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Biomedical Equipment Journeyman

Volume 2. Medical Terminology, Therapeutic and Related Support Equipment

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THIS SECOND VOLUME of CDC 4A251B, *Biomedical Equipment Journeyman*, pertains to medical terminology, therapeutic equipment, and related support equipment used in the medical facility.

Unit 1 discusses basic medical terminology you are required to know in your career field. The unit is broken down into word components, such as prefixes, suffixes, and root words. These basics are then applied to operative procedures, body movement, and structural relationships. This unit also covers a review of the anatomy and physiology of the cardiovascular, urinary, and musculoskeletal system.

Unit 2 contains an extensive look at the biomedical principles of electrodes and transducers. It also discusses the related physics principles of hydraulics, pneumatics, mechanics, and steam principles.

Unit 3 covers a wide assortment of therapeutic equipment found in patient care areas like the dental clinic, physical therapy, surgery and inpatient departments, and labor and delivery. The equipment covered includes dental operating systems, electrosurgical units, ventilators and anesthesia systems, infusion devices, defibrillators, lasers, dialysis machines, infant care centers, and infant incubators. It also includes related test equipment.

The volume concludes with unit 4, which contains information on therapeutic support elements such as central sterile supply, suction units, and refrigeration systems.

A glossary is included for your use.

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A-dec Inc.	500 series - chair/delivery system/lights manuals	3-1 to 3-4 and 3-7 to 3-12
	Cascade series – chair/delivery systems/lights manuals	3-5 and 3-6
BC Group International	OHMIC Instruments – UPM-DT-xPA Series User Manual 08/15 – Rev 01	N/A Text only
Community Eye Health Journal	"Electrosurgical units – how they work and how to use them safely" licensed by CC BY-NC 4.0	3-34
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	QA-ES III Electrosurgery Analyzer Users Manual PN FBC-0083 December 2015, Rev. 1	3-37
	VT Plus HF Gas Flow Analyzer Operators Manual PN 2137275 May 2008, Rev. 2, 4/09	3-23
	IDA-5 Infusion Device Analyzer Users Manual PN FBC-0039 April 2013, Rev. 2, 10/1	3-43
Laser Safety Facts	Laser Safety Facts website – Laser Classes http://www.lasersafetyfacts.com/laserclasses.html	3-49

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McGraw-Hill Companies, Inc.	Morgan & Mikhail's Clinical Anesthesiology, 5th edition.	3-22, 3-25, 3-28, 3-30, 3-31
T & L Publications, Inc.	Nuts and Volts Magazine - THE 'OPTO' IN OPTOELECTRONICS — Part 4 http://www.nutsvolts.com/magazine/article/the-opto-in-optoelectronics-part-4	3-48

NOTE:

In this volume, the subject matter is divided into self-contained units. A unit menu begins each unit, identifying the lesson headings and numbers. After reading the unit menu page and unit introduction, study the section, answer the self-test questions, and compare your answers with those given at the end of the unit. Then complete the unit review exercises.

Unit 1. Medical Terms, Anatomy and Physiology

THE MEDICAL SERVICE is like any other occupation or profession—members use unique terms and expressions to communicate with one another. Understanding how to properly communicate with hospital staff is vital to interpreting equipment malfunctions or implementing corrective actions. In technical school, you learned the basics of the "language of medicine." This lesson will expand on the concepts of medical terminology and how they relate to anatomy and physiology.

The first section of this unit discusses the elements of medical terminology and how these elements combine to form medical terms. In the second section, we introduce you to medical terms used to describe operations, and to medical reference terms for anatomical relationships and body movement.

1–1. Basic Medical Terms

Before you can become an adept medical linguist, you must learn more about the various components or elements that combine to form medical words, so we start there. This section gives you an understanding of the basic word components that, when put together, form those long, hard-to-pronounce (and spell!) medical terms and expressions.

A great number of the words used in medicine are combinations of units called prefixes, suffixes, and root words. Many of these units, when used alone, may already be familiar to you, but can become increasingly complicated (with very different meanings) when you combine them. Most of our medical words derive from ancient Greek and Latin word components.

The lessons that follow briefly discuss the three major word components, list examples of each, and provide their corresponding definitions. We then show you how these elements combine to form medical terms.

201. Word components

Since you should already have a basic working knowledge of medical word components, the simplest way for you to review them and introduce new ones is to provide you with lists of the common prefixes and suffixes.

Prefixes

Perhaps the best way to begin a discussion on terminology is to analyze the meaning of a prefix, which is a syllable or group of syllables joined to the beginning of a root word to alter its meaning or create another word. You would *always* use a prefix in conjunction with a root word, or with a root word and suffix. They cannot stand alone to form a word or term. With this definition fresh in your mind, carefully study the following list of medically related, common prefixes accompanied by their meaning. We arranged the list in alphabetical order to facilitate review.

Prefix	Meaning
a-, an-	absence of
ab-, abs-	away, from
ad-	to, towards, near
aer-	air
ambi-	both
ante-, antero-	before, forward
auto-	self
bi-	two
bio-	life
brady-	slow
circum-	around
co-, com-, con-	with, together
contra-	against, opposed
de-	from, not
dia-	across, through, apart
deca-	ten
demi-	half
di-	two
dis-	negative, apart
dys-	difficult, painful
ecto-	on the outside
en-	in
endo-	within
epi-	upon
erythro-	red
eu-	well, normal
ex-, e-, exo-	away from, without

Prefix	Meaning
exo-	outside
extra-	outside, beyond
fore-	in front of
glyco-	sugar
hemi-	half
hetero-	other
homo-	same, similar
hydra-, hydro-	water (H_2O)
hyp-, hypo-	below, less
hyper-	above, excessive, over
in-	not, in
infra-	below, beneath
inter-	between
intra-	within
iso-	equal
latero-	side
leuco-, leuko-	white
macro-	large
mal-	bad, disordered
med-	middle
meg-, mego-	great, large
melan-	black
meno-	monthly
meta-	beyond
micro-	small
mono-	single
multi-	many

Prefix	Meaning
neo-	new
non-	not
olig-	little
pan-	all
para-	beside
peri-	around
poly-	many, much
post-	after
pre-	before
pro-	before, in front of
pseud-, pseudo-	false
retro-	backward, behind
semi-	half
sub-	under
super-	above, excess
supra-	over, above
sym-, syn-	with, together
tachy-	fast
topo-	place
tox-	poison
therm-, thermo-	heat
trans-	across, through
tri-	three
ultra-	excess
uni-	one

There are many more prefixes that could go in this list, but the ones provided are a good foundation on which to build your medical vocabulary.

Let's look at one of these prefixes and see how we can use it to make a word. You are probably familiar with the word "biology," but did you ever stop to think where this word came from? Actually, biology is a combination of two Greek words, "bio" meaning "life," and "logy" meaning "the study of or the science of." When you combine "bio" and "logy," you form the word "biology," which means the science or study of life.

Simple, isn't it? "Biology" is just one example of how a prefix combines with other word components to form a term with a definite meaning. If you study (and memorize) the prefixes in the preceding list, you can break down just about any medical term and figure out what it means. Of course, to fully

analyze medical terms and decipher their meaning, you also need to understand the elements of medical language that appear at the tail end of a word—suffixes.

Suffixes

A suffix is a syllable or group of syllables added at the end of a word or word's base to change its meaning, give it grammatical function, or form a new word. You can use a suffix in combination with a prefix and a root word, or just with a root word. The following table contains a listing of common suffixes, along with their corresponding meanings, used to form medical terms.

Suffix	Meaning
-algia	pain
-asis	condition (usually abnormal)
-asthenia	weakness
-biotic	living matter
-cele	tumor, cyst, hernia
-centesis	puncture and aspiration of
-cide	causing death
-cyte	cell
-desis	binding or fusion
-ectasis	dilation, stretching
-ectomy	removal of
-emia	blood
-esthesia	feeling, sensation
-gene	production, origin
-genic	producing
-gram	a tracing or mark
-graph	a writing or record
-graphy	making a recording
-iasis	condition of
-iatry	treatment of a disease
-ism	a condition
-itis	inflammation
-ize	to treat by a special method

Suffix	Meaning
-malacia	softness, softening
-megaly	enlargement
-meter, -metry	measurement, measuring instrument
-oid	form, shape, resemblance
-oma	tumor
-osis	process (usually disease)
-pathy	disease, suffering
-penia	lack or reduction in number of
-pexy	fastening, fixation
-phagia, -phagy	relating to eating and swallowing
-phasia	ability to express one's self primarily by speech, also by gestures or writing
-phobia	an exaggerated fear
-plasty	surgical reshaping or remodeling
-plegia	paralysis
-poiesis	formation of
-ptosis	falling, sagging, or dropping down
-rhage, -rhagia, -rrhage, or -rrhagia	excessive flow, breaking or bursting forth
-rhaphy or -rrhaphy	a suturing or sewing together
-rhea or -rrhea	flow, discharge
-scope	examination instrument (usually lensed and lighted)
-scopy	act of examining; visual examination using a scope
-stasis	a standing still
-stomy	to create an opening

Suffix	Meaning
-ilith	stone or calculus
-logy	science or study of
-lysis	destruction of, decomposition

Suffix	Meaning
-tomy	incision or cutting into
-uria	relating to urine

Although limited, this list contains enough suffixes to strengthen your growing vocabulary. If you remember many of the suffixes from your technical school lessons, you can probably move very quickly through this segment on to less familiar material. Just remember, it does not hurt to review, so don't go too fast! Now, let's see how we can use these suffixes to form a medical term.

Let's take the prefix "an-" meaning "absence of" and couple it with the suffix "-esthesia" meaning "feeling or sensation." If you put them together, you get the word "anesthesia" meaning "absence of feeling or sensation." That is the perfect description of the use of the word in surgery. Now, let's try something a bit harder. If "tracheo" refers to your trachea or throat area, how would you change it to mean "a surgical incision into the trachea or throat"? If you look through the preceding list, you see the suffix "-tomy" (or "-otomy") means "incision or cutting into." To make the word you want, simply add one of these suffixes to the root word "tracheo." The term you form by combining the two elements is "tracheotomy," which basically means a "surgical incision into the throat or trachea."

You probably noticed there is very little difference between the meanings of some of these suffixes, but that there is a significant difference in the spelling (and use). It is very important to pay particular attention to learning the subtle differences so you will not become confused and misinterpret a term.

Study these word endings closely and notice how they are used in day-to-day verbal and written communications so you can avoid mixing them up. No discussion of medical terminology would be complete without mentioning the elements that form the "heart" of medical terms—root words.

202. Root words

With the definitions of medical prefixes and suffixes fresh in your mind, you now have the basis for becoming proficient in the language of your profession. However, to become more familiar with terms that apply to human anatomy and physiology, you need a knowledge of commonly used medical root words.

A root word means the main part or portion of a word from which you can form other words by the addition of a prefix, suffix, or both. When two root words combine or when adding a suffix to a root word, it is very common to add a vowel. This combining vowel is usually an "o" or an "i," but a "u" is also sometimes used. This combining vowel helps make pronunciation easier when there is no vowel between the two root words, or between the root word and suffix. The following alphabetical list of root words and their definitions relate to the human body and body processes. You will find the most common combining vowel shown in parentheses.

Root Word and Common Vowel	Definition
acou(i)	hearing
aden(o)	gland
adren(o)	adrenal gland
angi(o)	vessel (blood)
arteri(o)	artery
arthr(o)	joint

Root Word and Common Vowel	Definition
gyn(e), gynec(o)	woman
hem(a),(o) hemat(o)	blood
hepat(o)	liver
hydr(o)	water
hyster(o)	uterus
ile(o), ili(o)	ileum

Root Word and Common Vowel	Definition
phleb(o)	vein
physi(o)	relating to nature/life
pneum(o)	lung or air
proct(o)	rectum
psych(o)	mind, soul
pulm(o)	lung

Root Word and Common Vowel	Definition
audi(o)	pertaining to hearing
bil(i)	relating to bile
blephar(o)	relating to an eyelid or eyelash
brach(i)	arm
bronch(o)	pertaining to a bronchus or the bronchi
calcane(o)	heel
card(i)(o)	pertaining to the heart
carp(o)	wrist
cephal(o)	capit head
cervic(o)	neck
chol(e)(o)	bile
chol(e)cyst	gallbladder
chondr(o)	cartilage
col(o)	colon (large intestine)
colp(o)	vagina
cost(o)	rib
crani(o)	skull
cyst(o)	urinary bladder, cyst
cyt(o)	cell
dactyl(o)	finger or toe
dent(o)	relating to a tooth or the teeth
derm(a)	skin
doch(o)	duct
duoden(o)	duodenum
encephal(o	brain
enter(o)	intestines
fibr(o)	fiber, fibrous
gastr(o)	stomach
gen(u)	knee
gloss(o)	tongue

Root Word and Common Vowel	Definition
jejun(o)	jejunum
kerat(o)	cornea
kinesi(o)	movement
lapar(o)	abdomen, loin, or flank
laryng(o)	larynx
later(o)	side
lip(o)	fat
lith(o)	stone
lymph(o)	watery fluid from a special gland
mamm(o)	breast, mammary gland
mast(o)	breast, mastoid process
mening(o)	membrane
men(o)	menstruation
metr(a)(o)	uterus
myel(o)	bone marrow, spinal cord
my(o)	muscle
nas(o)	nose
necr(o)	death
nephr(o)	kidney
neur(o)	nerve
ocul(o)	eye
oophor(o)	ovary
ophthalm(o)	eye
opt(o)	relating to vision
orchi(o)	testicle
orth(o)	straight, normal, correct
os	bone or opening
oste(o)	bone
ot(o)	ear
path(o)	relating to

Root Word and Common Vowel	Definition
py(o)	pus
pyel(o)	relationship to renal pelvis of the kidney
rect(o)	rectum
ren(i)	kidney
rhin(o)	nose
sacr(o)	sacrum (vertebrae)
salping(o)	tube (i.e. uterine, fallopian or auditory)
sarc(o)	flesh (skeletal muscle tissue)
splen(o)	spleen
spondyl(o)	vertebrae, spine
sten(o)	narrow, constriction
stern(o)	sternum
stomat(o)	mouth
ten(o), tenent(o)	tendon
therm(o)	heat
thorac(o)	chest, thorax
thromb(o)	clot, thrombus
thyr(o)	thyroid gland
tox(o)	poison
toxic(o)	poison, poisonous
trache(o)	trachea
trachel(o)	cervix
ureter(o)	ureters
urethr(o)	urethra
ur(o), urin(o)	relating to urine or urinary organs
uter(o)	uterus
vas(o)	blood vessel, vas deferens
ven(o)	vein
ventr(i)(o)	abdomen
vertebr(o)	spine, vertebrae

Root Word and Common Vowel	Definition
gluc(o)	glucose, sweetness
glyc(o)	sugar

Root Word and Common Vowel	Definition
	disease
ped(o)	child, foot
pharyng(o)	pharynx

Root Word and Common Vowel	Definition
vesic(o)	urinary bladder

As with the prefixes and suffixes previously listed, this list of root words is not all-inclusive.

If you take the time to learn the elements of medical terminology presented in this section, you should be able to look at most medical terms and figure out what they mean, or at least be in the ballpark! When you put all of these word components together in different combinations, you formulate the words and expressions that are an integral part of everyday communication between members of the health care delivery team.

203. Common terms

In addition to the elements already presented, you must become familiar with terms medical personnel use to describe anatomical movement and structural relationships. After studying the information in this section and combining it with what you already know about medical terminology, you should have a good command of our unique language. This lesson in this section will expand your knowledge of terms that describe body movement and directions.

Terms that describe body movement

Most of the terms used to describe movement of body parts relate to the action that occurs when the extremities, or their component parts, move. You will need to know these terms to fully understand the lessons in this volume that deal with the musculoskeletal system.

The following terms describe the relative movement of body parts and commonly describe the range of motion of the extremities at their joints. As you study these terms, refer to figure 1–1 so you can understand the motion that the text describes.

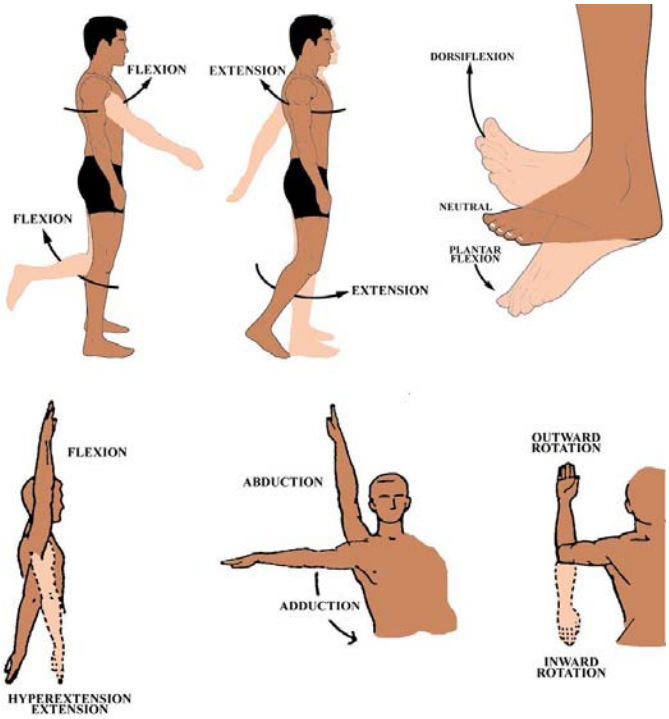

Figure 1–1. Examples of range of motion.

- Range of motion (ROM) – the range, measured in degrees of a circle, through which a body part can rotate, extend, or flex at a joint.
- Longitudinal axis – a line that passes lengthwise through a portion of the body or a bone. It divides the part equally and symmetrically. For example, rotation of the arm occurs around the long (longitudinal) axis of the humerus (the bone in the arm between the shoulder and elbow).
- Axis of joint rotation – a line projecting at right angles to the plane of motion. The axis of rotation for most joints changes with the motion of the joint due to the joint's structure and variety of angles in which it can move. The axis of joint rotation is also called the fulcrum.
- Rotation – a joint motion whereby a part moves or turns about its longitudinal axis. When you move your head from side to side looking for traffic before crossing a street, you are rotating your head on its axis.
- Circumduction – a movement whereby the distal end of a part (the end farthest from the point of origin) makes a circle while the rest of the part outlines a cone. This is the type of movement you create when you do an arm circle or "head roll" calisthenics as part of a warm-up routine.
- Supination – the movement that rotates the forearm outward so the palm of the hand faces forward. To make this a bit clearer, stand with your arms hanging loosely by your side, and then rotate your forearms so the palms of your hands face forward. This is the normal or standard anatomical position (fig. 1–2). Remember this term because we often refer to it when discussing anatomical terms of reference.

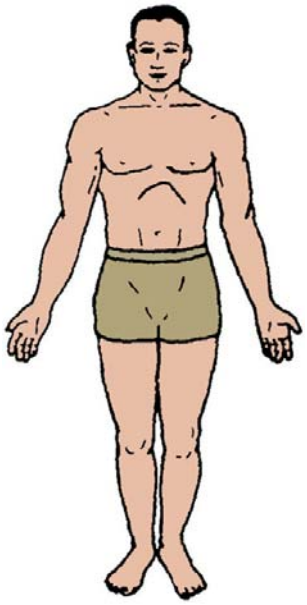

Figure 1–2. The normal anatomical position.

- Pronation – this movement is the opposite of supination. It rotates the forearm inward, causing the back of the hand to face forward (when your arms are in the normal anatomical position).
- Flexion – a motion described when adjacent body parts approach each other, thereby decreasing the angle between them. More simply stated, flexion is the act of folding, bending, or withdrawing a body part. When you move your forearm up towards your biceps muscle (as in doing a "curl" with free weights), you are "flexing" your forearm using the action of "flexion." Two other examples of flexion are moving your head forward so your chin rests on your chest, and bending your torso forward at the waist.

- Dorsiflexion – a special type of flexion used to describe ankle and foot movement where the top or dorsal surface of the foot moves closer to the leg, causing the angle between the leg and foot to decrease (just as you would in a calf stretch). The foot is in a neutral position when it is level or at a right angle to the leg.
- Plantar flexion – another special type of flexion used exclusively to describe ankle/foot movement. It occurs when the ankle moves so the bottom or plantar surface of the foot moves away from the leg, and the angle between the hind foot (heel) and the backside of the leg decreases, as when you "point" your toes. The reason that we do not refer to this movement as a foot extension is primarily because the heel portion of the foot actually moves closer to the leg. Therefore, this movement is not actually an extension because the angle between the entire foot and leg does not increase (as it does in a leg or arm extension). As a result, we are left with exceptions where foot movement is concerned, and developed two subcategories of flexion referenced to the dorsal and plantar surface of the foot—dorsiflexion and plantar flexion.
- Extension – a movement that increases the angle between two adjacent body parts, or a movement that brings the members (subparts) of an extremity into or toward a straight condition. Extension is the exact opposite of flexion. It returns a flexed part to its normal anatomical position. When you extend a body part, you straighten or stretch it. For example, when you straighten out a flexed forearm, you "extend" it. Another example is when you move your hand in line with your forearm from a flexed ("limp wrist") position.
- Hyperextension – a type of extension whereby a body part extends or stretches beyond its normal anatomical position. For instance, when you move your head backwards from its normal upright position, you are hyperextending it. Hyperextension also occurs when you move the back or topside of your hand closer to your forearm, away from the normal anatomical position (hand in line with the forearm).
- Abduction – movement of a body part away from the midline or medial plane of the body (more on planes later). For example, when you raise an arm from hanging at your side to shoulder level, you are abducting it. You can remember this term by identifying its prefix, "ab," which means "away from." (If all else fails, remember the word "ab/duct," which means "take away."
- Adduction – the opposite of abduction. This movement brings a body part closer to the midline or medial plane of the body. An example of this movement is lowering the arm from your shoulder to hanging by the side of the body. You can easily remember this term by identifying its prefix, "ad," which means "toward" (as in advance).
- Inversion – a special term used solely (pun intended) to describe the movement that turns the sole of the foot inward.
- Eversion – another special term used to describe the movement required to turn the sole of the foot outward.
- Protraction – movement of a body part forward, as in jutting out your jaw (pushing the chin forward).
- Retraction – the opposite of protraction. Retraction moves a protracted part backwards or inwards, closer to the middle of the body.

Now that you have a handle on the terms that describe body movement, it is time to wrap up this lesson by discussing the last category of terms you need to know—the ones used to describe the structural or positional relationships between different body parts.

Terms that describe anatomical relationships

These terms will help you understand directions and positions with regard to specific points on the human body. Look at figure 1–3 for clarification.

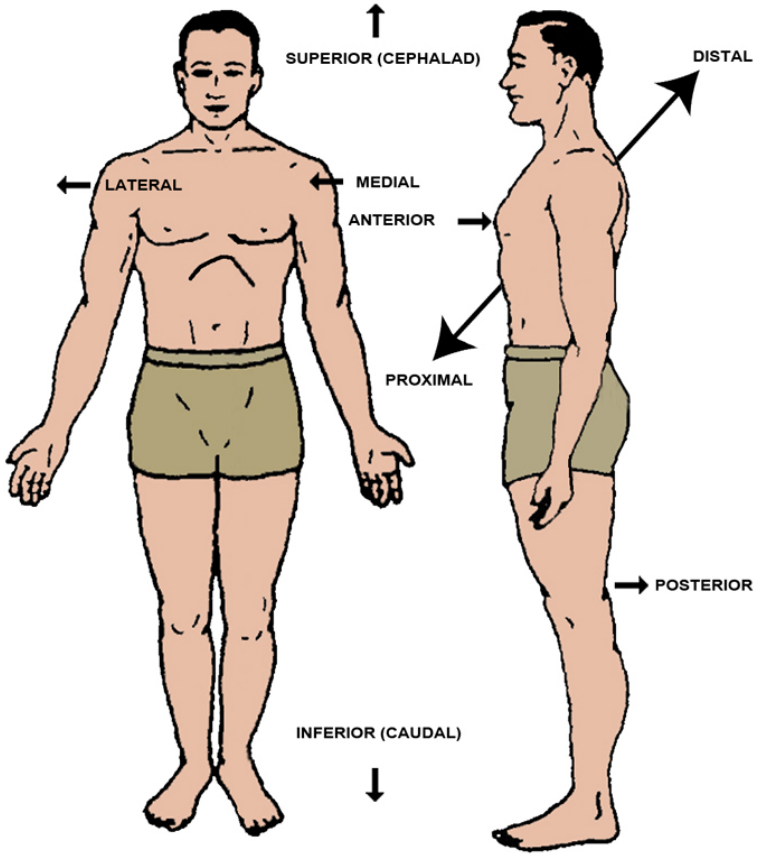

Figure 1–3. Terms of direction.

