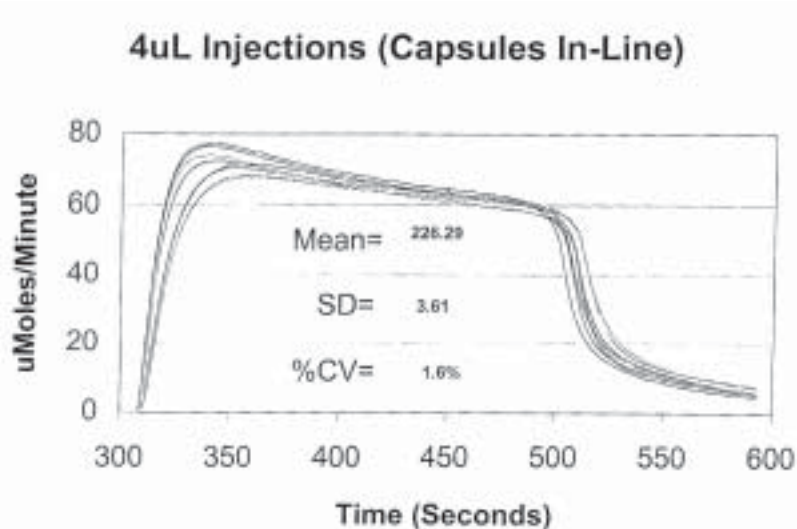


Fig. 14: Above is an example of what a series of multiple and identical Hamilton® syringe injections looks like when recorded by a single channel of a Q-Sweat™ device. Although this example shows a four-microliter injection, a standard five-microliter injection is used to calibrate production units.

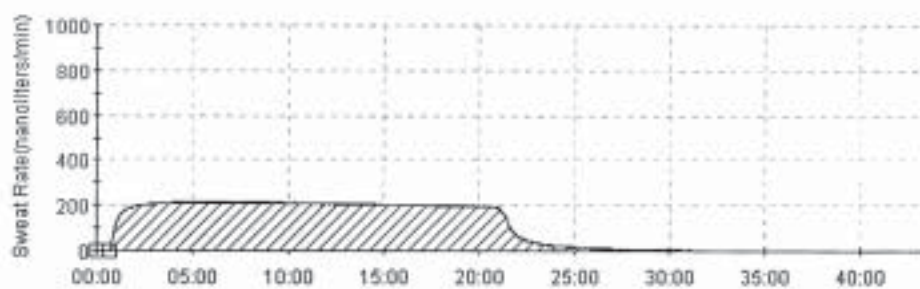


Fig. 15: Above is an example of what a five-microliter Hamilton® injection looks like on a production Q-Sweat™ unit.

Future Developments for the Q-Sweat™

- Future developments of the Q-Sweat™ may include software enhancements allowing you to type into the computer the various characteristics of the skin capsules so that the computer can make all of the calculations.
- Another enhancement may be to provide for the printing of the capsule characteristics and resulting computations on the test reports.
- More snap-on chambers may be designed and validated, eliminating the need to switch hose assemblies for different kinds of tests.
- Adaptors for fitting different capsules to the parking fixture may be added.
- A service bulletin may be written that would describe exactly how to set up your Q-Sweat™ with a refillable laboratory desiccant cylinder, allowing you to run your unit dry for a very long period of time, and allowing you to replace your own desiccant crystals. The modification involves taking the top off of the Q-Sweat™ and then plumbing in the gas drying unit into the system. The connections are simple but must be correctly configured; allowance needs to be made for routing of the tubing through the Q-Sweat™ enclosure to the external gas drying unit. The parts used are:

Drierite Laboratory Gas Drying Unit
Stock No. 26800
Anhydrous Calcium Sulfate (CaSO₄)
W.A. Hammond Drierite Co.
Box 460, Xenia, OH
513-376-2974

Replacement Calcium Sulfate
Stock No. 24001
1 lb. size 10-20 Mesh
W.A. Hammond Drierite Co.
Box 460, Xenia, OH
513-376-2974

- The use of nitrogen gas has been investigated. Because the molecular mass of nitrogen is different from that of room air, the humidity sensors used in this product cannot be used to measure the humidity within a nitrogen gas.
- An ongoing calibration source of extremely low emitted humidity may be found so that additional calibration methods may be employed to determine the accuracy of a given low-level initial rate, so that such rate could be used reliably in medical studies.



Fig. 16: Drierite Cylinder.

GENERAL READING RESOURCES

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