- Anterior (ventral) – toward or near the front side of the body (i.e., the eyes are anterior to the ears, and the rib cage is ventral to the heart).
- Posterior (dorsal) – toward or near the back side of the body (i.e., the spine is posterior to the ribs, and the buttocks are dorsal to the groin).
- Medial – toward or near the midline of the body (i.e., the umbilicus or navel is medial to the hips, and the chest is medial to the head).
- Lateral – away from the midline or toward the right or left sides of the body (i.e., the hips are lateral to the umbilicus, and the arms are lateral to the torso).
- Superior (cephalad) – toward the head or upper part of the body. In other words, a part above or closer to the head than another part (i.e., the head is superior to the torso, and the pelvis is cephalad to the legs).
- Inferior (caudal) – toward the feet or lower part of the body. Put differently, a part below or closer to the feet than another part (i.e., the neck is inferior to the head, and the buttocks are caudal to the chest).
- Proximal – toward or closer to the point of origin, usually in terms of the trunk of the body. Stated in a different manner, a part closer than another part to any given point of reference, usually the trunk or midline of the body (i.e., the elbow is proximal to the wrist, and the knees are proximal to the ankles).

- Distal – away or farther from the point of origin. A part farther from a given point of reference than another part—once again, usually the trunk or midline (i.e., the nose is distal to the face, the fingers are distal to the wrist, and the thighs are distal to the pelvis).
- Internal (deep) – toward the inside of the body or a body part (i.e., the intestines are internal as compared to the muscles of the abdominal wall, and the dermis is the deep or most internal layer of the skin).
- External (superficial) – toward the outside (surface) of the body or a body part (i.e., the mouth is an external opening in the body, and the epidermis is a superficial tissue layer).
- Peripheral – also means outward from the center of the body or closer to the body surface. This term often describes small arteries, veins, and nerves that branch off from larger, more centrally located structures (i.e., the spinal nerves that branch off from the spinal cord are part of the peripheral nervous system, and surgery on the arteries supplying the arms and legs is peripheral vascular surgery.)

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

201. Word components

1. Define prefix.

2. When are prefixes used alone to define a word or system?

3. Match the prefix in column B with its definition in column A. Items in column B may be used only once.

Column A	*Column B*
____ (1) With, together.	a. an-.
____ (2) White.	b. bio-.
____ (3) Difficult.	c. dys-.
____ (4) Red.	d. erythro-.
____ (5) Life.	e. glyco-.
____ (6) Little.	f. infra-.
____ (7) Absence of.	g. leuko-.
____ (8) Black.	h. co-.
____ (9) Sugar.	i. melan-.
____ (10) Excess.	j. olig-.
____ (11) Below, beneath.	k. para-.
____ (12) Beside.	l. retro-.
____ (13) Over, above.	m. supra-.
____ (14) Backward, behind.	n. tachy-.
____ (15) Fast.	o. ultra-.

4. Define suffix.

5. Match the suffix in column B with its definition in column A. Items in column B may be used only once.

Column A	*Column B*
____ (1) To create an opening.	a. -algia.
____ (2) Incision or cutting into.	b. -centesis.
____ (3) Puncture and aspiration of.	c. -ectomy.
____ (4) Removal of.	d. -esthesia.
____ (5) Act of examining.	e. -lysis.
____ (6) A suturing or sewing together.	f. -megaly.
____ (7) Excessive flow.	g. -pexy.
____ (8) Surgical reshaping or remodeling.	h. -plasty.
____ (9) Fastening/fixation.	i. -rhagia.
____ (10) Decomposition.	j. -rhaphy.
____ (11) Enlargement.	k. -scopy.
____ (12) A standing still.	l. -stasis.
____ (13) Feeling, sensation.	m. -stomy.
____ (14) Pain.	n. -tomy.

202. Root words

1. Define the term “root word.”

2. What is the purpose of a combining vowel?

3. Match the root word in column B with its definition in column A. Items in column B may be used only once.

Column A	*Column B*
____ (1) Vein.	a. acou(i).
____ (2) Hearing.	b. bronch(o).
____ (3) Pertaining to the heart.	c. cardi(i).
____ (4) Pertaining to a bronchus or bronchi.	d. chondr(o).
____ (5) Skin.	e. colpo.
____ (6) Cell.	f. cyt(o).
____ (7) Blood.	g. dactyl(o).
____ (8) Muscle.	h. derma.
____ (9) Stone.	i. enter(o).
____ (10) Bone.	j. hemat(o).
____ (11) Vertebrae, spine.	k. kerat(o).
____ (12) Cartilage.	l. lith(o).
____ (13) Finger or toe.	m. my(o).
____ (14) Intestines.	n. oste(o).
____ (15) Cervix.	o. pondyl(o).
____ (16) Vagina.	p. trachel(o).
____ (17) Cornea.	q. ven(o).
____ (18) Urinary bladder.	r. vesic(o).

203. Common terms

1. Define each of the following terms used to describe body movement:

   a. Range of motion.

   b. Circumduction.

   c. Supination.

   d. Flexion.

   e. Hyperextension.

   f. Abduction.

   g. Inversion.

   h. Protraction.

2. Define each of the following terms used to describe anatomical relationships:

   a. Anterior.

   b. Medial.

   c. Superior.

   d. Distal.

   e. Peripheral.

1–2. Related Anatomy and Physiology

This section presents the anatomy and physiology of systems related to therapeutic equipment. The systems covered are the respiratory, cardiovascular, urinary, and musculoskeletal.

We begin with the respiratory system, which includes the structures involved with the exchanges of gases. We call this exchange of gases respiration or breathing. Our bodies require a constant supply and exchange of these gases to carry on the chemical processes vital to life.

Next, we discuss the cardiovascular system, which is comprised of the heart and blood vessels. A system of arteries, veins, and capillaries direct blood flow in and out of the heart to supply oxygen and other nutrients needed to sustain life.

Then we dive into the urinary system, which includes organs associated with the production and elimination of waste. This system consists of the kidneys, ureters, urinary bladder, and urethra.

The last lesson covers the musculoskeletal system. The skeletal system provides the framework for the body, while the muscles provide movement for this framework. This system consists of bones, joints, muscles, tendons, ligaments, and cartilages.

204. The respiratory system

As you probably already know, the respiratory system consists of the nose, pharynx, larynx, trachea, bronchi, lungs, and pleurae. Accessory organs, which make breathing possible, are the thorax, ribs, diaphragm, and intercostal muscles.

Organs of the respiratory system

Let's look at each organ that deals directly with breathing.

Nose

The nose is a framework of bone and cartilage with an external covering of skin. The two external openings are nostrils. They form the nasal cavity, which divides into two parts by way of the nasal septum. The palate also separates the cavity from the mouth. Bones of the skull and face form the roof of the nasal cavity, which is lined with a mucous membrane. As air passes through the nasal cavity, it contacts the mucous membrane, which warms and moisturizes the air. Filtering of the air also takes place here; minute hair-like structures called cilia catch large foreign particles. The cilia cause wavelike movements of particles from the anterior part of the nose to the pharynx. From there, the foreign particles leave the nose in one of two ways: expelling from the mouth or swallowing.

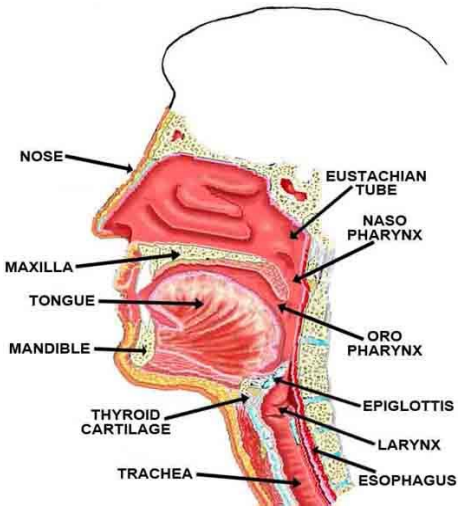

Figure 1–4. Upper respiratory structures.

Pharynx

The pharynx, or throat, is the passageway between the nasal chambers, nose, and larynx. Figure 1–4 shows the upper respiratory system. The pharynx consists of three parts—the nasopharynx, oropharynx, and laryngopharynx (latter not shown in figure).

The nasopharynx is the superior portion of the pharynx and contains the two eustachian tubes that communicate with the middle ear. These tubes permit the equalization of air pressure between the middle ear and the outside atmosphere.

The oropharynx is directly posterior to the mouth and contains the regular or palatine tonsils. The only known function of the tonsils is the formation of lymphocytes. The tonsils are often prone to infection, resulting in tonsillitis. A tonsillectomy is the removal of the tonsils by surgical excision.

The laryngopharynx contains an anterior opening into the larynx and a posterior opening into the esophagus. The esophagus is the passageway for food.

Larynx

The larynx, or "voice box," is a passageway from the pharynx to the trachea. It is a triangular, cartilaginous structure composed of nine cartilages joined together by ligaments. It lies in the middle of the neck, between the base of the tongue and the trachea. To prevent food from entering the trachea during the act of swallowing, the larynx moves upward and forward until it is under the base of the tongue. This action causes the epiglottis, a cartilaginous flap lying above the larynx, to move back and downward, directing the food into the esophagus.

The larynx is composed of three single and three paired cartilages. The largest of these is the thyroid cartilage. It is butterfly-shaped and forms the large prominence known as the Adam's apple.

Trachea

The trachea, or windpipe, extends from the larynx and terminates when it divides into the right and left bronchi. Look at the lower respiratory system in figure 1–5. The trachea is a cylindrical tube composed of 16 to 20 C-shaped cartilage rings. They give it firmness and prevent its collapse. Cilia and mucous glands, which help entrap dust and foreign matter, line the trachea.

Bronchi

The trachea divides into two primary bronchi that convey air from the trachea to the lungs. After entering the lungs, each bronchus divides and sends branches to each lobe of the lungs—three to the right and two to the left. From there, they further divide into many small branches called bronchioles. These bronchioles go to the alveoli, or air sacs, of the lungs. The alveoli are adapted for easy passage of gases to and from the lung capillaries.

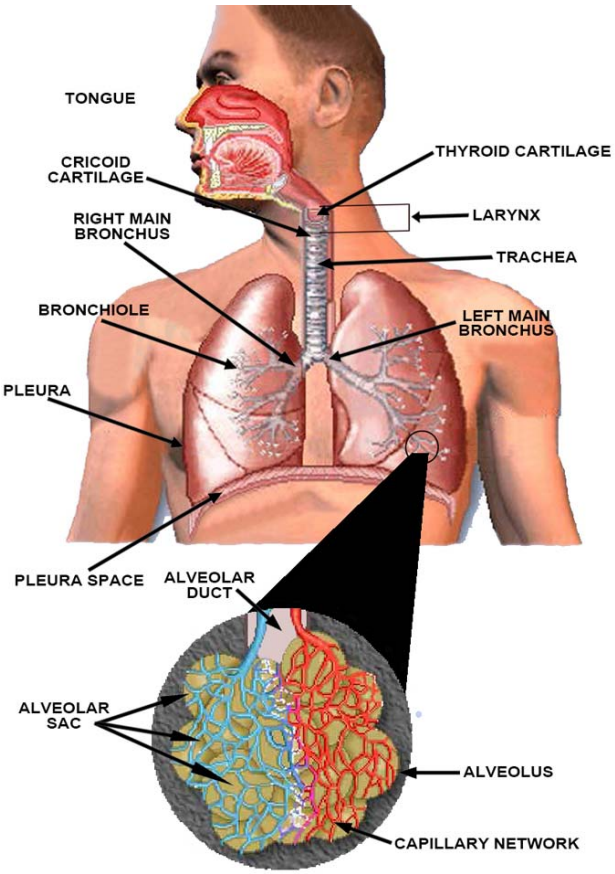

Figure 1–5. Lower respiratory structures.

Lungs

The lungs are the primary organs of respiration. They permit the interchange of gases between the blood and the air. The lungs are inside the thoracic cavity and enclosed in pleura. The right lung contains three lobes; the left contains two lobes. The lungs are soft and spongy, and constantly change their form with each respiratory movement.

Diffusion

A process that takes place in the lungs is diffusion, the equalization of gases (oxygen [O_2] and carbon dioxide [CO_2]) between the blood and air. Each lung contains thousands of tiny alveoli with blood capillaries in their membrane lining. Here, O_2 theoretically exchanges for CO_2. This exchange also takes place between the capillaries and tissues of the body. The lungs or body tissue cannot store oxygen, so there is a continuous equalization or exchange of gases. Inhaled air contains about 20 percent O_2 and .03 percent CO_2. Exhaled air contains about 16 percent O_2 and 4 percent CO_2.

Pleurae

Double-walled, serous membranes, called the pleurae, encloses the lungs. Each lung has a separate pleura (fig. 1–6). The membrane or sac covering the outer surface of the lung is the visceral pleura, and the layer lining the chest wall is the parietal pleura. The area between these two layers is the intrathoracic or pleural space. However, this is only a potential space since both pleural membranes are in very close contact with one another. The only substance separating them is a small amount of pleural fluid, secreted by the membrane. This pleural fluid reduces friction between the two pleural layers during movements of respiration.

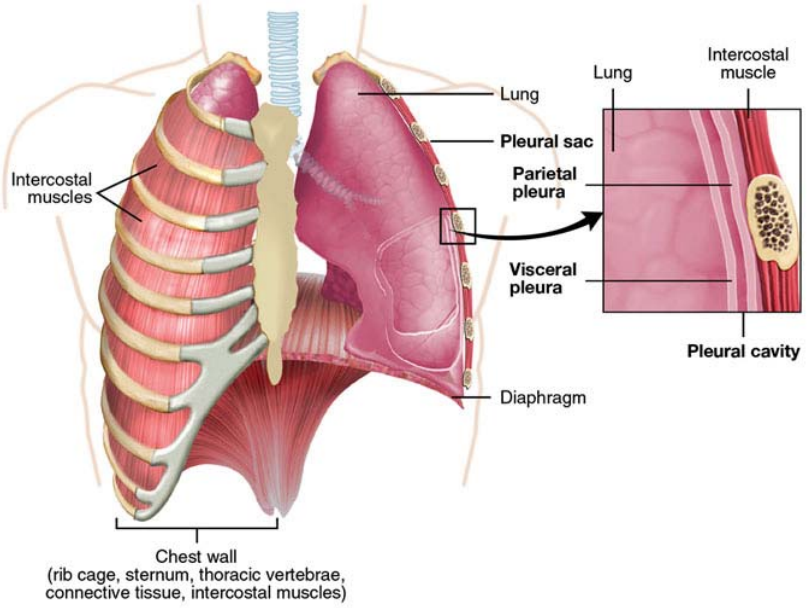

Figure 1–6. Pleura.

What causes us to breathe?

The simple process of breathing (inspiration and expiration) is far more complex than it appears. It is a harmonious interplay of nerve impulses, muscular activity, and mechanical pressure changes influenced by chemical changes in the blood. The inflation of the lungs occurs because the muscles of respiration—the diaphragm and intercostal muscles—contract.

Inspiration and expiration

In the act of inspiration, the intercostal muscles contract and help to enlarge the size of the thorax; the ribs move forward and slightly upward, increasing the front-to-back dimensions of the thorax. There

is a slight increase in the side-to-side dimensions at the same time. This mechanical change, combined with the downward movement of the diaphragm, enlarges the thorax and produces a pressure decrease in the intrathoracic space, the potential space between the surface of the lungs and the internal lining of the thorax. Since the lungs are inside the thorax, and the interior of the lungs are open to the atmospheric pressure outside the body, atmospheric pressure forces air through the conducting passages and into the alveoli. When inspiration is complete, the muscles of inspiration relax. Because of the elasticity of the chest wall and lungs, expiration occurs.

Breathing is normally an involuntary act controlled by the nervous system. A diffuse group of nerve cells, known collectively as the respiratory center, is in the medulla oblongata. The nerve impulses, which cause the muscles of respiration to contract, originate in the cells of the respiratory center. These impulses reach the respiratory muscles by two sets of nerves—the phrenic and intercostal. The phrenic nerves pass down into the thorax to the diaphragm. The intercostal nerves leave the spinal cord in the upper region of the back and pass to the intercostal muscles. Nerve impulses from the walls of the alveoli return to the respiratory center through two vagi—nerves that pass upward through the thorax and neck to the medulla.

At the particular time when the lungs inflate and the walls of the alveoli stretch to the maximum for the needs of the body, nerve impulses return to the respiratory center and stop the impulses to the muscles of respiration. Passive expiration then follows.

The controlling factor is not the O_2 requirement, as you might think, but the CO_2 level in the blood. For example, exercise increases our use of O_2 and increases the amount of CO_2 produced. The increase in CO_2 is the factor that causes a person to begin breathing faster and deeper. This increased rate of breathing results in bringing more O_2 into the body to meet the new O_2 requirements. Under such circumstances, the respiratory center responds by stimulating the nerves controlling respiratory movements; the respiratory rate increases and the body rids itself of the excess CO_2.

The average normal rate of breathing of an individual at rest is 14 to 18 times per minute. This rate is adequate to provide our body with the correct amount of O_2 needed for the metabolic requirements of the cells and for the elimination of the CO_2 produced. It is evident our breathing rate increases when we exercise and slows down when we sleep. So naturally, our need for O_2 increases during exercise and decreases during sleep.

The lungs hold about 6 liters of air when filled to capacity. Only .5 liter of this total volume enters and leaves the lungs at each natural respiration. This is tidal air. The volume of air that can be taken in by maximal inspiratory effort (over and above tidal air), and then expelled by the strongest possible expiratory effort after the tidal air has been allowed to escape naturally is the expiratory reserve. The sum of the tidal air and the inspiratory and expiratory reserves is the vital capacity. The volume of air that remains in the lungs after the strongest possible expiratory is the residual air. These are all common terms and values when dealing with ventilator and anesthesia units, which we will cover later in this volume.

Types of breathing

The way the patient is breathing determines which piece of therapy equipment, if any, would be most appropriate. Here are some of the terms used to describe the various types of breathing:

- Apnea is a temporary cessation of breathing. It tends to occur in newborn infants or in early asphyxia requiring the administration of artificial respiration and O_2 to restore breathing.
- Dyspnea is a shortness of breath, or labored or difficult breathing. The reason for this is a deficiency in the O_2 content of the body. Obstructions, congestion, pressure on the diaphragm, or any inflammatory condition of the chest can cause it.
- Hyperventilation is a condition in which breathing is abnormally prolonged, rapid, and deep, also referred to as O_2 poisoning. It sometimes happens under conditions of emotional stress,

pain, or fright. Its cause is usually psychological, rather than physical. The patient begins over-breathing and ventilating his or her lungs beyond the requirement to eliminate CO_2.

- Rales are abnormal respiratory sounds that are moist or dry, depending upon the amount of fluid in the air passages. You can usually hear them with a stethoscope or feel them by placing your hand on the chest wall. When you hear them with the naked ear, they are usually moist or noisy respirations.
- Asphyxia is suffocation. It is produced by O_2 starvation—a result of too little O_2 and too much CO_2 in the blood. It can result from anything that interferes with the combining of O_2 with the blood. Do you know what would happen if you close the garage door and start the engine of your car? The exhaust from your car contains a colorless and very poisonous gas called carbon monoxide. This gas combines with the air you breathe, affecting the ability of your blood to carry O_2. Of course, prolonged exposure to it results in asphyxia and death.

205. The cardiovascular system

One part of the circulatory system is the cardiovascular system, which comprises the heart and blood vessels. The heart propels blood through the blood vessels—a system of closed tubes composed of arteries, capillaries, and veins.

The heart

The heart is a hollow, muscular pump that lies in the middle portion of the chest, called the mediastinum, and slightly to the left side. The right and left lungs flank the heart. The sternum provides anterior protection, while the vertebral column provides posterior protection. The heart is about the size of a large fist. It is cone-shaped with the apex directed downward and to the left. A fibrous sac called the pericardium contains the heart. The serous inner layer of the pericardium normally allows free cardiac motion. This pericardium has two layers: the visceral and parietal pericardium. The space between these two layers contains pericardial fluid, which prevents external trauma from directly affecting the heart.

Components of the heart

The heart is composed of three separate layers of tissue—the epicardium, myocardium, and endocardium. The outer layer, the epicardium, covers the surface of the heart and is also the visceral layer of the pericardium. The myocardium is the muscle portion of the heart. The endocardium, or innermost layer, is a thin layer of tissue that lines the inside of the heart and covers the cardiac valves. Refer to figure 1–7 as you study this section.

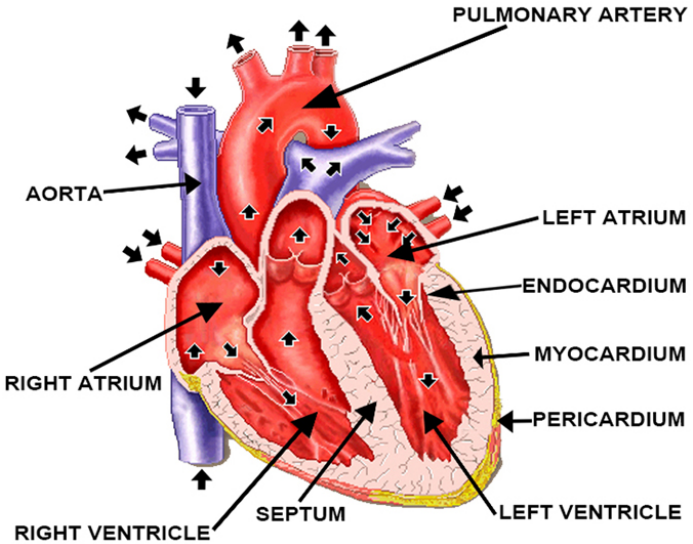

Figure 1–7. The heart.

The interior of the heart divides into a right and left portion by a septum (a dividing wall or partition). In each half, there is an upper chamber (the atrium) and lower chamber (the ventricle). The atrium receives blood from the veins; the ventricle receives blood from the atrium and pumps it out into the arteries. The openings between the chambers on each side of the heart have one-way valves that prevent a backward flow of the blood. The valve on the right is the tricuspid valve; the one on the left is the bicuspid or mitral valve (fig. 1–8). The outlets of the ventricles have similar valves. On the right, the pulmonary valve is at the origin of the pulmonary artery; on the left, the aortic valve is at the origin of the aorta.

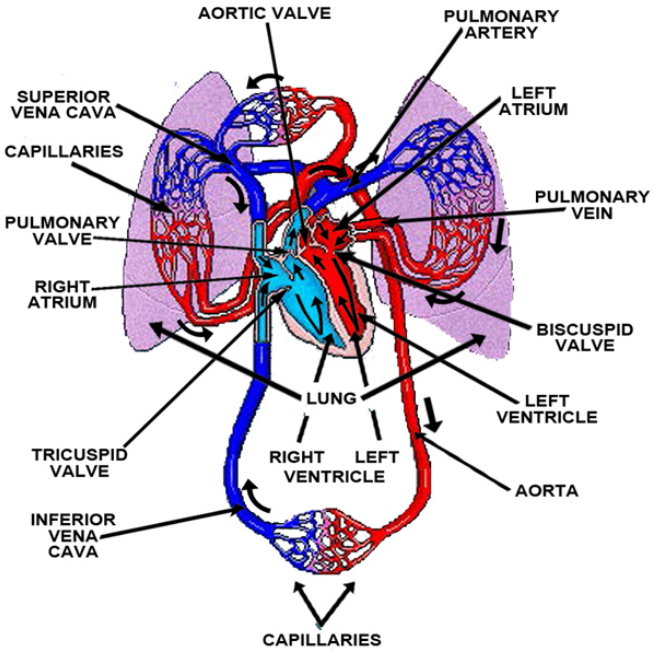

Figure 1–8. Circulation.

Physiologically, the heart acts as two separate pumps. The right side receives deoxygenated blood into the atrium from the various regions of the body. Then, the ventricle pumps it into the lungs, where it receives a fresh supply of O_2 and gives off CO_2. This phase is the pulmonary circulation. The left side of the heart receives the oxygenated blood from the lungs. It enters the atrium, passes down through the mitral valve into the ventricle. The ventricle then pumps it into all regions of the body through the arteries. This phase is the systematic circulation.

Limited relaxation follows each contraction of the heart. The cardiac muscle never completely relaxes, but always maintains a degree of tone. Contraction of the heart is systole and is the period of work; relaxation of the heart is diastole and is the period of rest. A complete cardiac cycle is the time from the onset of one contraction or heartbeat to the onset of the next.

The heart has its own system of blood vessels: the right and left coronary arteries. These arteries branch out from the aorta as soon as blood leaves the heart and the coronary sinus, which collects the venous blood from the heart and empties it directly into the right atrium.

The “electrical pacemaker” (sinoatrial [SA] node) inside the heart stimulates and maintains the contractions of the heart. Heart action can be changed by regulatory impulses from the central nervous system. The nervous system connects with the heart through two different sets of autonomic nerves: the parasympathetic and sympathetic. Parasympathetic stimulation decreases all activities of the heart, allowing the heart to rest at the same time the remainder of the body is resting. Sympathetic stimulation increases the activity of the heart as a pump. It is a standby mechanism held in readiness to make the heart beat with extreme vigor when necessary.

Reduced blood flow through the muscle fibers of the heart stimulates the sensory nerve fibers of the heart and produces the sensation of pain. The lower cervical and upper thoracic nerves supply the neck, jaw, shoulders, and arms. Nerve impulses leaving the pain-sensitive areas in and around the heart pass to the ganglia in the spinal cord at the lower two cervical and upper four thoracic levels. This explains why cardiac patients complain of pain in the neck, jaw, shoulders, and arms. You must remember nerve impulses from pain-sensitive areas in the heart reach the brain before you experience the sensation of pain (angina pectoris).

Electrical activity of the heart

Adequate circulation of blood through the body depends on the proper sequence of contractions of the chambers of the heart. Electrical impulses generated within the heart are what trigger the contractions. A small specialized area of heart tissue called the SA node, located in the function between the right atrium and the superior vena cava, is responsible for initiating cardiac contractions (fig. 1–9). The basic rhythm of the heart is self-sustaining by the synchronization pulses from the SA node. However, external nerve fibers reacting to an increased or decreased demand for blood by the body can change the rhythm.

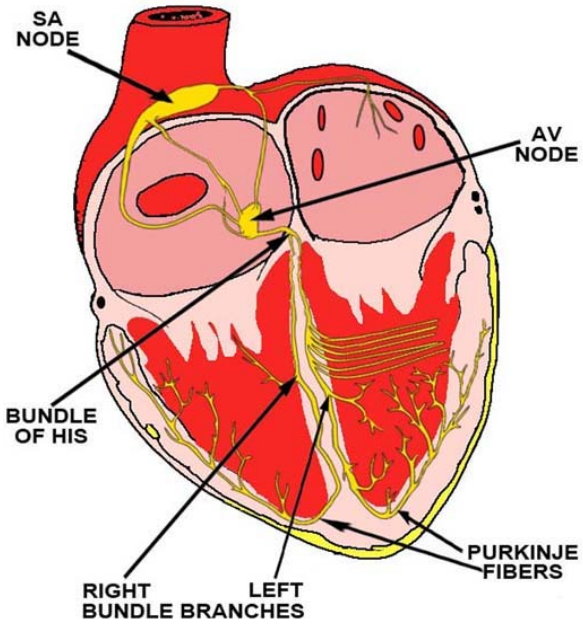

Figure 1–9. Electrical activity of the heart.

Impulses generated by the SA node travel through the muscle cells of the atria in a wave-like motion, causing them to contract and empty their contents into the ventricles. Specialized bundles of atrial muscle fiber, called internodal pathways, also carry the SA node impulses directly to another node, the atrioventricular (AV) node. The AV node is located on the bottom of the right atrium. There, the signal delays momentarily to allow the ventricles to fill completely with blood pumped from the atria. After this delay, the contraction signal proceeds from the AV node down the bundle of His to the right and left bundle branches where it splits. From each bundle branch, the contraction signal enters the Purkinje network, which spreads it quickly throughout the ventricles, causing contractions in a wave-like motion from the bottom to the top, toward the exit valves. When the ventricles complete their contraction, the network relaxes once more and awaits the next SA action potential or contraction pulse. Figure 1–10 shows a timeline in milliseconds (ms) for each contraction in sequence, starting with the SA node. It does not take much time at all for the initial contraction to affect the heart.

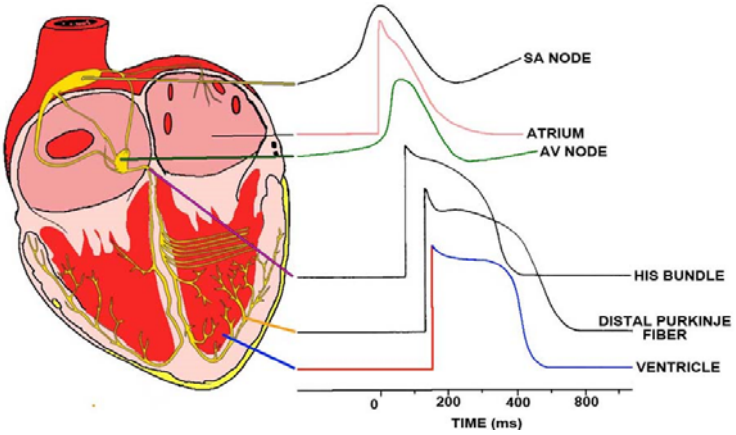

Figure 1–10. Heart activity time line.

The blood vessels

As you may know, blood vessels of the body fall into three principal classes—arteries, capillaries, and veins. The arteries carry blood away from the heart; the capillaries connect arterioles and venules, forming a network in the body; and, finally, the veins carry blood back to the heart. Let's look at each of these classes individually.

Arteries

The arteries are strong elastic tubes, constructed to withstand the high pressure placed upon their walls when the heart pumps blood to the body. They split off into branches of various sizes, which in turn divide and subdivide into smaller and smaller vessels. The terminal branches are arterioles. The muscular walls of the arteries contain smooth muscle cells. The arteries are under the control of nerves that relax or contract to increase or decrease the diameter of the vessels. This is how the arteries help regulate blood pressure. Figure 1–11 shows the major arteries in the body.

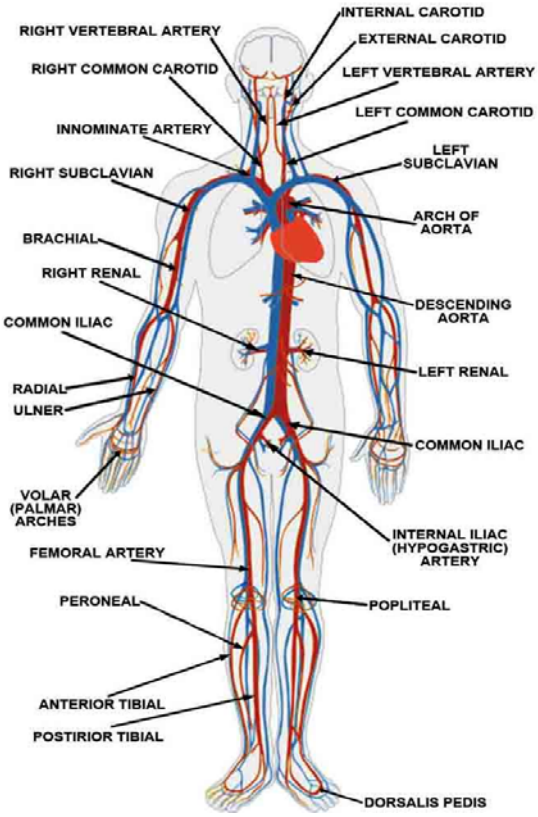

Figure 1–11. Arteries of the body.

Capillaries

The capillaries, located at the ends of the arteries (more specifically, arterioles) are so small, red blood cells must pass through in single file. These minute vessels must be plentiful since it is here where the body delivers food materials and O_2 to the cells. Also, capillaries are responsible for picking up waste products, which the veins carry away.

Veins

The veins comprise a system of vessels that collect the blood from the capillaries and carry it back to the heart. Their structure is similar to arteries, except their walls are thinner with less muscle tissue. Veins begin as tiny venules that form capillaries joining together, much as tiny streams connect and form a river. The force of muscles contracting adjacent to veins and the action of the diaphragm aid in the forward propulsion of blood on its return trip to the heart. Valves, spaced frequently along the larger veins, prevent back flow of blood. Figure 1–12 illustrates the major veins of the body.

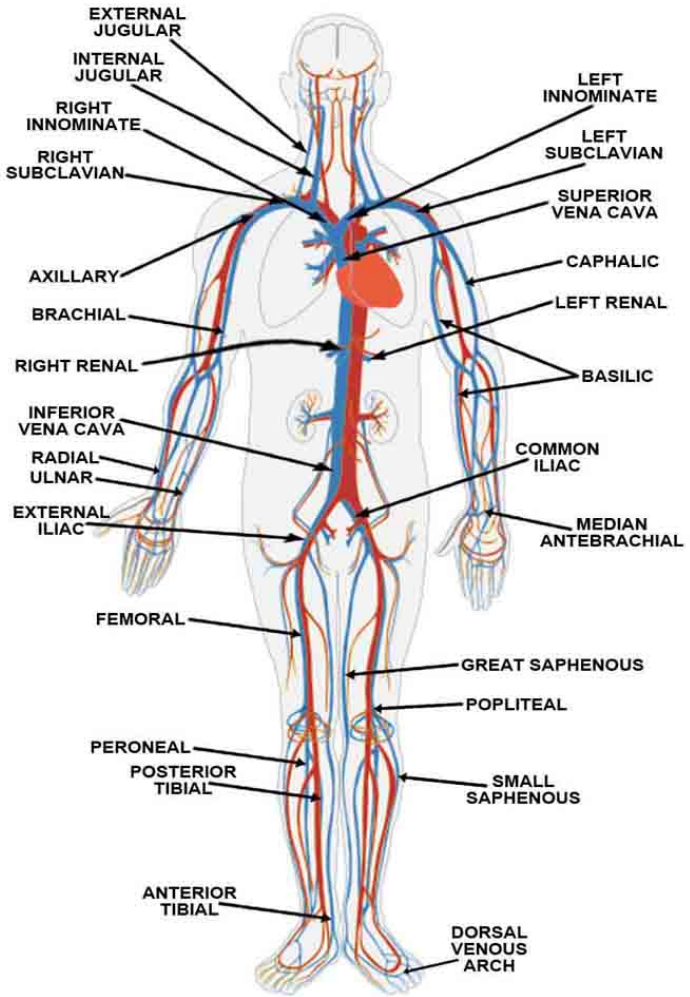

Figure 1–12. Veins of the body.

Every Biomedical Equipment Journeyman should know the route blood takes through the entire circulatory system. Refer again to figures 1–7 and 1–8 as we review the blood flow route.

The blood leaves the heart by way of the left ventricle, through the aortic valve, and passes into the largest artery, the aorta. The first branches from the aorta are the coronary arteries (not shown). These vessels supply the heart tissue with O_2 and nourishment. As the blood continues to travel through the arterial system, the arteries become smaller and smaller in size, ending in the smallest arteries, the

arterioles. From the arterioles, the blood enters the capillaries, the venules, and then the larger veins on its way back to the heart. The right atrium receives the blood and passes it through the tricuspid valve into the right ventricle, which then pumps it past the pulmonary valve and through the pulmonary artery to the lungs. Following the exchange of CO_2 and O_2, the blood returns to the left atrium by the pulmonary vein. From this point, the blood begins its travels through the system again.

206. The urinary system

The urinary system includes the organs concerned with the production and elimination of urine. This system consists of the kidneys, ureters, urinary bladder, and urethra. Together, these structures secrete and eliminate urine—a liquid waste product of cell metabolism. To understand the structure and function of this system, let's consider each part separately.

The kidneys

The kidneys are the real work centers for the urinary system. The kidney is a highly complex organ with three important functions:

1. To filter the blood (a process vital to life), discarding materials no longer needed and returning usable materials to the blood.
2. To maintain water (H_2O) and electrolyte balance.
3. To maintain acid-base balance.

Thus, it is correct to say the kidneys maintain homeostasis (uniformity or stability in the normal body state). Figure 1–13 shows the urinary system.

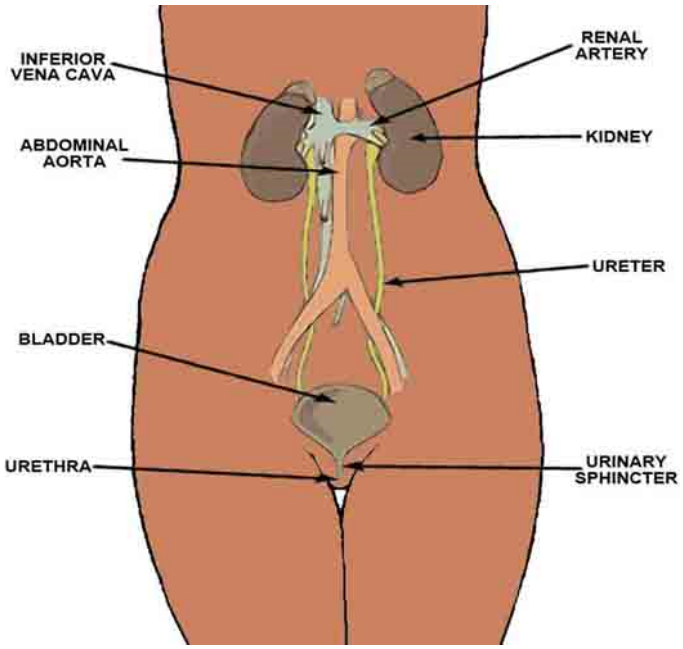

Figure 1–13. Urinary system.

The kidneys are two bean-shaped organs located on each side of the vertebral column, posterior to the abdominal cavity (retroperitoneal space) at about the level of the 12th rib. Fat and connective tissue surround each kidney, which rest in a fibrous-type capsule. Each kidney is about 1-inch thick, 2-inches wide, and 4-inches long, and weighs about 6 ounces. The right kidney is slightly lower than the left because of the position of the liver. The human kidney functions so well that if disease or injury requires the removal of one (a nephrectomy), you can maintain adequate kidney function as long as the other one is normal.

Each kidney has two main layers. The outer layer, which compares to the bark of a tree, is the cortex. The inner layer is the medulla. The medulla contains a number of cone-shaped divisions called renal pyramids. These pyramids (fig. 1–14) extend into a central or basin-like cavity called the renal pelvis. The renal pelvis connects with the ureter.

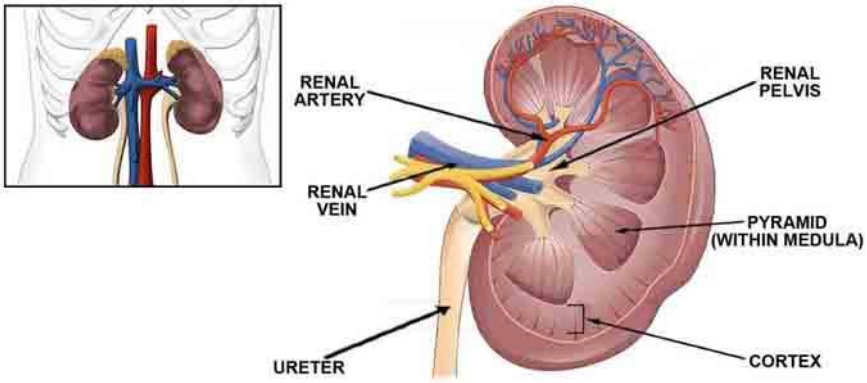

Figure 1–14. Kidney cross-section.

The renal artery and vein supply each kidney. The renal artery comes directly from the abdominal aorta, and the renal vein enters the inferior vena cava. At any given moment, the amount of blood flowing through the kidneys averages about 1,200 milliliters (mL) a minute. This is about one-fourth the total cardiac output. As this blood is flowing through the system, the kidneys filter waste products and purify blood for use throughout the body. The nephron units are the microscopic units responsible for filtering and purifying the blood. Each kidney contains about 1 million of these microscopic nephron units. These tiny units (fig. 1–15) are the structural and functional units of the kidney. Each unit consists of a series of tiny tubules; each tubule begins as a blind sac called Bowman's capsule.

The nephron units are responsible for all the filtering, excreting, and reabsorbing that take place within the kidneys.

The blood pressure influences the rate at which the blood filters through the kidneys. If blood pressure falls below normal for any reason, such as shock or hemorrhage, the kidneys will produce and discharge a substance called renin. Renin stimulates the contraction of the arterioles, which reduces the volume of the circulatory system. This, in turn, increases the blood pressure.

The end product of kidney filtration is urine. Normally it is an amber color, free of bacteria (unless there is an infection), and about 95 percent H_2O. The other 5 percent is various organic and inorganic compounds. Under normal conditions, an adult excretes about 1,500 mL of urine in 24 hours. However, factors such as body temperature, humidity, and fluid intake influence this amount. For example, on a hot day you drink more H_2O and urinate less because you lose an increased amount of H_2O through your sweat glands. H_2O or fluid intake, and a person's state of health will influence sweat excretion. A large H_2O intake does not put a strain on the kidneys as some might think. The kidneys absorb only the amount of H_2O needed by the body at that particular time. The rest passes off as urine. However, when fluid intake is low, urinary loss is nearly zero. By being able to function in this manner, the kidneys play the primary role in the maintenance of fluid balance in the body.

The ureter

Look back at figure 1–13 and notice the ureters are two tubes (one from each kidney) that convey urine from the kidney to the urinary bladder. As urine enters the upper end of the ureters (renal pelvis), a wave of muscular contraction begins and forces it down into the urinary bladder. As you know, this muscular contraction is peristalsis. In the digestive tract, the peristaltic action is responsible for moving food and waste products along the alimentary canal. Here, it moves the urine to the bladder.

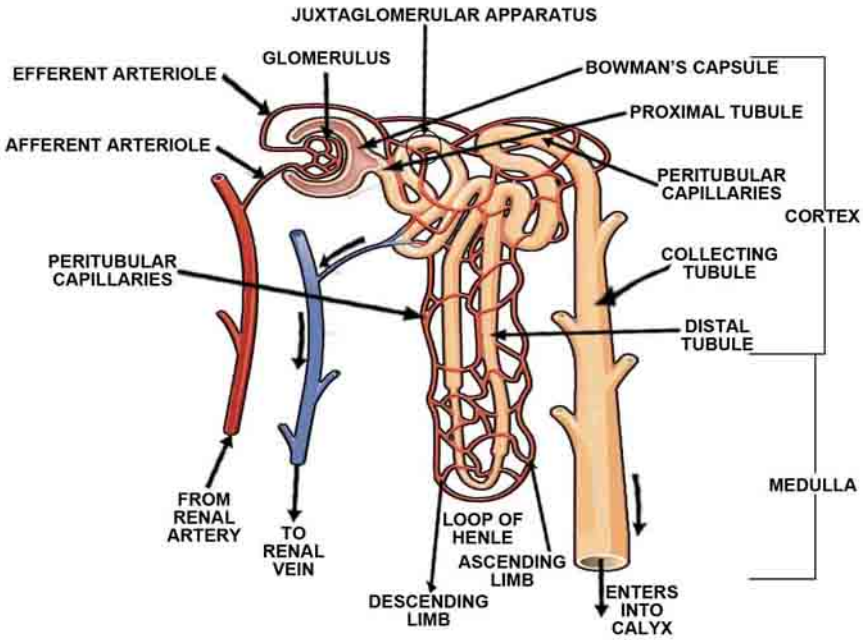

Figure 1–15. Nephron unit.

The urinary bladder

The urinary bladder is a muscular, sac-like organ lying in the anterior portion of the pelvis directly behind the symphysis pubis. It receives and temporarily stores urine. Bladder capacity varies, but usually it holds about 300 mL to 500 mL. The sensation to void usually occurs when the bladder contains about 150 mL of urine; urgency occurs when the bladder reaches about 300 mL of urine. The bladder discharges urine at intervals through the urethra.

The urethra

The urethra is a passageway or duct that conveys urine from the urinary bladder to the outside of the body. The male and female urethra differ greatly.

In the female, the urethra's only function is excretory. The female urethra is short, measuring 1- to 2-inches long (which is the primary reason why females are susceptible to urinary tract infections). It lies in the vestibule between the vaginal orifice and clitoris. It unites with the anterior wall of the vagina.

In the male, the urethra serves a double function. It carries semen, and serves as a common excretory and reproductive duct. The male urethra is normally about 8- to 10-inches long and is divided into three parts. The most posterior position is the prostatic urethra. The prostate gland surrounds the prostatic urethra, which contains the orifices of the prostatic and ejaculatory ducts. This part of the urethra is about 1-inch long. The membranous urethra is about ½-inch long and extends from the apex of the prostate gland to the body wall. The penile or anterior urethra is the longest portion—it is about 5- to 6-inches long and lies in the central portion of the pelvis. When infected, it results in a condition known as urethritis.

207. The musculoskeletal system

The bones, joints, muscles, tendons, ligaments, and cartilages of the body make up the musculoskeletal system. This system is really two systems combined: the muscular and skeletal. To help in your understanding, we will discuss these two areas separately.

Do you remember basic anatomy of the musculoskeletal system from your 3-level course? The 4A2X1 career field must have that basic understanding to relate to treatment that requires the use of

medical equipment. This lesson starts with our foundation—the skeletal system. From there, we add the mobility portion of our body—the muscles.

The skeletal system

The skeletal system is the framework of the body. Bones support the body in an upright position, protect vital organs, and afford attachment for tendons, muscles, and ligaments. They provide the leverage (by muscular contraction) that permits body movement. Bones also contribute to the formation of blood cells, and act as reservoirs for calcium and other minerals. Joints and ligaments are what aid in movement of the body.

Bone structure

Osteology is the study of bones. Calcium, phosphorus, mineral salts, and an organic substance called ossein make up bones. If you soaked a human bone in acid until all the mineral salts washed out, all you would have left would be a flexible piece of tissue that could bend and twist without difficulty. So, bones depend on inorganic minerals, such as calcium and phosphorus salts, for their strength and hardness.

Bone is hard and elastic. Its hardness comes from mineral matter (two-thirds); its elasticity comes from organic matter (one-third), which contains protein. A child's bones contain more organic matter than an adult's and, therefore, are more flexible and not so easily broken. As age increases, the proportion of mineral matter increases, so bones become more brittle and are more easily broken.

Bones consist of a hard, outer shell called compact bone, and a spongy, porous center called cancellous bone. The center of a long bone is the medullary canal and contains bone marrow. This is the manufacturing center for red blood cells. At the end of a long bone is a smooth, glossy tissue that forms the joint surfaces. The surfaces articulate with, fit into, or move in contact with similar surfaces of other bones. A thin membrane called periosteum, which is important in the nourishment of bones, covers the bone. It contains nerves and blood vessels, and is essential for bone growth. In the case of a fracture, the new bone regenerates from the periosteum. Figure 1–16 shows the periosteum and other parts of the bone.

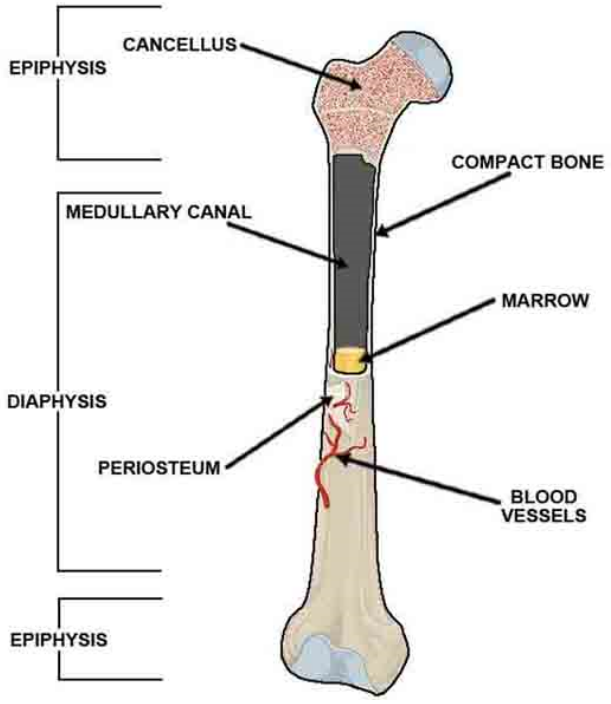

Figure 1–16. Anatomy of a bone.

If you closely examine a bone, you see many projections and depressions. The following list describes the terms commonly used to describe these areas:

Term	Description
Condyle	A rounded process at the articular (joint) end of a bone.
Crest	A prominent ridge.
Diaphysis	Shaft or body of a long bone.
Epiphysis	Ends of the long bone.
Fontanelle	An unossified, membranous area usually found in an infant's cranium.
Foramen	A hole in a bone for passage of vessels, ligaments, or nerves.
Head	The enlarged portion at the end of a bone.
Process	A general term for any bony prominence.
Sinus	A cavity in a bone.
Spine or spinous process	A slender projection.

Bones are classified according to their location and shape:

- Long bones—femur and humerus.
- Short bones—wrists and ankles.
- Flat bones—skull, shoulder, and sternum.
- Irregular bones—mandible and vertebrae.

Now that you know the function of bones and their general makeup and structure, let's examine some of the various bones of the body. We begin at the top and work our way down.

The skull

The skull is the bony framework enclosing the brain. It separates into two parts—the cranium and the face. Eight bones form the cranium and 14 form the face, for a total of 22 bones. The cranial bones support and protect the brain, and are very firmly united to each other. The junctions of these bones along their edges are sutures. Cranial bones include one frontal, one occipital, one sphenoid, one ethmoid, two parietal, and two temporal (fig. 1–17).

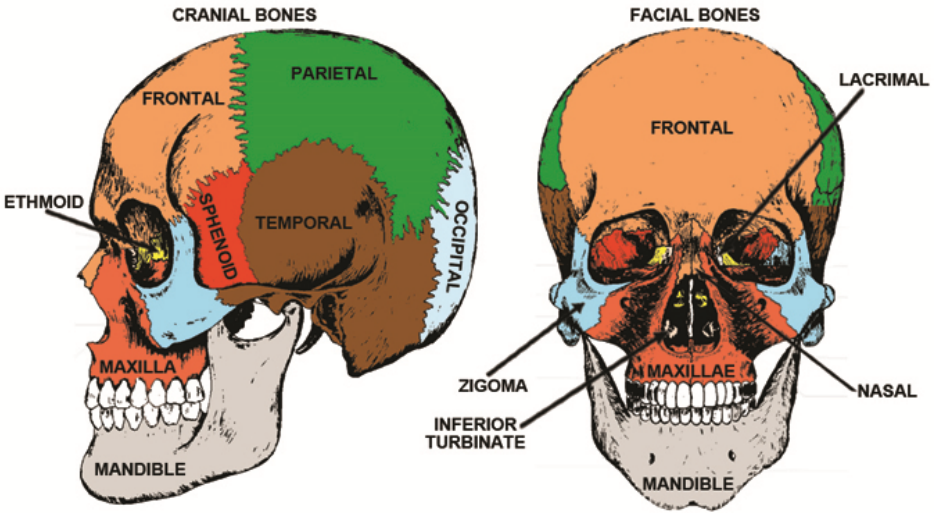

Figure 1–17. Bones of the skull.

In the remaining portion of the skull are the 14 facial bones. The two maxillary bones form the upper jaw, roof of the mouth, orbit, and walls of the nose. In each maxillary bone, there is a large cavity called the maxillary sinus that connects with the nose by a small opening. Two zygomatic bones form

the cheeks, and two nasal bones form the bridge of the nose. The lacrimal bones are two small bones situated on the medial wall of the orbit. They help form the nasolacrimal duct that leads from the orbit to the nasal cavity. The vomer is a thin, flat bone that forms the lower part of the nasal septum. Two inferior turbinates make up the lower part of the lateral wall of the nasal cavity. Two palatine bones together form the roof of the mouth and the floor of the orbit. The mandible, the only movable bone of the skull, holds somewhat of a horseshoe like shape and forms the lower jaw.

Vertebral column

The vertebral or spinal column (fig. 1–18) consists of 24 movable or true vertebrae, the sacrum, and the coccyx. The column divides into five regions: cervical, thoracic, lumbar, sacral, and coccygeal.

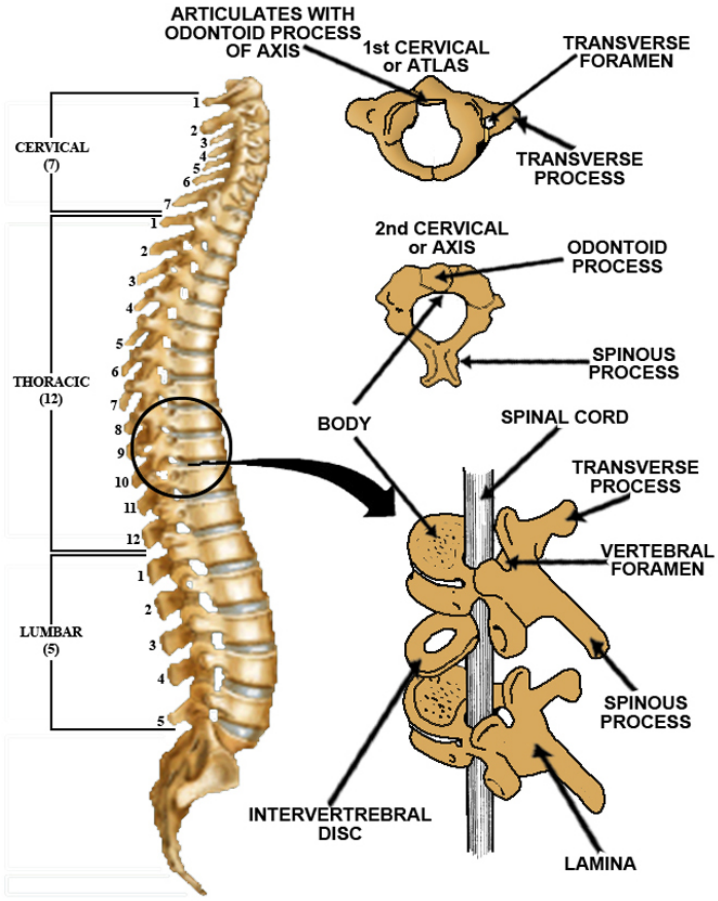

Figure 1–18. The spinal column.

The vertebrae to support and provide motion for the body and extremities, and to serve as a bony protection for the spinal cord from which nerves arise. A typical vertebra consists of an anterior portion or body, and a posterior portion or arch. The body of the vertebra provides support not only for the spinal cord, but for other organs of the body as well. Many of the main muscles also attach to it. The various surfaces and processes enable the vertebrae to move upon one another.

There are seven cervical vertebrae in the neck. The first is the atlas that supports the head and the second is the axis upon which the head turns. These are the only vertebrae with names; all others have numbers.

There are 12 thoracic vertebrae in the posterior chest region. They articulate with the ribs. There are five lumbar vertebrae. The sacrum articulates on each side with the hip bone and the coccyx, forming the posterior wall of the pelvis.

Between the vertebrae, from the second to the sacrum, are intervertebral disks. They act as shock absorbers for the vertebral column and contain an elastic, pulpy substance called nucleus pulposus. A rupture of one of these disks, especially those between the fourth and fifth lumbar, and between the fifth lumbar and sacrum, is a common occurrence called a "herniated nucleus pulposus" (HNP).

The thorax

The thorax, or chest, consists of 25 bones (fig. 1–19). It is located between the shoulders and hips, and is anterior to and attached to the vertebral column. The thorax consists of 12 pairs of ribs, and the sternum or breastbone. It houses the heart and lungs. The ribs are curved, flat bones that form most of the posterior and anterior structure, and all the lateral structure of the bony thorax.

We identify ribs by number and the location on either side of the body. The first seven pairs are true ribs because they attach to the thoracic vertebrae and sternum. The remaining five pairs are false ribs because they do not articulate directly with the sternum. The ribs from one to seven become progressively larger; after the seventh rib, they become progressively smaller. The sternum is long and flat, and is located at the midanterior part of the thoracic cage. It consists of three portions: the manubrium, body, and xiphoid process.

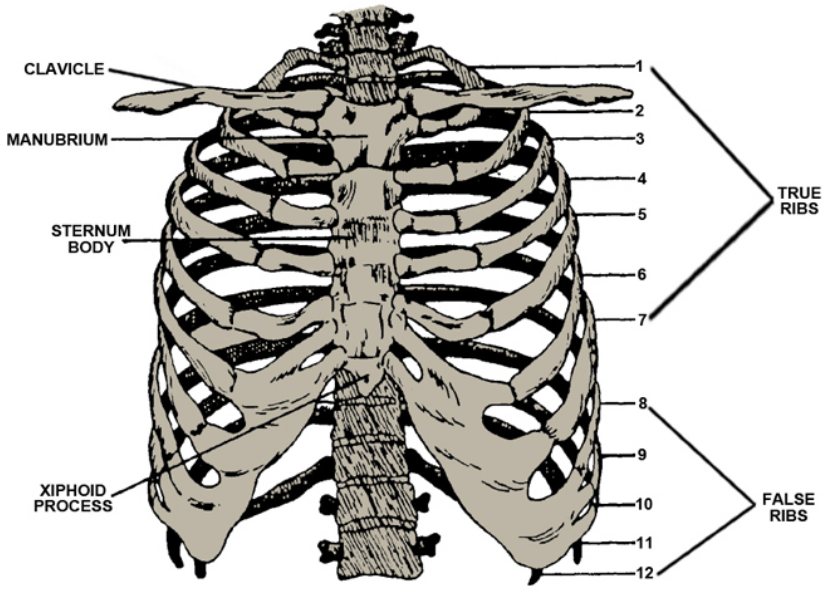

Figure 1–19. The bony thorax, anterior aspect.

The upper extremities

Each upper extremity (fig. 1–20) consists of the clavicle, scapula, humerus, radius, ulna, carpals, metacarpals, and phalanges. Both extremities together total 64 separate bones.

The clavicle, or collar bone, forms the anterior part of the shoulder girdle. It lies in a horizontal position just above the first rib, and attaches to the scapula and sternum. Because of its anterior location, it often fractures because of falls.

The scapula is a triangular-shaped bone lying in the upper part of the back. It forms the posterior portion of the shoulder girdle and part of the shoulder joint.

The humerus is the bone of the upper arm and classified as a long bone. It articulates with the shoulder girdle to form the shoulder joint, and with the bones of the forearm to form the elbow joint.

The bones of the forearm are the ulna and radius. From an anatomical position, the radius is on the lateral or thumb side; the ulna is on the medial or little finger side. The ulna and radius articulate at their proximal ends with the humerus and at their distal ends with some of the carpal bones.

Twenty-seven separate bones make up the wrist and hand. The wrist contains eight small bones called carpals. The hand consists of five metacarpal bones and 14 phalanges. The metacarpal bones number from one to five to correspond to the five fingers; the thumb is the first finger. The phalanges are the small bones of the fingers.

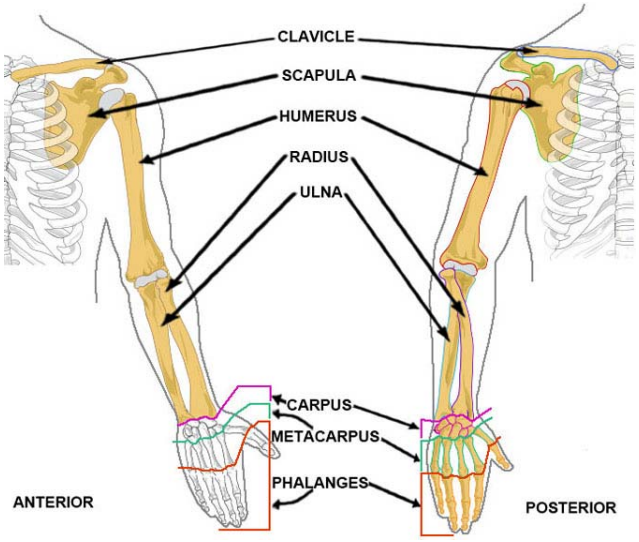

Figure 1–20. Upper extremities bone structure.

The lower extremities

The bones that make up the lower extremities are the innominate, femur, patella, tibia and fibula, tarsals, metatarsals, and phalanges. Refer to figure 1–21 throughout the study of this section.

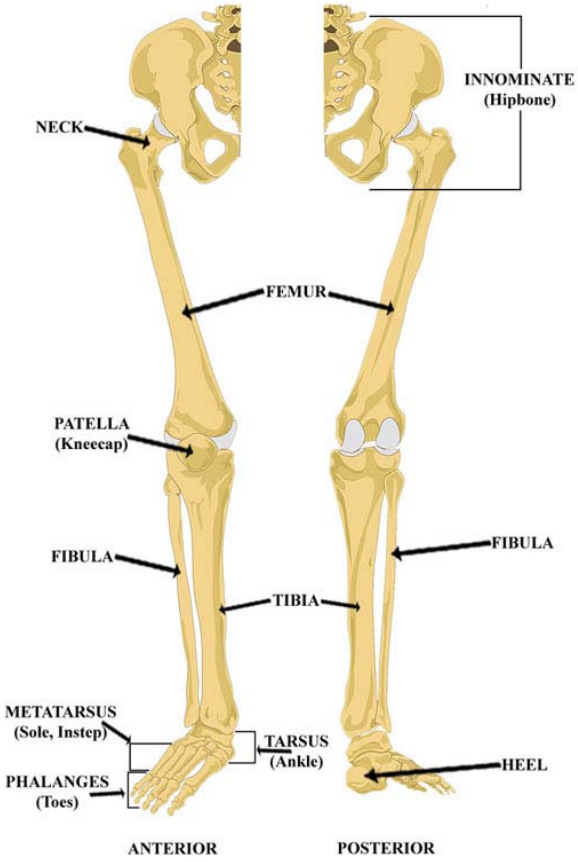

Figure 1–21. The lower extremities bone structure.

The innominate, or hip bone, has three parts: the ilium, ischium, and pubis. These firmly unite into one bone. The lateral portion of the hip bone has a cup-shaped formation in which the ball-like head of the femur articulates. We call this cup-shaped formation the acetabulum. The pubis comprises the anterior part of the hip bone; where the right and left pubis meet in the midline, a joint forms known as the symphysis pubis. The two hip bones, together with the sacrum and coccyx posteriorly, form the pelvic girdle. This girdle forms a deep basin that protects the organs of the lower abdomen, bladder, lower bowel, and reproductive organs.

The femur, or thigh bone, is the longest and heaviest bone in the body. The proximal end is rounded and has a head that fits into the acetabulum. It also has a neck, the part of the femur most frequently fractured.

The patella, or kneecap, is a small oval-shaped bone overlying the knee joint. The patella rests inside the tendon of the quadriceps muscle of the thigh. A bone, such as the patella that develops inside a tendon, is a sesamoid bone.

The tibia and fibula are the two bones of the lower leg. The tibia, commonly called the shinbone, is the larger of the two and lies on the medial side. The fibula, located on the lateral side of the leg, serves as an attachment place for tendons and muscles. It also acts as a splint for the tibia.

The bones of the foot are similar in structure and arrangement to those of the hand. They include seven tarsals, five metatarsals, and five phalanges. The tarsals form the ankle bones, and the metatarsals form the soles of the feet. The phalanges form the toes.

Joints

A joint is the place of union between two or more bones of the skeleton. Because of the way the bones attach, the body position can change, making hundreds of motions possible. Some patients must exercise their joints to prevent flexion deformities and aid circulation.

A membrane that secretes a fluid, called synovial fluid, lines the joints. This fluid serves as a lubricant and keeps the joint working smoothly. Cartilage plates cover the ends of the bones and provide a smooth surface for rotation in freely movable joints. When the bones meet to form a joint, they require assistance to stay in place. This is the responsibility of the ligaments. Sacs with a viscid fluid, called bursae, are located between the ends of bones and act as cushions. They are also between muscles and bone, or tendons.

Joints are primarily of three different types: immovable, slightly movable, and freely movable. Refer to figure 1–22 as we discuss these three joint types.

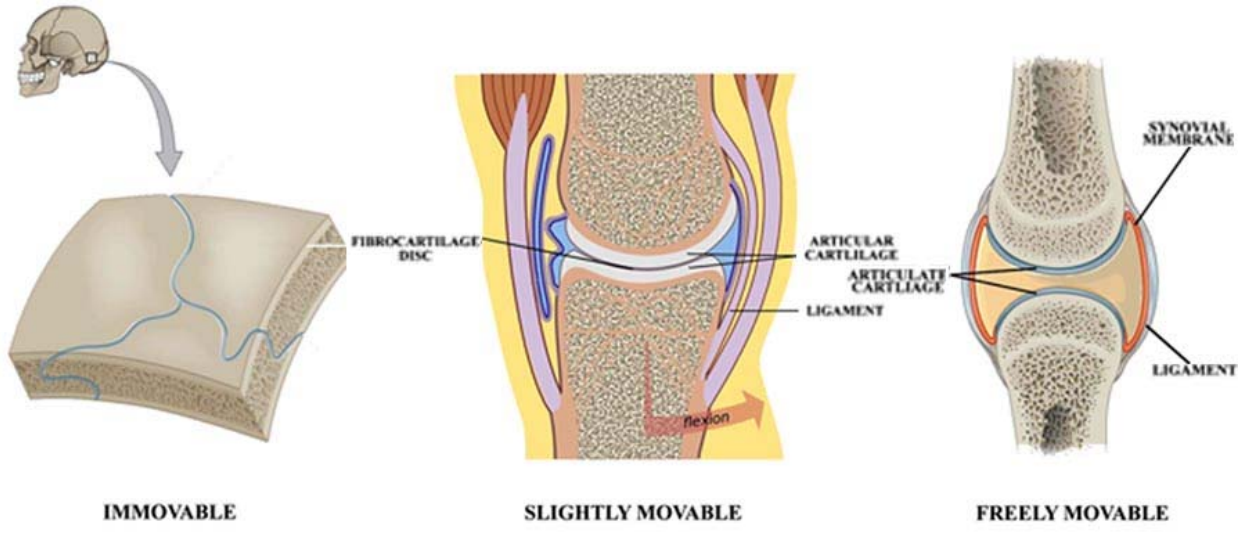

Figure 1–22. Types of joints.

Joint Type	Description
Immovable	The surfaces of the bones are almost in direct contact and fastened together with a thin layer of intervening fibrous tissue or cartilage. An example of this type of joint is the joining of the bones in the skull.
Slightly movable	Fibrous ligaments between the bones or broad, flattened disks of fibrocartilage connect the bony surfaces. Examples of this type of joint are articulations of the bones of the vertebrae and the symphysis pubis.
Freely movable	The most numerous in the body and have a more complex arrangement. Articular cartilage covers the surface of each bone. The bones are connected by ligaments that pass from one to the other on all sides of the joint, thus forming a capsule. This articular capsule has two layers of tissue. The outer layer is fibrous tissue; the inner layer is the synovial membrane that secretes synovial fluid.

Ligaments

Ligaments are tough, fibrous bands that connect bones or support organs within the body cavities. An injury to some ligaments may cause dislocations or sprains.

The muscular system

Before we study the various groups of muscles, let's look at the muscular system as a whole. The study of muscles is important because muscular contraction results in movement, locomotion, and maintenance of erect posture. However, remember that muscles also involve such essential body functions as pumping the blood throughout the body, respiration, and digestion. Even speaking and seeing are dependent on muscular activity.

A muscle is a tissue composed of a number of fibers held together by connective tissue and enclosed in a fibrous sheath called fascia. We characterize muscles by their ability to contract and move the various parts of the body. All motion of the body, whether conscious or unconscious, is due to action of the muscles. All muscle is in a state of partial tension at all times, so we say muscle has tone or tonus.

The muscle tissues of the body vary in shape and structure according to the functions they perform. There are two main groups—voluntary and involuntary muscles:

1. Voluntary muscles – A muscle that we consciously control is a voluntary muscle. All the muscles attached to the skeleton are of the voluntary type. Groups of muscle bundles held together by fascia make up the individual muscles; each gets its name according to its location, action, or other distinguishing features. Each skeletal muscle has three main parts: the origin, body, and insertion. The origin is the point where the muscle anchors, and it usually consists of a short tendon attached to the bone. The body is the largest part of the muscle body and has many fibers. The insertion is the point at which you apply the action of the muscle, resulting in motion. Here the muscle attaches to a bone by a tendon. Tendons are nonelastic, dense, fibrous tissue. They unite with periosteum of bones to form secure attachments for the muscles.
2. Involuntary muscles – A muscle whose nerve supply comes from the autonomic nervous system is an involuntary muscle. These muscles are in the walls of the blood vessels, intestinal tract, and glands. The intestinal tract, where food pushes along by rhythmic contraction, illustrates involuntary muscle action. A special kind of involuntary muscle is the cardiac muscle. Its structure is quite different from that of any other muscle.

Let's now concentrate on the major functional muscles.

Major muscle groups

The body contains many major muscle groups, but for the purpose of this lesson, we will only discuss a few. Figure 1–23 shows these major muscles and muscle groups.

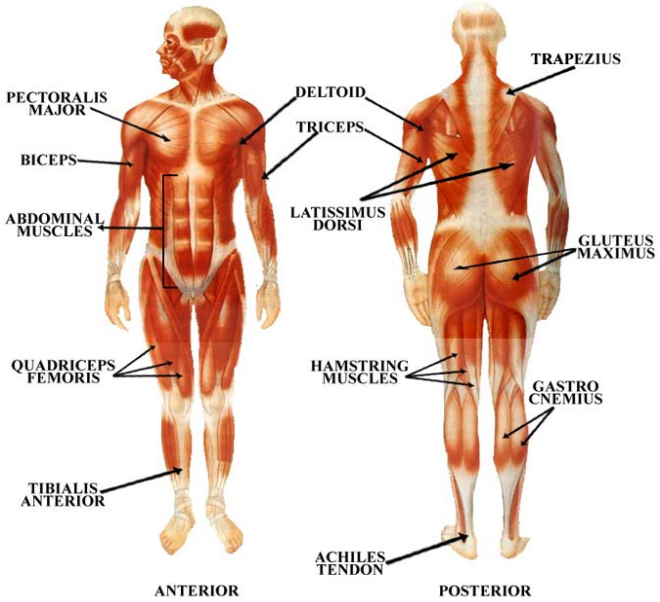

Figure 1–23. Major muscle groups.

Upper extremities

The major muscles of the upper extremities covered here are the deltoid, biceps brachii, and triceps brachii. The first of these, the deltoid, fits as a "cap" over the shoulder and occupies the superolateral portion of the shoulder prominence. The deltoid is commonly used for intramuscular injections. The biceps brachii is a large spindle-shaped muscle forming the major portion of the bulge on the anterior surface of the upper arm. The triceps brachii occupies the posterior surface of the upper arm.

Lower extremities

The lower extremities have several major muscles, but our discussion is limited to the gluteus maximus, quadriceps, hamstrings, and gastrocnemius. The first of these, the gluteus maximus, is the large, fleshy muscle forming the buttocks. The quadriceps are a four-headed group of muscles forming the anterior portion of the thigh. The hamstrings are three muscles located on the posterior thigh. The gastrocnemius is the large, superficial muscle forming the major portion of the calf of the leg. It inserts into the heel bone by the Achilles tendon, the largest tendon in the body.

Trunk

There are several different abdominal muscles forming broad, thin layers that support the internal organs. These muscles also assist in breathing, flexing the thorax on the pelvis, and flexing and rotating the spine.

The muscles of the back are large and broad. They attach to the vertebrae and keep the trunk in an erect position, permitting it to bend and turn. These movements occur mainly in the cervical and lumbar regions.

Muscle action

Muscles seldom act alone, but usually move in muscle groups held together by fascia—a tough, connective tissue. When a muscle contracts, it uses energy, does work, and produces chemical waste products. For this process, it must have fuel in the form of glucose and O_2. Glucose occurs naturally

in many foods and is a product of metabolized carbohydrates (sugar and starch). The waste products are CO_2, lactic acid, and acid phosphates, which increase muscle irritability.

When a muscle contracts continually, it eventually remains in a contracted state or cramp. We call this fatigue. After repeated contraction, muscle cells break down and require replacement. The repair material for worn-out muscle cells is protein. Muscles also need rest to allow the blood to carry away waste materials and bring in fresh glucose, O_2, and protein to restore muscle protoplasm. If muscle contraction continues for a long period without protein replacement or sufficient rest, it results in permanent damage.

During exercise, massage, or ordinary activity, the blood supply to muscles increases. This action provides fresh nutrient material, carries away waste products more quickly, and enables the muscles to build up and restore efficiency and tone. The importance of exercise for normal muscle activity is clear, but excessive muscle activity or strain is damaging. Similarly, muscle cells that do not work results in muscle atrophy which is weakness due to muscle wasting away from lack of exercise. Exercise should be adapted to the individual and never done to the point of extreme fatigue.

Sometimes muscles are damaged and you must carefully work them in order to restore their freedom of movement without pain. To rehabilitate a musculoskeletal injury, physical therapy is often prescribed. The physical therapy clinic is located in a hospital or clinic, and requires the use of different types of equipment for this treatment and rehabilitation.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

204. The respiratory system

1. Match each term in column B with its description or function in column A. Items in column B may be used more than once.

Column A

____ (1) The passageway between the nasal chambers and larynx.
____ (2) This passageway, commonly called windpipe, extends downward from the larynx and divides into the right and left bronchi.
____ (3) The serous membrane covering each lung.
____ (4) That portion of the respiratory system that has a framework of bone and is covered externally by skin.
____ (5) A passageway lying in the middle of the neck, between the base of the tongue and the trachea.
____ (6) Passageways made by the division of the trachea. They convey air from the trachea to the lungs.
____ (7) The process of exchanging gases between the blood and the air that takes place in the lungs.
____ (8) The primary organs of respiration.
____ (9) The part of the respiratory system that is divided into the nasopharynx, oropharynx, and laryngopharynx.
____ (10) This structure moves upward and forward during the act of swallowing to prevent food from entering the trachea.
____ (11) A cylindrical tube composed of 16 to 20 C-shaped cartilage rings.
____ (12) A triangular, cartilaginous structure composed of nine cartilages.
____ (13) These organs are soft and spongy, and constantly change their form with each respiration.
____ (14) This action also takes place between the capillaries and the tissues of the body.

Column B

a. Lungs.
b. Nose.
c. Larynx.
d. Bronchi.
e. Pharynx.
f. Trachea.
g. Pleurae.
h. Diffusion.

2. Where is the respiratory control center located?

3. What is the controlling factor in breathing?

4. Match each term in column B with its description in column A. Items in column B may be used only once.

Column A	*Column B*
____ (1) A condition in which there is abnormally prolonged, rapid, and deep breathing.	a. Rales.
____ (2) Suffocation; a result of too little O and too much CO_2 in the blood.	b. Hyperventilation.
____ (3) Temporary cessation of breathing.	c. Dyspnea.
____ (4) Abnormal respiratory sounds that are moist or dry, depending upon the amount of fluid in the air passages.	d. Asphyxia.
____ (5) Shortness of breath, or labored or difficult breathing.	e. Apnea.

205. The cardiovascular system

1. Match each term in column B with its description in column A. Items in column B may be used more than once.

Column A	*Column B*
____ (1) A hollow, muscular pump in the middle portion of the chest.	a. The heart.
____ (2) A fibrous sac containing the heart.	b. Right and left coronary arteries.
____ (3) The tissue layers of the heart.	c. Veins.
____ (4) Upper chambers that receive blood from the veins and lower chambers which pump blood into the arteries.	d. Pericardium.
____ (5) Acts as two separate pumps.	e. Right and left atria; right and left ventricles.
____ (6) Receives oxygenated blood from the lungs.	f. Epicardium, myocardium, and endocardium.
____ (7) The time from the onset of one contraction or heartbeat to the onset of the next.	g. Arteries.
____ (8) Carries the blood to the heart muscle.	h. Sympathetic nervous system.
____ (9) Increases the activity of the heart.	i. Left atrium.
____ (10) Strong elastic tubes, constructed to withstand the high pressure placed upon their walls when the heart pumps blood to the body.	j. Capillaries.
____ (11) Located at the ends of the arterioles and are so small red blood cells pass through in single file.	k. Complete cardiac cycle.
____ (12) The contracting force of adjacent muscles and the action of the diaphragm aid in the forward movement of blood through them.	

2. What part of the heart is responsible for initiating cardiac contractions?

3. Why is the cardiac contraction signal delayed at the AV node?

206. The urinary system

1. Name the important functions the kidneys perform.

2. Where are the kidneys located?

3. What is the function of the nephron units?

4. What is the normal output of urine over a 24-hour period?

5. How does urine move through the ureters?

6. How much urine does the bladder hold at any given time?

7. Name the duct that conveys urine from the urinary bladder to the outside of the body.

207. The musculoskeletal system

1. Name the materials that make up bone matter.

2. What is the hard, outer shell of bone called?

3. What is the spongy, porous center of bone called?

4. What is the thin membrane that covers bone called?

5. Match each term in column B with the phrase that best describes it in column A. Items in column B may be used once or not at all.

Column A	*Column B*
____ (1) A hole in a bone for passage of vessels or nerves.	a. Condyle.
____ (2) A general term for any bony prominence.	b. Crest.
____ (3) A slender projection.	c. Diaphysis.
____ (4) A prominent ridge.	d. Epiphysis.
____ (5) A cavity in a bone.	e. Fontanel.
____ (6) A rounded process at the articular end of a bone.	f. Foramen.
____ (7) The enlarged portion at the end of a bone.	g. Head.
____ (8) The shaft or body of a long bone.	h. Process.
____ (9) An unossified, membranous area usually found in the infant cranium.	i. Sinus.
	j. Spine.

6. Match each term in column B with the phrase that best describes it in column A. Items in column B may be used only once.

Column A	*Column B*
____ (1) A cone-shaped bony cage; it houses the heart and lungs.	a. Cranium.
____ (2) Is made up of 7 bones, two of which are named.	b. Facial bones.
____ (3) Eight bones that house and protect the brain.	c. Cervical vertebrae.
____ (4) Twelve bones in the posterior chest that articulate with the ribs.	d. Thoracic vertebrae.
____ (5) The major bones of this group are the innominate, femur, patella, tibia and fibula, tarsals, metatarsals, and phalanges.	e. Lumbar vertebrae.
____ (6) Articulated on each side with the hip bone and the coccyx.	f. Sacral vertebrae.
____ (7) Made up of 14 bones, only one of which (mandible) is movable.	g. Thorax.
____ (8) Five bones located between the thoracic vertebrae and the sacrum.	h. Upper extremities.
____ (9) A total of 64 bones; the primary ones are the clavicle, scapula, humerus, radius, and ulna.	i. Lower extremities.

7. What is an immovable joint?

8. What is a slightly movable joint?

9. What is a ligament?

10. What is a muscle composed of?

11. What are the two types of muscles?

12. What type of muscle is under our conscious control?

13. Name the main parts of a skeletal muscle.

14. An involuntary nerve supply comes from what part of the nervous system?

15. What muscle fits over the shoulder and occupies the superolateral portion of the shoulder prominence?

16. What muscle forms the anterior portion of the thigh?

17. What are the functions of the abdominal muscles?

18. Where are the muscles of the back attached?

Answers to Self-Test Questions

201

1. A syllable or group of syllables joined to the beginning of a root word to alter its meaning or create another word.
2. Never.
3. (1) h.
   (2) g.
   (3) c.
   (4) d.
   (5) b.
   (6) j.
   (7) a.
   (8) i.
   (9) e.
   (10) o.
   (11) f.

(12) k.
(13) m.
(14) l.
(15) n.

4. A syllable or group of syllables added at the end of a word or word's base to change its meaning, give it grammatical function, or form a new word.

5. (1) m.
(2) n.
(3) b.
(4) c.
(5) k.
(6) j.
(7) i.
(8) h.
(9) g.
(10) e.
(11) f.
(12) l.
(13) d.
(14) a.

202

1. The main part or portion of a word from which other words may be formed by addition of a prefix, suffix, or both.
2. To make pronunciation easier when there is no vowel between the two root words, or between the root word and suffix.
3. (1) q.
(2) a.
(3) c.
(4) b.
(5) h.
(6) f.
(7) j.
(8) m.
(9) l.
(10) n.
(11) o.
(12) d.
(13) g.
(14) i.
(15) p.
(16) e.
(17) k.
(18) r.

203

1. a. The range measured in degrees of a circle, through which body parts can be rotated, extended, or flexed at a joint.
   b. A movement whereby the distal end of a part makes a circle while the rest outlines a cone.
   c. The movement that rotates the forearm outward so the palm of the hand faces forward.
   d. A motion described when adjacent body parts approach each other, thereby decreasing the angle between them.
   e. A type of extension whereby a body part is extended and stretched beyond its normal anatomical position.
   f. Movement of a body part away from the midline or medial plane of the body.
   g. A special term used solely to describe the movement that turns the sole of the foot inward.
   h. Movement of a body part forward.
2. a. Toward or near the front side of the body.
   b. Toward or near the midline of the body.
   c. Toward the head or upper part of the body.
   d. Away or farther from the point of origin.
   e. Outward from the center of the body or closer to the body surface.

204

1. (1) e.
   (2) f.
   (3) g.
   (4) b.
   (5) c.
   (6) d.
   (7) h.
   (8) a.
   (9) e.
   (10) c.
   (11) f.
   (12) c.
   (13) a.
   (14) h.
2. In the medulla oblongata.
3. The amount of CO_2 in the blood.
4. (1) b.
   (2) d.
   (3) e.
   (4) a.
   (5) c.

205

1. (1) a.
   (2) d.
   (3) f.
   (4) e.
   (5) a.
   (6) i.

(7) k.
(8) b.
(9) h.
(10) g.
(11) j.
(12) c.

2. The SA node.
3. To allow the ventricles to fill completely with blood pumped from the atria.

206

1. Filter the blood; maintain H_2O and electrolyte balance; and maintain acid-base balance.
2. On each side of the vertebral column, posterior to the abdominal cavity at about the 12th rib.
3. They are responsible for all the filtering, excreting, and reabsorbing done within the kidneys.
4. 1,500 mL.
5. A wave of muscular action that forces it down into the urinary bladder.
6. 300 mL to 500 mL.
7. The urethra.

207

1. Calcium, phosphorus, mineral salts, ossein.
2. Compact bone.
3. Cancellous bone.
4. Periosteum.
5. (1) f.
(2) h.
(3) j.
(4) b.
(5) i.
(6) a.
(7) g.
(8) c.
(9) e.
6. (1) g.
(2) c.
(3) a.
(4) d.
(5) i.
(6) f.
(7) b.
(8) e.
(9) h.
7. A joint where the surfaces of the bones are almost in direct contact and are fastened together with a thin layer of intervening fibrous tissue or cartilage.
8. A joint where the bony surfaces are connected by broad, flattened disks of fibrocartilage, or by a fibrous ligament between the bones.
9. Fibrous tissue bands connecting bones or support organs.
10. A number of fibers held together by connective tissue and enclosed in fascia.

11. (1) Voluntary.
    (2) Involuntary.
12. Voluntary muscles.
13. Origin, body, and insertion.
14. Autonomic nervous system.
15. Deltoid.
16. Quadriceps.
17. Support the internal organs, and assist in breathing, flexing the thorax, and flexing and rotating the spine.
18. To the vertebrae.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

1. (201) What does the prefix mean in the word "retroperitoneal"?
   a. Above.
   b. Before.
   c. Behind.
   d. Outside.

2. (201) The suffix in the word "chondromalacia" means
   a. disease.
   b. softness.
   c. hardness.
   d. enlargement.

3. (201) A suffix that means "fastening" or "fixation" is
   a. -rrhaphy.
   b. -plasty.
   c. -pexy.
   d. -rhea.

4. (202) What is the purpose of a combining vowel being placed between a root word and a suffix in medical terminology?
   a. Make the spelling easier.
   b. Make the pronunciation easier.
   c. Clarify the meaning of the root.
   d. Clarify the meaning of the suffix.

5. (202) The root word that refers to the "head" is
   a. colpo.
   b. crani(o).
   c. cephal(o).
   d. chondr(o).

6. (202) The root word that refers to the urinary bladder is
   a. urethra(o).
   b. nephr(o).
   c. ventr(o).
   d. vesic(o).

7. (203) Movement of a body part *toward* the body's midline is called
   a. abduction.
   b. adduction.
   c. inversion.
   d. aversion.

8. (203) A term that means "toward or near the front side of the body" is
   a. ventral.
   b. dorsal.
   c. mesial.
   d. caudal.

9. (204) What part of the pharynx contains the palatine tonsils?
   a. Larynx.
   b. Oropharynx.
   c. Nasopharynx.
   d. Laryngopharynx.

10. (204) What is the flap-like structure that covers the entrance to the larynx?
   a. Thyroid cartilage.
   b. Laryngopharynx.
   c. Epiglottis.
   d. Circoid.

11. (204) What structure is butterfly-shaped and forms the large prominence known as the Adams's apple?
   a. Thyroid cartilage.
   b. Trachea.
   c. Circoid.
   d. Larynx.

12. (205) The heart lies in the portion of the chest called the
   a. vena cava.
   b. mediastinum.
   c. thoracic cavity.
   d. pulmonary cavity.

13. (205) What part of the cardiac cycle is a contraction and is referred to as the "period of work"?
   a. Systole.
   b. Diastole.
   c. Sinoatrial.
   d. Atrioventricular.

14. (206) Where in the kidneys are the renal pyramids located?
   a. Calyx.
   b. Cortex.
   c. Medulla.
   d. Nephrons.

15. (206) *All* filtering, excreting, and reabsorbing in the kidneys are done by the
   a. glomerular capsules.
   b. nephron units.
   c. pyramids.
   d. calyces.

16. (206) What substance produced by the kidneys stimulates the contraction of the arterioles, which causes an increase in blood pressure?
   a. Renin.
   b. Nephrons.
   c. Epinepherine.
   d. Norepinepherine.

17. (207) What is the name of the bone that forms the *anterior* part of the shoulder girdle?
   a. Manubrium.
   b. Clavicle.
   c. Scapula.
   d. Thorax.

18. (207) Which major muscles are located in the upper extremities?
    a. Triceps brachii, biceps brachii, and Achilles.
    b. Deltoid, biceps brachii, and triceps brachii.
    c. Deltoid, triceps brachii, and hamstrings.
    d. Deltoid, biceps brachii, and quadriceps.

19. (207) What is the name of the muscle that is commonly used for intramuscular injections and fits as a cap over the shoulder?
    a. Triceps brachii.
    b. Biceps brachii.
    c. Pectoralis.
    d. Deltoid.

20. (207) What is the name of the group of muscles that forms the *anterior* portion of the thigh?
    a. Quadriceps.
    b. Hamstrings.
    c. Gastrocnemius.
    d. Gluteus maximus.

21. (207) Which muscle forms the *major* portion of the calf of the leg?
    a. Hamstring.
    b. Gastrocnemius.
    c. Achilles tendon.
    d. Gluteus maximus.

22. (207) The repair material for worn-out muscle cells is
    a. acid phosphates.
    b. lactic acid.
    c. glucose.
    d. protein.

Please read the unit menu for unit 2 and continue ➔

Unit 2. Applied Biomedical and Physics Principles

THROUGHOUT YOUR CAREER, you will work on a variety of equipment ranging across a full spectrum of concepts. The equipment a biomedical equipment technician (BMET) will see in a medical facility all operate using biomedical and/or physics principles. Whether you realize it or not, even the actions that you take leading up to working on equipment involve the physics of movement. Understanding how these concepts relate to your job will make you more efficient as a medical maintenance technician.

The next few lessons will break down principles as they relate to your job. First, we will discuss related biomedical principles, transducers, and electrodes. Next, we will discuss related physics principles to include hydraulics, pneumatics, mechanical, steam and laser.

2–1. Related Biomedical Principles

A human is a biological machine based on the fundamental relationship of cause and effect. In other words, something happens in our environment to become a cause. We observe this cause through our senses and communicate it to our brain. In our brain, the cause evaluates and it issues a response command to our muscles, which then initiate an effect. The basic purpose of medical equipment is to extend the range of human ability; it is logical to assume instrumentation systems follow this same pattern of cause and effect. An instrument observes through sensors and transducers and reacts through a display unit or some mechanical activation device, just as a person responds to a cause with an effect.

In this lesson, we discuss the sensor principles (transducers and electrodes) used in physiological monitoring systems so you will have a better understanding of the sensitive patient/equipment interface where electronics and the life sciences merge.

208. Electrodes

Bioelectric electrodes detect cellular ionic potentials. Based on their physical construction, bioelectric electrodes separate into three categories: skin surface electrodes, needle electrodes, and microelectrodes. Of the three, we concentrate on the skin surface electrode, although they all function in basically the same fashion.

Electrode principles

By definition, electrodes are conductors that provide a current path between the body's potentials and the signal processor unit of the monitoring system. The bioelectric potentials developed in the body are ionic potentials, caused by the ionic current flows discussed earlier. To measure these ionic potentials, we must convert them into electronic potentials so we can measure those using conventional electronic means. We use electrodes to convert these ionic body fluid potentials into electronic potentials, which we can electrically measure. They do this by forming a half-cell potential between the electrode and skin surfaces, just as the metal electrodes of a battery do when immersed in

an electrolyte. The original electrocardiograph used immersion electrodes to obtain bioelectric potentials.

When you immerse metal in an electrolyte solution, two opposing reactions take place:

1. Oxidation – the loss of metal to ions and electrons.
2. Reduction – the formation of metal from ions and electrons.

The difference in the rates of these two reactions results in a potential developing across the metal/electrolyte interface. When the two reactions have reached a state of equilibrium, the resulting potential is the half-cell or electrode potential. The layer of charge, which forms at the interface, acts as a capacitor in parallel to a resistance. The fact that developed electrode potentials are directly proportional to the ionic exchange between the metal and the electrolytes of the body is what enables a body surface electrode to detect the ionic currents within the body. Ionic currents induce through the body when the polarization and depolarization waves travel through the cardiac muscle during contraction. This causes the ionic exchanges at the electrode-skin interface to change proportionally. This results in variations in the electrode or half-cell potentials. When you use at least one other identical electrode as a reference at another location, the small potential difference recorded between the two represents the electrocardiogram (EKG) waveform for that specific lead configuration. This is proportional to the magnitude of the instantaneous difference of ionic potential between the two points.

Electrode applications

You must carefully choose the electrode metal to permit a stable current transfer and prevent chemical reactions with the skin. Metals such as zinc and nickel, when in contact with the skin, cause ions to gather and polarize the electrodes, which block the desired signal. Silver is the most commonly used metal for skin surface electrodes, because it produces fewer ions and less blocking polarization. Specifically, silver-plated electrodes with a coating of silver chloride, called silver-silver chloride electrodes, are the most common skin surface electrodes in use.

The half-cell potentials established at the electrode sites are delicate and sensitive interfaces. In other words, they are highly susceptible to electrical and mechanical interference. Electrical interference in the EKG signal can come from ionic currents established by the contraction of muscles other than the heart, or induced 60 Hertz (Hz) interference from machinery or overhead fluorescent lighting. Mechanical interference comes from patient movement, which can cause direct physical movement of the electrode. This movement results in a deformation of the electrode/skin interface and a change in the electrode half-cell potential. Ensuring the electrodes are clean, adequately jelled, and snugly attached, helps eliminate unwanted electrical interference. To minimize motion artifact, floating electrodes have been developed. Floating electrodes do not contact the skin surface directly and, because of this, have nearly eliminated the problem of motion artifact.

In figure 2–1 (A), you can see the metal type electrodes. They are reusable and usually used for short-term monitoring. You find these in use in the emergency room (ER), cardiopulmonary clinic, family practice clinic or flight medicine where they conduct EKG screenings. Conductive electrolyte paste inserted between the skin and electrode forms the electrolyte path for ion exchange. Reference the cross-sectional drawing of this popular type of electrode in figure 2–1 (B). Note the cup-shaped insulating package filled with electrolyte paste. Disposable floating electrodes are particularly popular because of their reduced cleaning requirement. The disposable electrode and gel attach to the patient by an adhesive ring, and the reusable monitor leads snap onto the back of the floating electrode disc. Finally, figure 2–1 (C) is a sample of the electrodes used with telemetry systems. They are less bulky than the other electrodes and are less restrictive when worn under clothing. However, they do have a tendency to break easily.

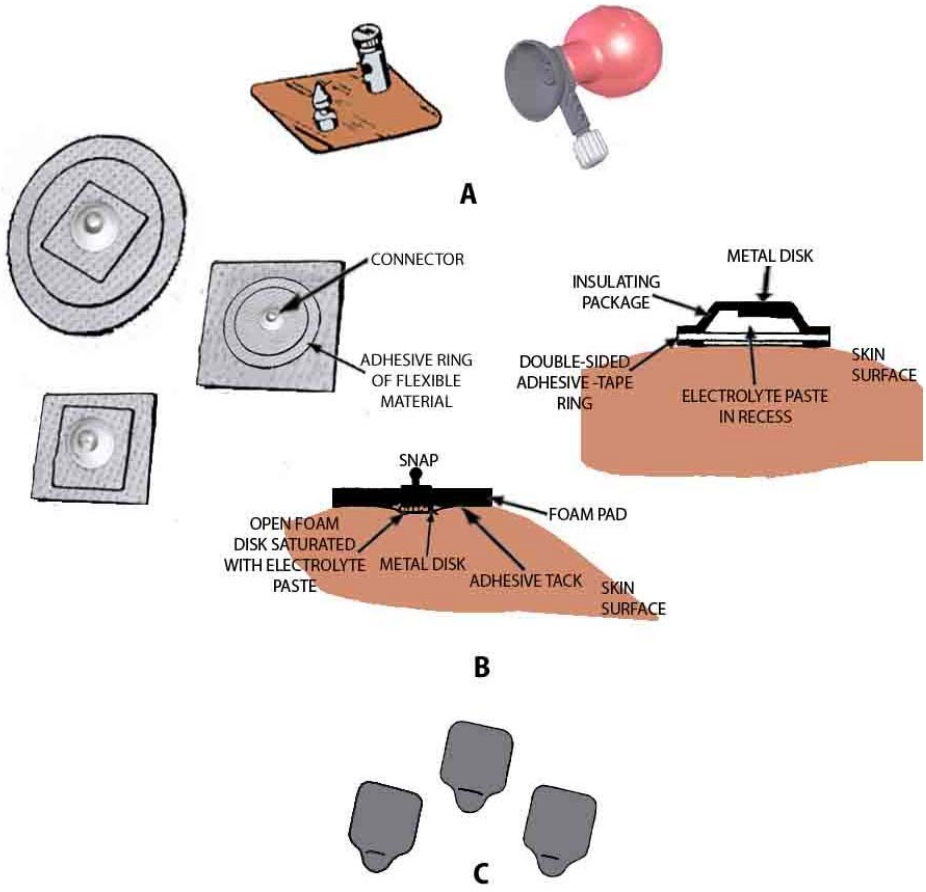

Figure 2–1. Common electrodes.

209. Transducers

Transducers are devices that convert one form of energy to another more useful form for the purpose of measurement or control. In physiological monitoring, the energy form converted to is usually electricity. Pressure transducers are a good example of energy conversion devices.

Naturally, the transducers we discuss all convert some physical parameter into electrical signals, which are then processed and displayed to describe the physical parameter. Although there are many different kinds of transducers in use in a wide variety of clinical and medical research applications, our discussion is limited to pressure and temperature transducers. Blood pressure and temperature monitoring are routine procedures in intensive care and coronary care settings.

Blood pressure transducers

Blood pressure transducers are usually the strain gauge or the linear variable differential transformer (LVDT) type. Strain gauges work on the physical principle that the resistance of a wire is directly proportional to its length and resistivity, and inversely proportional to its cross-sectional area. The resistance of the wire becomes the operating point around which the strain gauge will vary resistance. Reducing the tension on the wire results in a reduction in length, an increase in cross-sectional area, and a net decrease in resistance from the operating point. Likewise, stressing the wire beyond the original operating point increases its length and reduces the cross-sectional area. This causes the resistance to rise above that of the operating point.

The strain gauge configuration types are unbonded or bonded. The unbonded strain gauge consists of four sets of wires that connect a stationary frame with a displaceable floating inner section (fig. 2–2, B). As the center displaces to the left, resistances in R2 and R3 reduce, and resistances in R1 and R4

increase. When the four strain gauge resistances, R1 through R4, are interconnected to form a balanced Wheatstone bridge (fig. 2–2, A), the unbalancing of the bridge is proportional to the stress on the strain gauge.

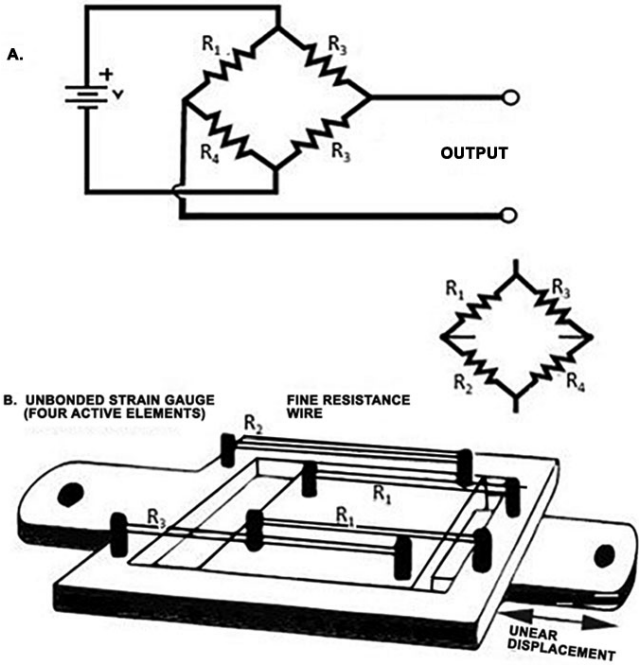

Figure 2–2. Wheatstone bridge and unbonded strain gauge.

Bonded strain gauges use changes in resistivity due to a bending force, rather than the stretching forces applied to unbonded gauges. The construction of a bonded strain gauge forms by laminating a pattern of fine wire between two pieces of paper, which allows flexibility. The semiconductor strain gauge works in a similar way; however, instead of a wire, it uses a silicon chip. The deformation of this material changes resistivity.

LVDTs operate on an induction principle. The LVDT's primary (fig. 2–3,A) and two series secondary windings (fig. 2–3,B) have a movable magnetic core.

When the magnetic core is located in the center, the alternating current (AC) voltage induced in each secondary is equal in amplitude, but opposite in phase, causing the net output from the secondaries to be zero since they cancel each other. Displacing the core in either direction causes coupling of the electromagnetic field to one secondary more than the other. The phase of the net output is then dependent on whether winding 1 or 2 has the greater coupling, with the net output signal reversing phase as the core passes through the center. The output to the LVDT couples to a phase-sensitive rectifier, which produces a direct current (DC) output proportional in magnitude to the displacement of the LVDT's core.

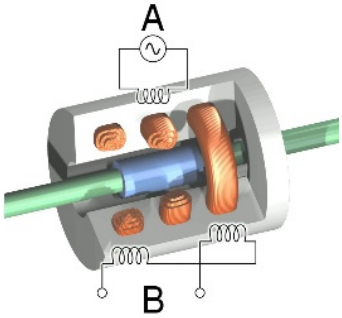

Figure 2–3. Linear variable differential transformer.

Temperature transducers

There are three types of common temperature transducers: thermocoupled, thermistor, and solid-state positive-negative (PN) junction. The last two are in greater use in biomedical applications, although all three are common uses for physiological and biophysical research applications.

A thermocouple consists of two dissimilar conductors or semiconductors joined at one end. Because the work functions of the two materials are different, there is a potential generated when this junction is heated. The potential is roughly linear with changes of temperature over a relatively wide range. Yet, at extreme limits of temperature for any given pair of materials, nonlinearity increases notably.

Thermistors are variable resistances formed into disks, beads, rods, or other shapes. Their composition consists of mixtures of oxides (sometimes sulfates or silicates) of various elements, such as nickel, copper, magnesium, cobalt, titanium, and aluminum. To create this form you would compress the mixture into shape, and then heat it at a high temperature to form a solid mass. The result is a resistor with a large temperature coefficient. Where most metals show an increase of resistance of about 0.3 to 0.5 percent per °C temperature rise, thermistors decrease their resistance by 4 to 6 percent per °C rise. We refer to this as a negative temperature coefficient (NTC).

Most thermistors have a nonlinear curve when plotted over a wide temperature range; but when limited to a narrow temperature range (such as human body temperatures), the linearity is better. When thermistors are used, it is necessary to ensure the temperature does not reach ranges where the calibration is unknown or nonlinear. Most medical temperature transducers are thermistors.

If you take an ordinary solid-state PN junction diode and connect an ohmmeter across it, it is possible to observe its reaction. Notice the forward-biased resistance at room temperature, and then heat the diode temporarily with a soldering iron. The diode resistance drops as the heat increases.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

208. Electrodes

1. What are the three categories of bioelectric electrodes?

2. What function do electrodes serve?

3. What is half-cell or electrode potential?

4. What causes electrical interference in EKG signal?

209. Transducers

1. What do transducers do?

2. How is an unbonded strain gauge configured?

3. Name three types of common temperature transducers.

2–2. Related Physics Principles

Everything in this world is governed by the laws of physics, from the breaths that you are currently taking to the equipment that you will work on throughout your career. Understanding the basic principles and logic behind physics concepts will help you interpret how equipment should work. This knowledge could also help you determine why that equipment might not be working as intended.

In this lesson, we will explore some basic physics concepts as they relate to hydraulics, mechanics, pneumatics, lasers and steam. Let's talk science.

210. Introduction to physical principles

Before learning about the actual inner workings of a machine, it is prudent to understand the principles of how it works. This is especially true when talking about the equipment you will be maintaining in the military treatment facility (MTF). Let's begin by refreshing our memory on physical principles.

States of matter

There are three states of matter: gas, solid, and liquid. Substances are classified in these three states according to their properties under normal conditions of temperature and pressure. Many substances can change from one state to another simply by changing the pressure or temperature (e.g., water exists in all three of these states as ice, liquid water, and steam). Gases and liquids are classified as fluids because they change shape when external forces are applied. For the purposes of our discussion, fluids pertain to liquids. Now would be a good time to review the properties of gases, solids, and liquids.

Gases

A gas has neither a distinct shape nor a distinct volume. It expands to fill whatever closed container it resides in. If you place it into an open container, it expands into the surrounding atmosphere. Gases are considered to be compressible.

Solids

A solid has a definite shape and volume. The shape can changed, but only when considerable force is applied.

Liquids

A liquid has a definite volume and takes the shape of the container it is placed in. Liquids are also considered to be non-compressible under most circumstances.

Principles of work and energy

Now that you have had an overview of the properties of matter, it is time to review the principles of work and energy.

Work

Work equals the force exerted times the distance moved in the direction of the force, and is expressed as the formula $W = F \times S$, where W equals work, F equals force, and S equals the distance moved in the direction of the force (fig. 2–4).

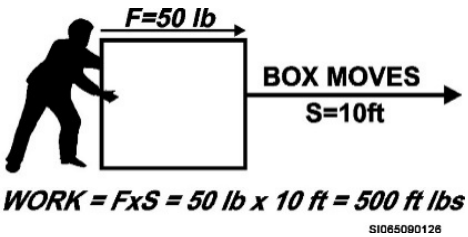

Figure 2–4. Illustration of work.
(Reproduced by permission, Copyright 1980 W.B. Saunders Company.)

Energy

You can loosely define energy as the capacity for doing work. Energy can take many forms (i.e., heat, electrical energy, nuclear energy, or mechanical energy). Many of the tasks accomplished by machines can be classified as changing energy from one form to another. For example, when you burn coal, the stored chemical energy converts to energy in the form of heat and light. The heat may be used to boil water and provide high-pressure steam to turn a turbine. This is an example of converting heat to mechanical energy.

Mechanical energy can divide into two classes:

1. Kinetic energy, which is energy in motion (a bowling ball rolling down a bowling alley).
2. Potential energy, which is the energy associated with being stored (when you are holding the bowling ball perfectly still). That potential energy becomes kinetic energy when you release it.

The common measurement for energy is the joule.

Conservation of energy

The conservation of energy principle states that energy can neither be created nor destroyed, only changed from one form to another.

Power

Power is the rate of doing work. It is often confused with work and energy. The average power is defined by the relationship:

$$\text{Average power} = \frac{\text{Work}}{\text{Time}}$$

The common measurement for power is the watt (W).

211. Hydraulic and pneumatic principles

Now that we have covered the states of matter and principles of work and energy, let's focus on hydraulic and pneumatic principles.

Hydraulic principles

Hydraulics deal primarily with fluids in an enclosed system and the equal distribution of pressure. Pressure is the amount of force applied perpendicularly to a unit area.

Pascal's principle

Pressure applied anywhere in an enclosed fluid system is transmitted equally in every direction, undiminished, to all parts of the system. This is known as Pascal's principle, also called Pascal's Law.

In Pascal's experiment, he put tightly fitted pistons into openings filled with water, the area of one of the openings being 100 times as large as the other opening. Pascal stated that one person pushing against the small piston could hold it against the force of 100 people pushing against the larger piston. This mechanical advantage is expressed as $F = P \times A$, where F equals force (measured in pounds), P equals pressure (measured in pounds per square inch [psi]), and A equals area (measured in square inches).

This principle is used in areas such as hydraulic lifts. Let's apply this concept to figure 2–5 below with the surface of area 2 (A2) being 10 times larger than that of area 1 (A1).

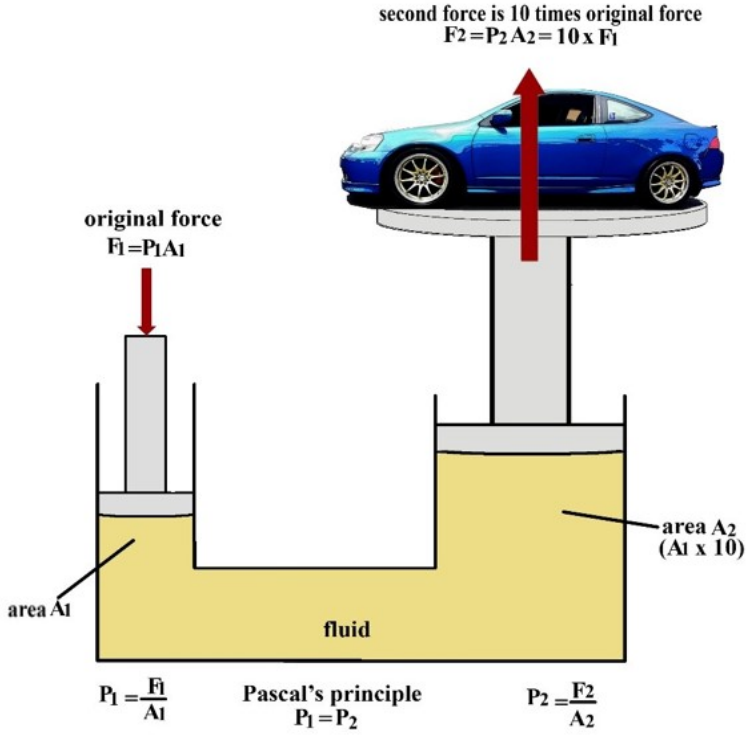

Figure 2–5. Pascal's principle.

Basic hydraulic system

A basic hydraulic system has a pump, reservoir, cylinder, and fluid. You can find these systems in many areas of the MTF; their controls vary from electric motors (most dental chairs) to manual foot pumps (surgical tables and emergency room gurneys).

Pneumatic principles

The word pneumatics derives from the Greek word "pneuma," which means air or wind. This concept in the biomedical maintenance world pertains to gas pressure and air flow. We employ pneumatics in a variety of settings in a medical facility to include dental air drills, air compressors, and vacuum pumps.

Gases serve the same purpose in pneumatic systems as oil would in a hydraulic system. Though they share many of the same qualities, there are some principles unique to gases that we must discuss. These principles fall under the ideal gas law. Boyle's, Charles's, Gay-Lussac's, and Avogadro's Laws, in combination, form the ideal gas law.

Boyle's Law

Boyle's Law is named after Robert Boyle's discovery in 1662 stating that if temperature is constant, the volume of gas in a fixed quantity is inversely proportional to the pressure. While maintaining a fixed temperature setting, the pressure of a gas decreases if the volume of the gas is increased. Conversely, the pressure of the gas increases if the volume is decreased. Remember temperature rarely remains constant, so this situation could rarely occur and is discussed in the next law.

Charles's Law

The relationship between volume and temperature is known as Charles's Law, named after the French physicist Joseph Charles, who made the discovery in 1787. He stated that a volume of gas under constant pressure increases or decreases in relation to temperature. If constant pressure is maintained, there is a direct relationship between volume and temperature. With an increase in temperature, there is an increase in volume.

Gay-Lussac's Law

This law is named after the French physicist who performed the experiments and reached similar results as his colleague Charles. Gay-Lussac's Law states that in a fixed volume of gas, the pressure is directly proportional to the temperature. In this situation, if the temperature of a fixed quantity of gas increases, the pressure increases. Conversely, if the temperature of a fixed quantity of gas decreases, the pressure decreases.

Avogadro's Law

Count Lorenzo Avogadro was an Italian scientist, who is known for his contributions to the molecular weight and molarity theories. He determined that one mole of gas takes up 22.4 liters at a standard temperature and pressure. So, the theory states that equal volumes of gas at the same temperature and pressure contain the same number of molecules. This allowed him to determine the molecular mass of almost any given gas.

212. Mechanical principles

Machines in general may be looked upon as devices for transforming energy. The applications of simple machines (i.e., hand tools) are often for the purpose of multiplying force—that is, for obtaining a larger output force than one exerts on the tool. However, a machine cannot supply more output energy than it is given as input energy (i.e., the output energy is always less than or equal to the input energy). This follows from the conservation of energy principle—energy cannot be created by the machine.

Ideal mechanical advantage

One of the reasons for using a machine is to overcome a large resistance by exerting a relatively small effort (i.e., the machine is used to multiply force). The ideal mechanical advantage (IMA) is the number of times your input force is multiplied under ideal conditions.

$$\text{IMA} = \frac{\text{Effort distance}}{\text{Resistance distance}}$$

While IMA is a great way to illustrate the mechanical advantage concepts that each simple machine affords, it does not take friction into consideration. In an ideal situation, each advantage would be

applied directly as intended without having to factor any lose in efficiency caused by friction. In the case of a simple machine, the IMA is often the most important factor.

Actual mechanical advantage

The number of times your input force is multiplied under real world conditions is known as the actual mechanical advantage (AMA). Considering that actual machines usually have to overcome some sort of inherent friction, they are not as efficient and do not have as high of a mechanical advantage as ideal machines. The AMA is equal to the output force of the machine divided by the input force to the machine, and as such gives the factor by which the machine multiplies the input force. It may be written as:

$$\text{AMA} = \frac{\text{Output force}}{\text{Input force}}$$

Because the exact amount of frictional losses cannot be predicted, the AMA can only be precisely determined by actually measuring the input and output forces for an actual machine. Your AMA will always be less than your IMA, but the frictional losses are often small enough that the IMA is a pretty good approximation. Given that the purpose of this lesson is to teach you the basic concepts of how the various machines work, we will use IMA to illustrate each theory.

Efficiency

How effective a machine is can be referred to as its efficiency. In theory, a machines principle concept should equate to its IMA, and its relation of IMA to AMA can determine how efficient that machine is performing. Efficiency is expressed as a percentage and can be determined using:

$$\text{Efficiency} = \frac{\text{Actual mechanical advantage}}{\text{Ideal mechanical advantage}} X\ 100$$

Simple machines

Although machines vary greatly in type and complexity, most of them can be described in terms of a relatively small number of basic “simple machines.” We will look at two classes—levers and inclined planes.

Levers

The basic lever consist of any bar or rod (bent or straight) arranged in such a way that it can pivot about some definite point, so it can overcome some resistance (fig. 2–6). By moving the pivot point closer to the resistance, the mechanical advantage is increased. If the pivot point is moved further away from the resistance, the mechanical advantage is lessened. The simple formula for calculating the amount of force required to overcome a resistance is $F_eL_e = F_rL_r$, where F_e equals force effort, L_e equals lever effort arm, F_r equals force resistance, and L_r equals lever resistance arm.

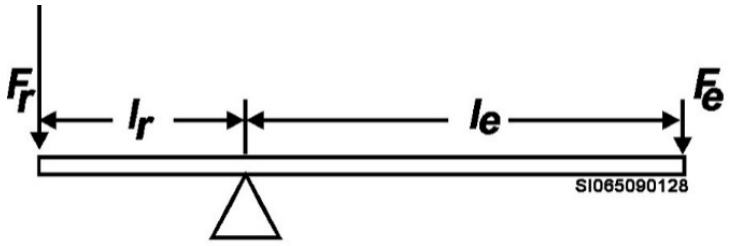

Figure 2–6. Basic lever.
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For example, if a seven-foot rigid bar is used as a lever and the pivot point is placed one foot from the end of the bar, what force is required to lift a 300-pound load? Calculate the mechanical advantage using the equation:

$$F_e \times 6\text{ ft.} = 300\text{ lb.} \times 1\text{ ft.}$$

$$F_e \times \frac{6\text{ ft.}}{6} = \frac{300\text{ ft. lbs.}}{6}$$

$$F_e = 50\text{ lbs.}$$

As you can see, it takes 50 pounds of force to move the object.

Since rigid levers are considered 100 percent efficient for all practical purposes, the IMA can be expressed as lever effort arm divided by the lever resistance arm, or $\mathbf{IMA} = \frac{L_e}{L_r}$. To show the IMA from the previous problem, the formula would be $\mathbf{IMA} = \frac{6ft}{1ft} = 6.$

Levers fall into three classes referred to as first-, second-, and third-class levers.

First-class levers

For first-class levers, the pivot point is located between the effort force and resistance force (fig. 2–7). First-class levers are commonly used when a large mechanical advantage is needed. Some common examples of the first-class levers are scissors, pliers, and hemostats.

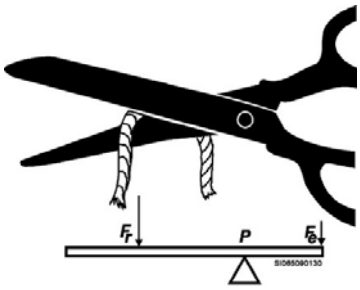

Figure 2–7. First-class lever.
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Second-class levers

For second-class levers, the pivot point is at the extreme end of the lever. This means the resistance force is exerted between the pivot point and effort force (fig. 2–8). Some common uses of this type of lever are lifting one end of a hospital bed or moving a load of dirt in a wheelbarrow.

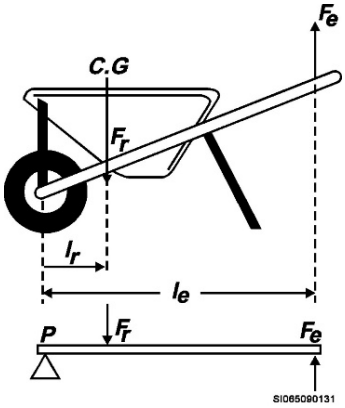

Figure 2–8. Second-class lever.
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Third-class levers

For third-class levers, the effort force is exerted between the resistance force and pivot point. The mechanical advantage is always less than one. The action of the biceps lifting the forearm is one example of a third-class lever (fig. 2–9). Forceps and tweezers are also examples of third-class levers. This class of lever is useful because of its ability to hold small objects and probe into small places.

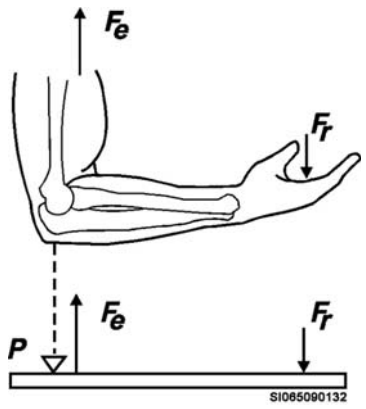

Figure 2–9. Third-class lever.
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Wheel and axle

One of the main limitations of the simple lever is it can move only through a simple arc. The wheel and axle as a machine uses the lever principle and is capable of continuous rotation (fig. 2–10). A large resistance applied to an axle can be overcome by a smaller effort applied at the outside of the wheel. Some autoclave manufacturers use this principle for the steam chamber door.

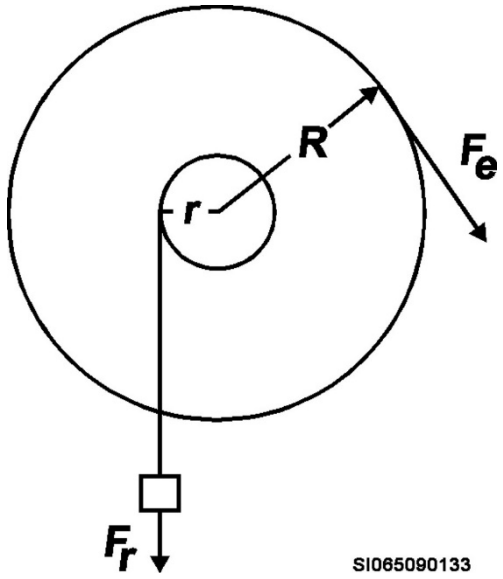

Figure 2–10. Wheel and axle.
(Reproduced by permission, Copyright 1980 W.B. Saunders Company.)

Pulley

Another modification of the lever principle is the pulley. The single fixed pulley (fig. 2–11) merely serves to change the direction of the force and does not multiply the force; it is considered to have an IMA of one. As the pulley systems get more complicated, the IMA increases. Single, fixed pulley systems are often found on traction setups. Multiple pulley systems are found in elevators.

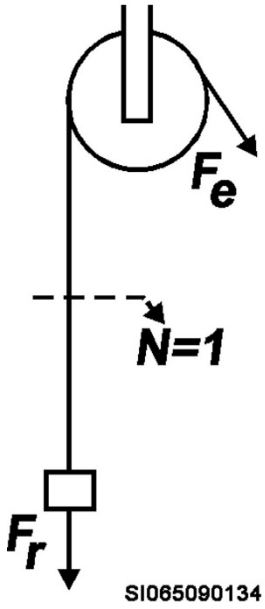

Figure 2–11. Single fixed pulley.
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Inclined plane

It requires less force to push an object up an inclined plane than to lift the object directly (fig. 2–12). The force required to lift an object from one level to another is equal to the weight of the object. Because the incline provides a multiplication of force, it can be called a machine. One common example of this type of machine is a wheelchair entrance ramp to the MTF.

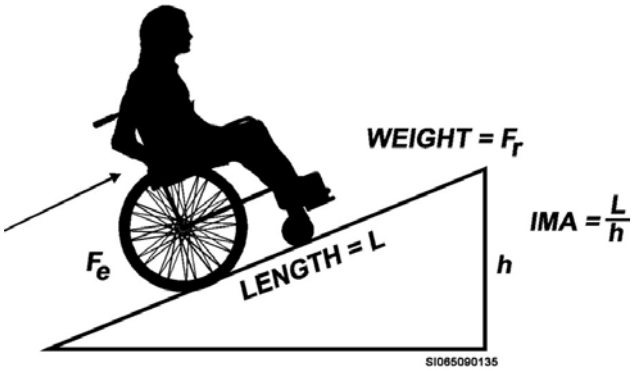

Figure 2–12. Inclined plane.
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The IMA of an incline is the ratio of the length of the incline to the change in height (i.e., if an incline is 20 feet long and raises two feet in height, the IMA is 10). One important fact to remember is a gradual incline has a larger IMA than a steep incline.

Screw

A very large mechanical advantage can be achieved by winding a very gradual incline around a shaft to form a screw. Screws are used to lift and support heavy machinery as in a screw jack (fig. 2–13). Screws are also used as fasteners because of their extraordinary holding power, attributed to the large IMA.

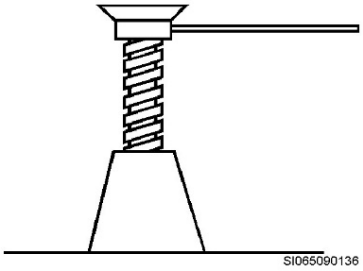

Figure 2–13. The screw jack.
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Wedge

The wedge is another simple machine that is basically a double inclined plane (fig. 2–14). The IMA depends on the angle between the surfaces. A sharper wedge has a greater IMA and, therefore, exerts a larger separating force with a given force of effort. Scalpels and other surgical cutting tools use this principle.

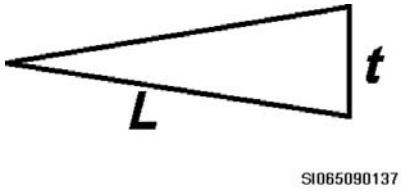

Figure 2–14. The wedge.
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213. Principles of steam

Steam is the water vapor that is given off by boiling water at 212° F at 14.7 pounds per square inch absolute (psia). The temperature of steam is raised by increasing the pressure. Saturated steam is the steam that contains the maximum amount of water vapor or, if you prefer, exerts the maximum pressure for water vapor at a given temperature. Saturated steam cannot undergo a reduction in temperature without lowering its pressure, nor can the temperature be increased unless there is also a corresponding increase in pressure. For sterilization processes, steam under pressure is used rather than atmospheric steam for the sole purpose of attaining higher temperatures. Pressure in and of itself has nothing whatsoever to do with the microbicidal properties of steam.

Upon entering the chamber of a sterilizer, steam contacts cold objects and condenses. This act of condensation liberates a great amount of latent heat (latent, meaning the lag between stimulus and reaction). This factor is of great importance in its application to the permeation of dry goods, fabrics, or textiles. For example, as steam contacts the outer layer of fabrics, the cooler substance immediately causes a film of steam to condense, leaving in the fabric a very small amount of water. The next film of steam immediately fills the space created by the volume collapse of the previous film, but it does not condense in this outer layer. Rather, it passes through and attacks the second layer of fabric—condenses, heats it, and continues until the entire mass is heated. The package contains an amount of moisture (condensate) equivalent to the amount of heat abstracted from the steam. Continuation of the process causes no further condensation, but the temperature of the mass remains constant at the temperature of the surrounding steam.

Since all steam sterilization is based upon direct steam contact, it follows that the same process of condensation in heating applies to instruments, utensils, or other articles undergoing surface sterilization. With such materials, there is no permeation with steam through the metal; the object is to heat and sterilize the surface. In this case, the cold metal condenses the steam until the article is heated to the temperature of the steam.

Throughout sterilization, the metal surfaces are bathed with an abundance of moisture, which greatly facilitates sterilization. Because of the rapid heating effect and the abundance of moisture, it becomes possible to prescribe a shorter period of exposure for instruments than for fabrics, which require time for permeation.

The correct period of exposure is one that provides for complete penetration of the load and also ensures destruction of microbial life with a liberal margin of safety. It is well known there are far too many time-temperature ratios being used for the sterilization of hospital supplies.

In general, all supplies requiring a common exposure period may be safely sterilized in the same load, with the exception of rubber goods and solutions. For bulk loads, a temperature of 250 – 254° F is maintained for 30 minutes in the conventional downward placement sterilizer. Of late, we are frequently speaking of the same goods for the high vacuum sterilizer; therefore, the same category of goods at 250 – 254° F would take 10 minutes or ⅓ of the 30 minutes. These exposures are practicable, safe, and do not destroy materials.

Be aware of the human element in sterilizer operation so the hospital is safeguarded against failures in the sterilization of supplies. Some of the factors normally associated with human error can be controlled through appropriate instrumentation or by suitable mechanical means. This was demonstrated in the last few years by manufacturers who recognized and accepted the responsibility of doing their part in bringing about better control and more effective methods of sterilization in hospitals.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

210. Introduction to physical principles

1. What are the three states of matter?

2. Describe the properties of a gas.

3. Describe the properties of a solid.

4. Describe the properties of a liquid.

5. Define energy.

6. Define the two classes of energy.

7. What is the common measurement for energy?

8. What does the conservation of energy principle state?

9. Define power.

10. What is the common measurement for power?

211. Hydraulic and pneumatic principles

1. Hydraulics primarily deal with what?

2. Define pressure as it applies to hydraulics.

3. What does Pascal's Principle state?

4. What are the components of a basic hydraulic system?

5. What four laws form the ideal gas law?

6. Which law states that if temperature is constant, the volume of gas in a fixed quantity is inversely proportional to the pressure?

212. Mechanical principles

1. Machines in general can be looked upon as devices that have what effect on energy?

2. Define the AMA.

3. Levers and incline planes represent what type of machine?

4. How can you increase the IMA of a lever?

5. If an 11-foot rigid bar is used as a lever, and the pivot point is placed one foot from the end of the bar, what force is required to lift a 500-pound load? What is the AMA?

6. There are how many classes of levers?

7. Give an example of a first-class lever.

8. What is the main limitation of a simple lever?

9. The wheel and axle uses what type of movement?

10. What is the IMA of the single fixed pulley?

11. What is the IMA of an inclined plane?

12. How is the screw used?

13. Describe a wedge. What dictates the wedge's IMA?

14. What kind of tools use the wedge principle?

213. Principles of steam

1. How do you increase the temperature of saturated steam?

2. Why is steam under pressure used instead of atmospheric steam for sterilization?

3. What is the correct period of exposure for steam sterilization?

4. All supplies requiring a common exposure period may be safely sterilized in the same load with the exception of what two items?

Answers to Self-Test Questions

208

1. (1) Skin surface electrodes.
   (2) Needle electrodes.
   (3) Microelectrodes.
2. Conductors that provide a current path between the body's potentials and the signal processor unit of the monitoring system.
3. The resulting equilibrium of oxidation and reduction.
4. Ionic currents established by the contraction of muscles other than the heart, or induced 60 Hz interference from machinery or overhead fluorescent lighting.

209

1. Convert one form of energy to another more useful form for the purpose of measurement or control.
2. It consists of four sets of wires that connect a stationary frame with a displaceable floating inner section.
3. (1) Thermocoupled.
   (2) Thermistor.
   (3) Solid-state PN junction diode.

210

1. (1) Gas.
   (2) Solid.
   (3) Liquid.
2. Has neither a distinct shape nor a distinct volume; expands to fill whatever closed container it is placed in; if placed into an open container, it expands into the surrounding atmosphere; are considered to be compressible.
3. Has a definite shape and volume; the shape can changed, but only when considerable force is applied.
4. Has a definite volume and takes the shape of the container it is placed in; considered to be non-compressible under most circumstances.
5. The capacity for doing work.
6. (1) Kinetic energy, which is energy in motion.
   (2) Potential energy, which is the energy associated with being stored.
7. Joule.
8. Energy can neither be created nor destroyed, only changed from one form to another.
9. The rate of doing work.
10. Watt.

211

1. Fluids in an enclosed system and the equal distribution of pressure.
2. The amount of force applied perpendicularly to a unit area.
3. Pressure applied anywhere in an enclosed fluid system is transmitted equally in every direction, undiminished, to all parts of the system.
4. Pump, reservoir, cylinder, and fluid.
5. Boyle's, Charles's, Gay-Lussac's, and Avogadro's Laws.
6. Boyle's Law.

212

1. Transform energy.
2. The number of times your input force is multiplied under real world conditions. It is equal to the output force of the machine divided by the input force to the machine.
3. Simple.
4. By moving the pivot point closer to the resistance.
5. 50 lbs.; 10.
6. Three.
7. Any one of these: pliers, scissors, hemostats.
8. It can move only through a simple arc.
9. Continuous rotation.
10. One.
11. The ratio of the length of the incline to the change in height.
12. To lift and support heavy machinery; as fasteners.
13. A simple machine that is basically a double inclined plane; it depends on the angle between the surfaces.
14. Scalpels and other surgical cutting tools.

213

1. By increasing the pressure.
2. For the sole purpose of attaining higher temperatures.
3. One that provides for complete penetration of the load and also ensures destruction of microbial life with a liberal margin of safety.
4. Rubber goods and solutions.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to AFCDA.

23. (208) Which is the *most* common metal used for skin surface electrodes?
    a. Zinc.
    b. Nickel.
    c. Copper.
    d. Silver-silver chloride.

24. (208) Floating electrodes were developed to
    a. minimize temperature variations.
    b. eliminate chemical reactions.
    c. generate higher conductivity.
    d. minimize motion artifact.

25. (209) On what principle does a linear variable differential transformer transducer operate?
    a. Induction.
    b. Resistance.
    c. Piezoelectric.
    d. Thermocouple.

26. (209) What type of temperature transducer is used with *most* medical equipment?
    a. Thermistor.
    b. Thermometer.
    c. Thermocouple.
    d. Solid-state positive-negative junction diode.

27. (210) What statement *best* describes the properties of a liquid?
    a. It takes the shape of its container and has a definite volume.
    b. It has neither a definite shape nor definite volume.
    c. It has a distinct shape, but not a distinct volume.
    d. It has a definite shape and a definite volume.

28. (210) The *common* measurement for energy is the
    a. potential.
    b. joule.
    c. watt.
    d. heat.

29. (210) The *common* measurement for power is the
    a. potential.
    b. joule.
    c. watt.
    d. heat.

30. (211) Hydraulics *primarily* deal with
    a. gases in an open system and the unequal distribution of pressure.
    b. fluids in an open system and the unequal distribution of pressure.
    c. gases in an enclosed system and the equal distribution of pressure.
    d. fluids in an enclosed system and the equal distribution of pressure.

31. (212) How would you *increase* the mechanical advantage of a lever?
    a. Use a bent bar.
    b. Use a straight bar.
    c. Place the pivot point closer to the resistance.
    d. Place the pivot point further away from the resistance.

32. (212) The wheel and axle machine is capable of what type of motion?
    a. Half arc.
    b. Quarter arc.
    c. Continuous rotation.
    d. Redirection of force.

33. (212) What is the ideal mechanical advantage (IMA) of a single fixed pulley?
    a. 7.
    b. 5.
    c. 3.
    d. 1.

34. (212) What is the ideal mechanical advantage (IMA) of an incline that is 20 feet long and increases 4 feet in height?
    a. 4.
    b. 5.
    c. 10.
    d. 24.

35. (213) A *true* statement about saturated steam and temperature is a reduction in pressure
    a. results in a reduction in temperature.
    b. results in an increase in temperature.
    c. does not change temperature.
    d. increases the vacuum.

36. (213) All supplies requiring a common exposure period may be safely sterilized in the same load with the *exception* of rubber goods and
    a. instruments.
    b. dry goods.
    c. solutions.
    d. utensils.

Student Notes

Unit 3. Therapeutic Equipment

MOST BMETS WILL SERVICE two categories of medical equipment—diagnostic and therapeutic. This unit will discuss various pieces of therapeutic equipment found in a medical facility. Therapeutic equipment consists of monitoring, treatment, or alleviation of a medical condition or disease. The most common forms of therapeutic equipment are infusion pumps, electrosurgical units, and defibrillators.

This unit will cover all types of therapeutic equipment categorized by different areas of a medical facility. Dental, physical therapy, and labor and delivery will be covered with a heavy emphasis on anesthesia, ventilation, and surgery.

3–1. Dental Clinic

A BMET may expect to spend considerable time in the dental clinic performing scheduled and unscheduled maintenance. Most equipment found in the dental clinic operates on air and water, and will require special attention. We will focus on the dental operating system, ultrasonic prophylaxis unit and dental lab equipment.

214. Dental operating system

The dental operating system is usually the first thing you see when you enter a dental suite (fig. 3–1). Very simply, dental operating systems aid in the restoration of teeth and treatment of gum diseases. The most common application is the removal of decay and filling of the teeth, and the subsequent cleaning and polishing. The system consists of three major components—the chair, unit, and light.

Figure 3–1. Dental operating system.
(Reproduced by permission courtesy of A-dec Inc.)

Dental chair

The dental chair provides comfort to a patient and, more importantly, positions the patient's mouth so the dentist can comfortably see inside the mouth. The chair should provide support for the reclined patient and have independently powered back (tilt) and seat (lift) controls that can be conveniently adjusted by either the provider or assistant. The chair should also provide rotation for better patient positioning.

The dental chair is electronically controlled and hydraulically powered. An electric motor drives the hydraulic pumps, which enables the back of the chair to tilt and the base of the chair to lift (fig. 3–2). These movements are controlled by switches located on a control pad attached to the chair. There is a set on each side of the chair for the provider and assistant adjustment. More recent models also use foot controls for infection-control purposes and hand-free adjustment by the provider during patient treatment. The brake lever controls the chair rotation. You can see the amount of movement in the upper right hand side of figure 3–2.

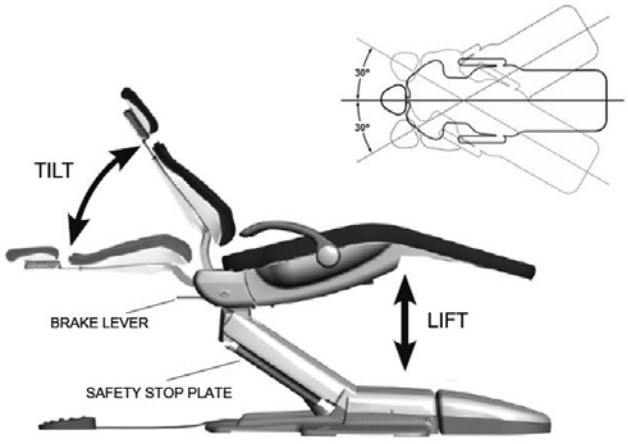


Figure 3–2. Dental chair.
(Reproduced by permission courtesy of A-dec Inc.)

As you can see in figure 3–3, modern foot switches provide multiple functions including base up/down and back up/down, as well as a variety of preset and programmable positions. The pre-position switch places the chair into a pre-set treatment position. If you have ever sat in a dental chair, you know what I mean. The provider comes in and says "Let's take a look," presses a button (pre-position), the chair magically starts to lift, the back goes down, and the provider is ready, with explorer in hand, to look into your mouth. Once the pre-position switch is activated, it can be stopped by pressing any of the other switches or the safety stop plate. The automatic return switch takes you from your laid out position to your original entry position.

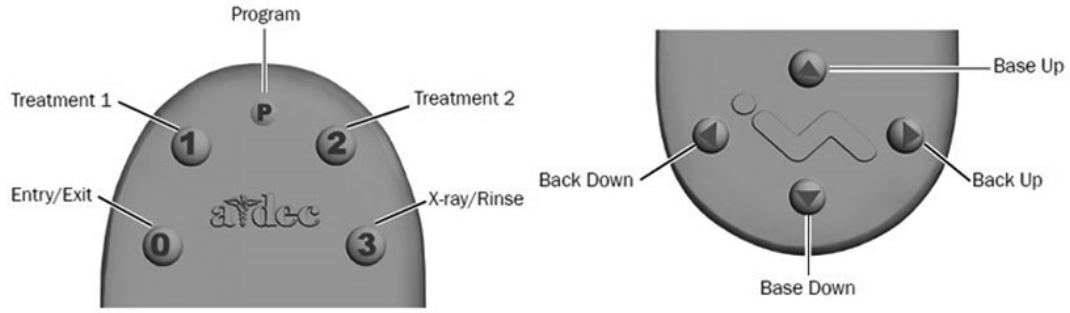


Figure 3–3. Foot switch to dental chair.
(Reproduced by permission courtesy of A-dec Inc.)

Newer chair models have a feature similar to the safety stop plate, which immediately stops the chair movement if a foot or piece of equipment becomes lodged under the chair. Very little pressure on the plate halts all chair movement, except for the base up function. This allows the chair to be raised off the item, releases the pressure on the stop plate, and returns all switch functions to the chair.

Most dental chairs have moveable armrests. Notice, I said moveable, not removable. You will get many calls on dental units with broken armrests. These armrests are mobile so a patient can easily enter and exit the chair. Dental chairs are also equipped with two different style headrests—articulating and horseshoe. The articulating headrest allows the patient's head to move in a 60 degree arc, whereas the horseshoe headrest maintains the head in a set position.

The newer dental chairs have the capability of converting from a right-handed provider approach to a left-handed approach. This conversion is extremely important for proper dental care, so if that request comes in, do not assume it is a routine job. A left-handed dentist must struggle to provide care with a right-handed system. You may wonder why we mention that here with the chair. The chair is the base of the whole system and everything mounts to it.

Dental unit

The dental unit is a vital and complex piece of equipment. When a dental unit is down for repairs, patient treatment is usually no longer available in that treatment room. Therefore, it is essential you understand how the unit works so repairs are efficient and effective!

Clinical application

The dental unit provides the basic utilities required for dental treatment, including H_2O, compressed air, electricity, and vacuum. It may also include hand-piece controls, foot controls, bracket tray, tubing flush system, syringes, cuspidor, and suction apparatus. The unit design should be compact, and hose attached equipment, such as hand pieces and syringes, can sit so they do not drape onto the patient.

Operation and maintenance

As a BMET, you must care for the dental units. There are many types of these units—each different in design, shape, and manufacturer. Most units have H_2O, air, electrical, and vacuum systems. As we review each system, we will discuss, in a limited manner, some specific maintenance procedures. For

practical reasons, the maintenance instructions given here are mostly general in nature. You must always refer to the manufacturers' literature for maintenance and repair.

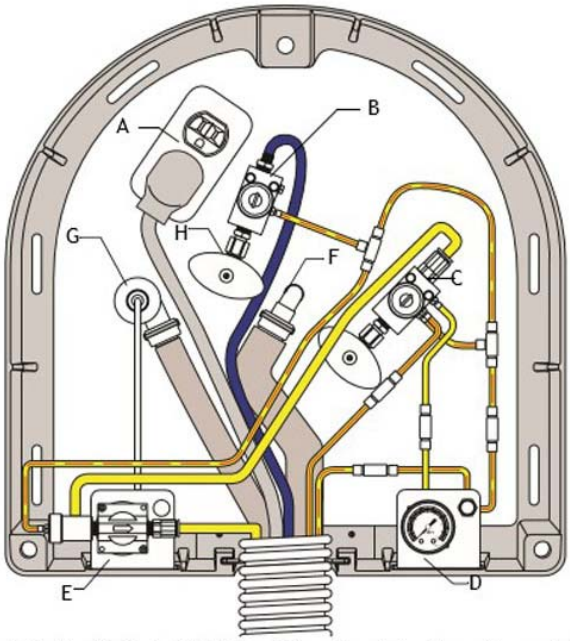
As with the dental chair, begin each inspection by making a visual inspection and operational check of the unit. During the visual inspection, look for obvious problem areas, such as frayed electrical wires, missing screws, H_2O leaks, and so forth. Then, make an operational check of each system. For example, you can test the H_2O, air, electrical, and vacuum systems by operating the 3-way syringe, fiberoptic hand piece, dental light, and saliva ejector.

Basic systems

Let's look at each of the basic systems and equipment of the dental unit, along with the routine adjustments and maintenance of each.

H_2O system

H_2O enters into the dental unit via the floor utility center (fig. 3–4). This center houses the interfaces for all utilities. It has a manual control valve for the H_2O, along with a pre-regulator valve.



(A) Electrical Duplex Outlet; (B) Water Filter Regulator (cuspidor only);
(C) Air Filter Regulator; (D) Gauge and Pre-regulator Assembly;
(E) Moisture Separator (optional); (F) Vacuum Drain; (G) Cuspidor Drain;
(H) Manual Shutoff Valves

Figure 3–4. Floor utility box.
(Reproduced by permission courtesy of A-dec Inc.)

A malfunctioning H_2O system affects the operation of the H_2O 3-way syringe. If any of its systems fail to operate, ensure all necessary valves and switches are in the on position. Then, check the associated filters and screens. H_2O leaks are usually a culprit, and rather obvious. Loose connections, or defective washers and valves are secondary considerations. If you cannot solve the problem at this point, break out the manufacturer's literature before continuing with troubleshooting. The H_2O system is very important to the operation of the dental unit; without it, items such as the syringe, cuspidor, saliva ejector, cup filler, and hand piece H_2O spray are inoperable and of no use to the dentist or technician. The saliva ejector (or oral evacuator) system is also H_2O-activated by using a venturi principle to create a vacuum.

Air system

Modern dental units employ an air system designed to run the various air-driven dental hand pieces. These systems have become more elaborate and complex over the years, but can be logically troubleshot using the manufacturer's literature and some basic knowledge of the operating principles. On some dental units, air is used to operate up to three air-driven hand pieces—an air syringe, spray syringe, and hand piece lubricating system. Dental operating units generally have two types of syringes—air and H_2O syringes. Most modern units combine these syringes into a multi-syringe package that has air and H_2O available from one syringe hand piece.

A large central air compressor provides compressed air. Because of the noise level and for safety reasons, this system is located outside the patient treatment area. The BMET or facility manager usually must blow out the system. This keeps the air from building a lot of moisture. Moisture in the compressed air lines causes sediment to form. Moisture can also result in algae that ruins precision-engineered hand pieces in rapid order and causes debris to be ejected into the patient's mouth. As the temperature of the air changes throughout the day, the condensation accumulates. To remove this condensation from the air compressor, locate the jet opening, which is usually at the lowest point of the compressor tank. This is usually a jet fitting that allows you to loosen it, resulting in a combination of H_2O and air to blow, or bleed out. Allow the H_2O to completely drain and have air only in the system, before closing the jet valve opening. Purge or bleed the air lines daily of any built-up condensation. (This is usually a user maintenance type item.)

On some dental units, there is a moisture separator on the air line in the floor utility box. The moisture separator consists of a filter encased in a transparent bowl. At the bottom of the bowl is a purge valve. This should be pressed when moisture accumulates in the separator. When the filter becomes clogged, the BMET replaces it.

Another problem that occurs in the air system is incorrect air pressure at critical points. Most hand pieces operate on air pressure within the 20 to 80 psi range, with a specific pressure recommended for each hand piece. Most units have a control system located on the bracket tray where the air pressure can be adjusted.

Before making any adjustments to the system pressure, verify the air compressor is on and the psi ranges from 80 to 100 in the tank. Ensure the air and H_2O manual shut off valves remain fully open, unless the unit is being serviced. Locate the air and H_2O pre-regulator adjustment knobs in the floor utility box. Turn on the master control switch located on the dental unit, and then check the system pressure gauges. Air pressure should range from 70 to 80 psi, and H_2O pressure should range from 35 to 40 psi. If it is necessary to adjust pressure, always adjust air pressure first. Turn the pre-regulator knob clockwise to increase, or counterclockwise to decrease pressure. To get an accurate gauge reading when decreasing pressure, bleed the system pressure after each adjustment before reading the gauge. You can bleed the system by pressing the three-way syringe button.

Electrical system

When electrical systems are used, they can provide power to indicator lights, solenoid valves for hand piece operation, and warm air or H_2O application.

Central vacuum system

Generally, the central vacuum system provides suction to numerous dental units. The vacuum is connected to the unit and oral evacuation equipment (i.e., high volume evacuation [HVE] and saliva ejectors) with hoses. The dental technicians draw clean clear H_2O through the HVE and saliva ejector to clear any debris after each patient. After rinsing with H_2O, they draw air through the system to clear all H_2O from the hoses. A filtering component of the central vacuum system for the HVE and saliva ejector is the solids separator (fig. 3–5). It contains a strainer that collects large pieces of debris that could clog the suction hoses. Remove and clean this strainer if a decrease in vacuum is experienced. You will receive many calls by dental technicians who accidentally suction a gauze pad

into the system. It usually lodges somewhere in the hose. The only way you can remove it is to disconnect one end of the hose and massage it to locate the gauze pad, and then continue to massage it towards the disconnected hose end. This can be quite a disgusting job, depending on what was suctioned just subsequent to or after the gauze pad. Many times, blood and tooth debris come out of the hose with the gauze so wear rubber gloves. This job can easily be demonstrated to the users so they can clear their hoses without the assistance of the BMET.

The HVE uses low pressure and high volume to remove the hand piece and three-way syringe H_2O spray from the patient's mouth. A tip is placed into the HVE hand piece, and the suction is turned on and off by the control valve. Remove, clean, and disinfect the control valve daily. Apply a light coating of silicone lubricant to the O-ring seals of the valve prior to reassembly. Check the operation of the HVE to ensure it works properly.

The saliva ejector is used when the dentist wants to keep the treatment sight very dry. This suction is good only for the removal of small amounts of liquid, such as saliva. A disposable plastic tip inserts into the rubber tip of the saliva ejector. The rubber tip and rotary valve are removed for cleaning, disinfecting, and inspection. The rotary valve requires silicon lubricant subsequent to reassembly.

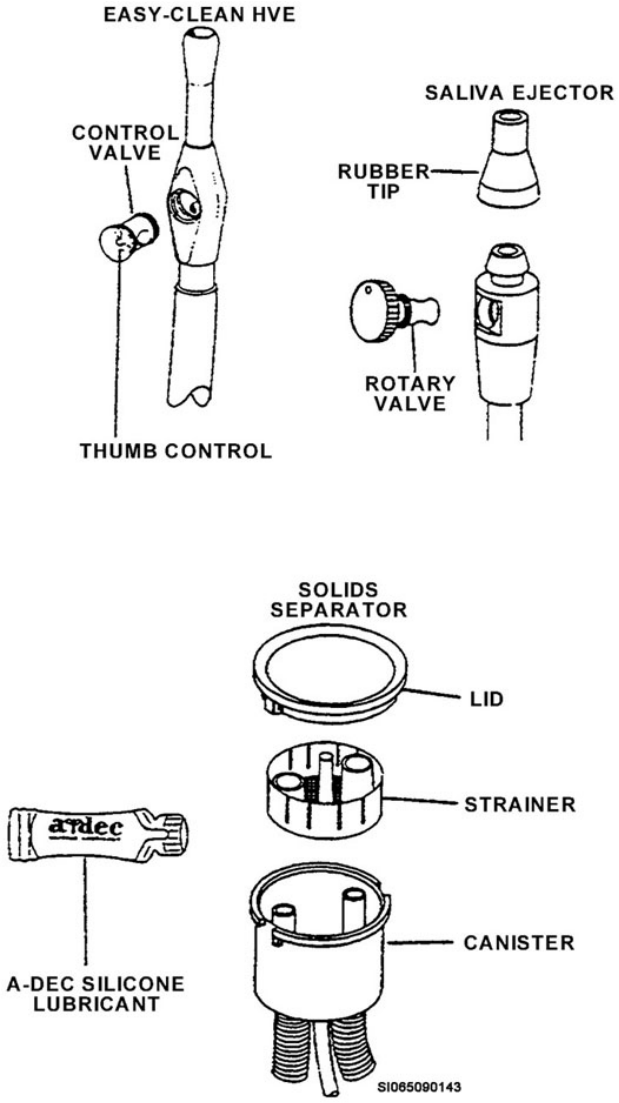


Figure 3–5. Central vacuum components.
(Reproduced by permission courtesy of A-dec Inc.)

Control system

Please refer to figure 3–6 for this discussion. This system automatically delivers the drive air and coolant to whichever hand piece is lifted from its holder. The control system has two main component parts: hand piece and foot controls.

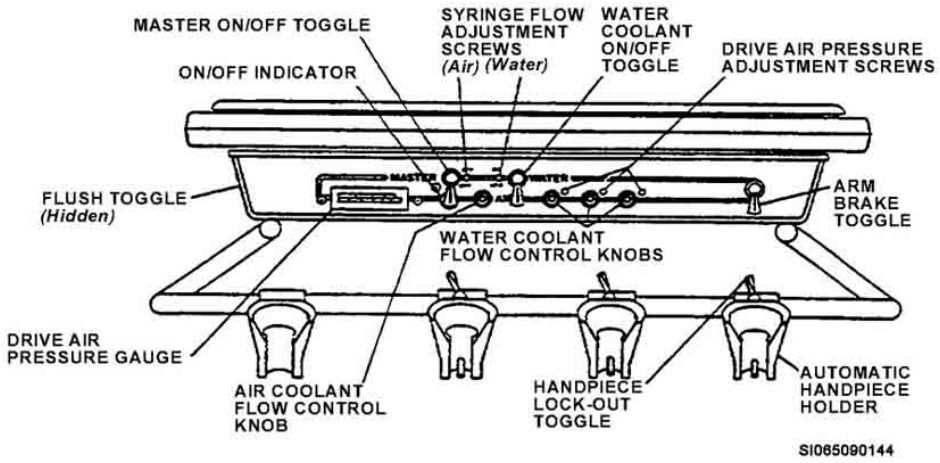


Figure 3–6. Hand piece control system.
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Most hand piece controls are located on a bracket tray that can accommodate three hand pieces. The H_2O coolant flow and maximum drive pressure are individually adjustable for each hand piece. Most units use international color symbols for identification of utilities.

- A blue dot identifies an H_2O control.
- A yellow dot identifies an air control.
- A red dot identifies the ON or activated position.

Every unit has a master on/off toggle or switch. It turns on the air and H_2O to the control system. When it is turned off, none of the items on the unit function. Ensure this switch is in the off position whenever the unit is not in use to prevent flooding in the event of a leak while the system is unattended. The on/off indicator provides a visual indication that the system is pressurized when the master switch is on.

The water coolant on/off toggle stops the flow of H_2O coolant to all the hand pieces. Adjustments of the H_2O coolant flow to each hand piece are made with the individual H_2O coolant flow control knobs. For best results, turn the knob for the selected hand piece clockwise until you feel a slight resistance. As you operate the hand piece at medium speed, turn the knob counter clockwise until a fine mist is visible around the bur. It takes very little H_2O to produce excellent cooling with fog spray. The process is repeated for each of the other hand pieces.

The air coolant flow control knob adjusts the air coolant flow to all hand pieces and can completely shut off the air coolant. To make adjustments, first turn the wet/dry toggle on the foot control to the off position. As you operate the hand piece at medium speed, adjust the air coolant knob to the desired flow (strong flow is recommended). Air coolant is now set for all hand pieces.

The drive air pressure control adjusts the drive air pressure to the hand piece with an adjustment screw for each individual hand piece. Adjust the maximum drive air pressure to meet the hand piece manufacturer's specifications listed in the instruction manuals. With the hand piece attached to the unit and a bur in the chuck, lift the hand piece from the holder and depress the foot control. A visual indication of the hand piece psi is viewed on the drive air pressure gauge. Watch this gauge while turning the adjustment screw until the hand piece runs at the specified maximum pressure when the foot control is fully depressed. Repeat the process for the other hand pieces.

The syringe flow control adjusts the air and H_2O flow from the three-way syringe. Generally, there are two adjustment screws to control the flow—one for air and one for H_2O. First, depress the H_2O button on the three-way syringe and adjust the H_2O screw. Repeat the process for the air adjustment.

The automatic hand piece holder shuts off air and H_2O to the hand piece when it is in its holder. When the hand piece is lifted from the holder, the valve inside the holder allows drive air and coolant to reach the hand piece. The automatic hand piece control function can be overridden with the hand piece lock-out toggle. This is used to lock-out a hand piece when two hand pieces are out of their holders at the same time. Use this feature as a safety precaution whenever burs are being replaced.

The entire bracket tray is mounted to an arm with adjustable height. The arm brake toggle secures the arm at the selected height. Once it is positioned, set the arm brake as a safety precaution to prevent the tray height from being accidentally moved during treatment. Remember to release the arm brake prior to moving or adjusting the bracket tray height. You will get many complaints about drifting trays because the technicians forget the simple release step, thus causing the brake to loosen and not perform properly.

All hand pieces are operated by the provider through the use of a foot control device (fig. 3–7). A valve inside the foot control regulates the hand piece speed and provides an air signal that activates the air and H_2O coolant flow. The foot control is operated by light foot pressure applied to any part of the disk.

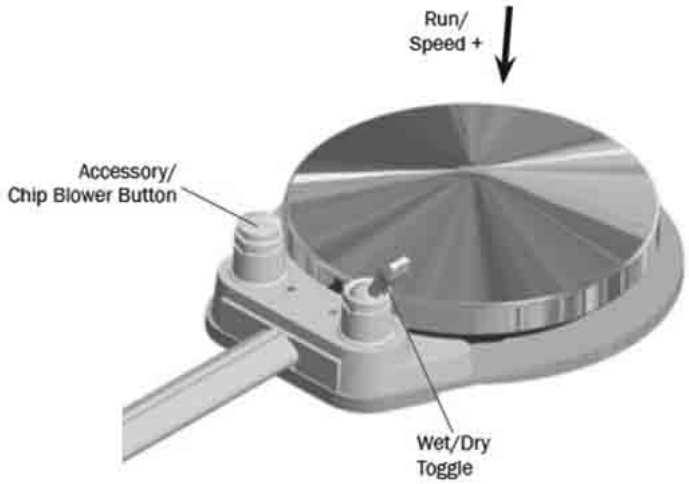

Figure 3–7. Foot control.
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The foot control is also equipped with a wet/dry toggle and a chip blower. The wet/dry toggle allows the H_2O coolant to the hand piece to be shut off without moving the hands from the oral cavity. To remove debris from the treatment site, send a jet of air through the hand piece when it is not running by activating the chip blower.

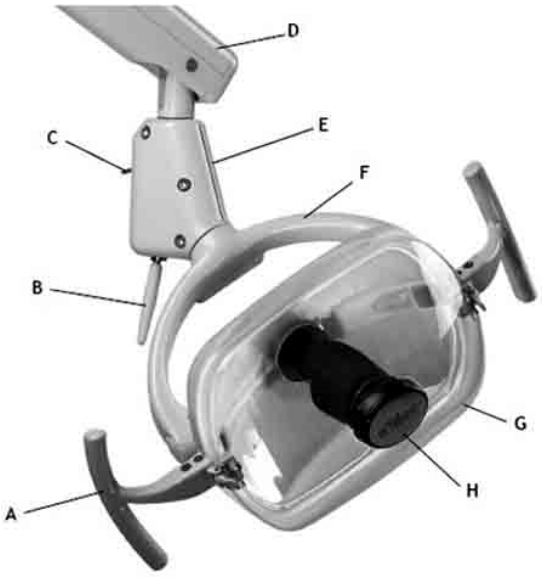
The foot control really takes a beating in the dental treatment room. Even when being used properly, the foot control remains on the floor and may have heavy items dragged across it or people tripping over it. A lot of time is spent replacing the foot control tubing that has holes in the air or H_2O line. Also, the main valve requires regular replacement due to the nature of its use.

Dental light

The dental light illuminates the patient's mouth. The light may be ceiling track-mounted, wall mounted, or mounted to the dental chair. Either type is easily adjusted by the provider or assistant. When the light is properly positioned, it illuminates the treatment site without projecting shadows of the provider's or assistant's hands onto the oral cavity.

Because of the physical location of the ceiling track-mounted lights, most maintenance is performed by the BMET. Most operational aspects and adjustments are the same as the chair-mounted light.

The chair-mounted light consists of three major assemblies: the transformer and rigid arm, flex arm, and light head assemblies (fig. 3–8). The light is activated by the on/off switch located on the flex arm, behind the light head assembly. Use the intensity switch, located on the transformer housing, to set the intensity at low, medium, or high settings.



A – Light Handle
B – On/Off Switch
C – Intensity Switch
D - Flexarm
E – Switch Housing
F – Light Yoke
G – Light Shield
H – Nosepiece

Figure 3–8. Components of the chair-mounted dental light.
(Reproduced by permission courtesy of A-dec Inc.)

The flexible arm is counterbalanced to the weight of the light head in any position and can be adjusted, if necessary. If the arm moves too easily, or tends to drift up or down, adjust the spring tension. However, if the arm is difficult to position, decrease the spring tension.

For ultimate positioning flexibility, the light head rotates on three different axes (fig. 3–9). It can rotate as much as 180° horizontally, 125° vertically, and 45° diagonally from either side.

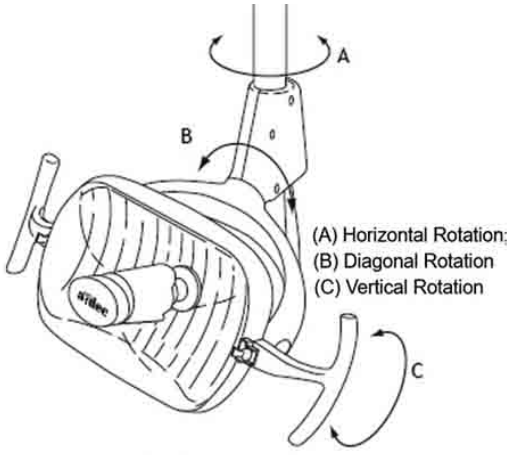


Figure 3–9. Positioning the dental light.
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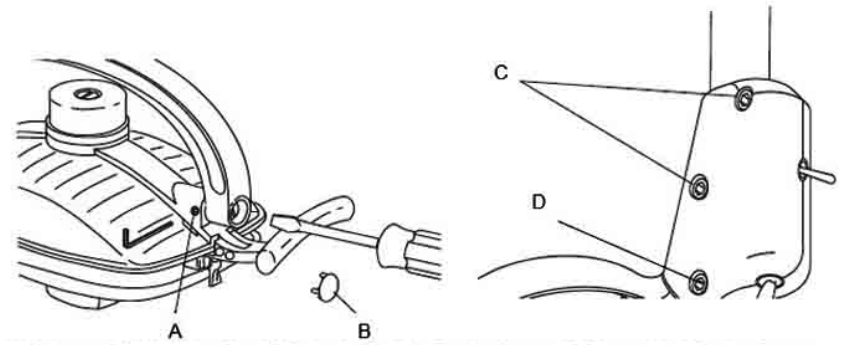
The pivot tension of the light head adjusts easily. This is necessary if your light head is difficult to position, moves too easily, or drifts out of position. You will receive a lot of calls about drifting lights! To adjust the vertical pivot tension, loosen the setscrew on the light and remove the end cap (fig. 3–10). If the light head moves too easily or drifts out of vertical position, increase the tension. If the light is too difficult to move vertically, decrease the tension. When the adjustments are complete, replace the end cap and tighten the setscrew. To adjust the horizontal pivot tension, turn the adjustment screw at the top of the on/off switch housing. Increase the tension if the light head moves horizontally too easily or drifts out of position. Be extremely careful not to overtighten this adjustment screw because it is possible to crush the bearing out of shape. Loosen the tension if the light head is difficult to move horizontally.



(A) Setscrew; (B) Light Yoke Plug; (C) Horizontal Rotation Tension Screws; (D) Diagonal Axis Tension Screw

Figure 3–10. Light head tension adjustments.
(Reproduced by permission courtesy of A-dec Inc.)

To adjust the diagonal pivot tension, turn the adjustment screw at the bottom of the on/off switch housing. Increase the tension if the light head moves diagonally too easily or drifts out of position. Decrease tension if the light is too difficult to move diagonally. All movement in the diagonal axis can be eliminated by turning the screw clockwise until it stops.

One of the major concerns with the light is the light bulb. Often, it burns out at the most inopportune times. Though this replacement is considered user maintenance, you should understand how to replace the bulb. Turn the light off and allow the burned out bulb to cool. Release the fastening devices on the light shield and move the shield aside. Very carefully, pull the old bulb from the socket and discard it. Open the wrapper of the new bulb to expose the bulb pins, but do not remove the bulb from the wrapper (fig. 3–11). Use the wrapper to protect the bulb while installing it. This is necessary because finger oils limit bulb life and can affect light performance. If you inadvertently touch the bulb, gently clean it with cotton soaked in ethyl alcohol. Carefully insert the new bulb into the socket and remove the wrapper. Replace the light shield and test the light.

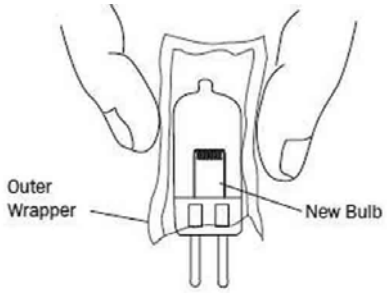


Figure 3–11. Bulb replacement.
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CAUTION: Never operate the light with the light shield removed. The shield is your protection against injury in the event the bulb shatters.

There are many times when you must give advice on how to perform user maintenance. Therefore, you need to understand how the light shield and reflector are cleaned, and what can and cannot be used in the cleaning process. Always ensure the light is cool before cleaning. Remove the light shield to thoroughly clean by releasing the toggles on either side (fig. 3–12). Immerse the shield in warm soapy H_2O, rinse in clear H_2O, and then wipe dry with a lint-free cloth.

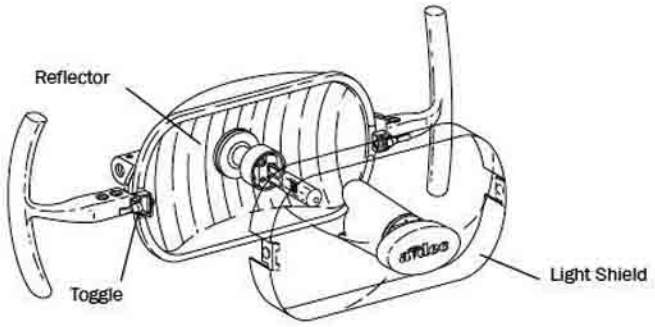

Figure 3–12. Light shield.
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Clean the inside surface of the reflector when dust or spots impair the efficiency of the light. Use a soft lint-free cloth to gently remove the accumulated dust particles. For a more thorough cleaning, dampen the cloth with isopropyl alcohol. Wipe the inside reflector surface in one direction only! Ensure the cloth is not so wet that it drips into the electrical part of the light. Never use abrasives, chlorine, H_2O, or any H_2O-based cleaning solution on the inside reflector surface. These can damage or discolor the reflector surface, impairing the effectiveness of the light. Do not rub heavily or clean the reflector when it is hot. Never soak the reflector in cleaning solution. When performing a visual inspection of the light assembly, you will know if the user was cleaning it properly. If the reflector has scratch marks, discolorations, peeling reflector material or cracks within the reflector surface, proper user maintenance was not performed. It's time then to hold a training class on the proper care of the dental light. Light reflectors can be a costly replacement item due to improper care!

215. Ultrasonic prophylaxis unit

The ultrasonic prophylaxis unit is standard issue for most dental rooms. It is an ultrasonic or simply a sonic scaler designed to remove heavy calculus deposits from the teeth without the use of hand instruments and extensive patient torture.

History

Ultrasonic instrumentation first came about in dentistry in the 1950s. An ultrasonic drill prepared teeth for restorations, but it relied on an abrasive slurry to cut the tooth and, therefore, reduced visibility considerably. High-speed turbine drills were developed about that time as well. As the turbine drill gained in popularity, the ultrasonic drill was phased out.

An ultrasonic instrument reappeared in 1955 for periodontal (area around the tooth) instrumentation. It has undergone many changes in design and usefulness since that time. The bulky complex units are now compact and easy to adjust. The variety of tips increased and many tips carry the needed H_2O supply through an internal tube, rather than by means of an external tube, which can easily bend out of alignment with the tip. Several manufacturers developed these units, each with unique features. Air-driven units that generate less heat are available for direct connection to air turbine hoses, competing with the ultrasonic devices largely because of their ease of operation, lower cost, and simple storage.

Operation

Ultrasonic instruments use high-frequency sound waves to fracture deposits from teeth and cavitate the accompanying H_2O supply to mechanically flush the area. The instrument tip vibrates at

approximately 30,000 cycles per second, with the H_2O spray creating a halo of tiny bubbles surrounding the tip in a fine mist.

Whereas ultrasonic scalers oscillate at 30,000 or more cycles per second, “sonic” scalers follow an elliptical pattern of 16,000 to 18,000 cycles per second. These are air-driven devices, rather than electrical. A sonic scaler consists of an autoclavable hand piece and a set of tips. The hand piece attaches to the tubing of the air turbine hand pieces used for caries removal or polishing. These are the most portable scalers. They typically operate with an H_2O spray. This remains an important aspect of the therapeutic benefit of this type of scaling, even though the air-driven sonic scaler does not require H_2O as a coolant.

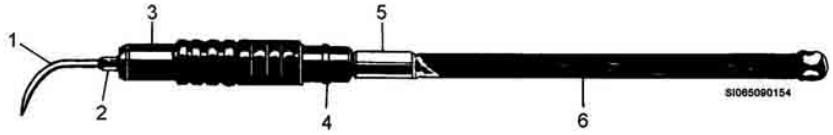
Because the vibrating tip and cavitating H_2O cleanse the tooth, there is no need for sharp instruments. In fact, for purposes of scaling and curettage, the tips must be dull. There is no need to engage a sharp blade against the deposit or tissue; the vibrations merely from placing the activated tip on the operative area cause the deposits to fracture away and necrotic tissue to coagulate.

The equipment (fig. 3–13) for most ultrasonic prophylaxis units includes a control box, foot control, H_2O connector, and hand piece and cable assembly. Insert tips for the hand piece are separate.

Figure 3–13. Standard ultrasonic prophylaxis unit.

The control unit is moved close to the chair for easy access for adjustments. It should be plugged into the electrical outlet. If the foot control is separate, it usually plugs into the back of the unit. Matching the shape of the plug prongs with the shape of the holes in the unit determines the correct outlet. Next, attach the H_2O hose to the unit. Usually it is a “quick disconnect” clip on junction or a junction with threads for screwing the hose end piece into the unit. It is important all connections are secure. If the hand piece is a separate system, matching the prongs with the outlet (usually found in the front of the control box) is again important.

When starting the ultrasonic unit after several hours or more of nonuse, turn the unit on the high setting and activate the foot pedal, allowing the H_2O to flow through the system for at least two minutes. This clears the stagnant H_2O and associated contaminants. Bleed air from the hand piece by holding the hand piece up so the H_2O flows back over the edge of the hand piece, allowing air bubbles to rise and dissipate. This is necessary to prevent overheating. Repeat this procedure each time an insert is changed. Figure 3–14 is an example of one of the interchangeable inserts. Once the H_2O flows upward from the hand piece without spurting, an insert can be placed in the hand piece. Select the proper power setting for the tip.



1) INSERT TIP
2) WATER OUTLET
3) PLASTIC GRIP
4) O-RING
5) CONNECTING BODY
6) MAGNETOSTRICTIVE STACK

Figure 3–14. Interchangeable insert.

Most units tune automatically. Simply lock in the hand piece insert (fig. 3–15) and activate the foot pedal; the tip tunes in a few seconds. Manual tune units require turning the tune control to its highest position and backing it downward while activating the foot pedal.

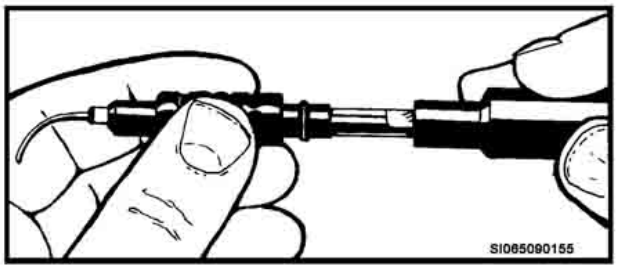


Figure 3–15. Placement of the insert into the hand piece.

When the tip is in tune, the H_2O bursts from the tip in a halo of fine mist. The H_2O flow can be adjusted so it cools properly and produces a manageable spray in the mouth. Because a wide variety of ultrasonic and sonic units are available, read and follow the manufacturer's instructions for each unit you encounter.

Clinical applications

Use the ultrasonic scaler for patients who have large, tenacious deposits and stains on their teeth. It is used to remove deposits from teeth that will be extracted, minimizing the possibility that calculus will lodge in the extraction site. Its greatest usefulness is in preparing teeth for definitive periodontal therapy.

Ultrasonic scaling is extremely useful for clearing local irritants in pericoronitis, and gingival and periodontal abscesses. It is used to clear deposits in cases of chronic marginal gingivitis, periodontitis, idiopathic fibrous hyperplasia, drug-induced hyperplasia, and hormonal gingivitis, such as that associated with pregnancy, puberty, or menopause.

Ultrasonic instrumentation with an H_2O lavage appears to have an antimicrobial effect. The cavitation activity, heat, and acoustic streaming are the probable causes for the decrease in numbers of bacteria at sites that were ultrasonically debrided.

In addition to removing deposits, ultrasonic tips are used for soft tissue curettage, periodontal surgery, irrigating periodontal abscesses, recontouring restorations, removing orthodontic cement, administering drugs, cleansing root canals, and stripping contact areas of crowded teeth.

There are times when the ultrasonic scaler should not be used! Ultrasonic instrumentation tends to damage amalgam restorations, widening or chipping the margin between the tooth structure and the alloy or roughening the surface. Ultrasonic scaling is contraindicated for any patient with a pacemaker, because the sound frequencies of the scaler may disrupt the electronic mechanism with electromagnetic interference. Although most new model pacemakers have shielding to prevent just such interference, it is unwise to subject the patient to such a risk. Patients with tuberculosis or hepatitis should not undergo ultrasonic scaling due to the increase in airborne microorganisms associated with the procedure. When the ultrasonic device is being used, airborne microorganisms increase by thirty fold. Though a large percentage of the contaminants are filtered out due to the laminar flow through the room, there is still the possibility of infecting the technician or subsequent patients.

Remember, the most frequent use of ultrasonic instrumentation is in periodontal procedures.

216. Dental lab equipment

Although dental lab equipment is more of a therapeutic support element, we will discuss the lab equipment in this section to fully encompass the functions of a dental clinic. There are several

different types of ovens in the dental lab. This lesson talks about three of them—the porcelain, fixed prosthetic burnout, and super ticonium ovens. We will also briefly discuss casting machines, blasters, benches, and dental lathes.

Porcelain oven

There are many types of porcelain ovens, also called porcelain furnaces. The ovens can vary in design from the vertical muffle type to the horizontal muffle type. Newer models are programmable and run many different settings based on the required application. These units operate in various heat ranges up to roughly 1,200° C. Let's look at the application of a porcelain oven.

Clinical application

Porcelain is a tooth-colored, sand-like material, consisting mainly of kaolin, feldspar, and flux. It fuses at high temperature to form a hard substance similar to enamel in appearance. It is used in dentistry for inlays, jacket crowns, denture teeth, fixed partial denture pontics, and complete crown veneers. The porcelain oven is a specialized unit designed solely for firing or fusing the porcelain in crowns and fixed partial denture works.

Operational inspection

Each manufacturer furnishes detailed instructions for its furnace; however, all operate basically the same.

First, you must preheat the muffle to drive out all moisture. Preheating must be done slowly to avoid damage to the muffle. Adjust the amperage control to the lowest point and turn on the furnace. Leaving the door slightly ajar, adjust the control to provide 2 amps of current. Set the temperature control on 1,000° F. When the temperature reaches this point, increase the current to 5 amps and raise the temperature to 1,950° F. When the buzzer sounds, return the amp setting to 2. The furnace will cool down and hold between 800° F and 1,000° F. It is now ready to operate. Follow this procedure each time the unit is turned off and restarted by the operator and during your operational inspections.

If you are continuing on with your inspection, close the door and apply a vacuum, which should reach 28 – 30 pounds. Set the temperature control for the fusing temperature of the porcelain sample being tested. Adjust the amperage level to achieve a heat rise of 90° – 100° F per minute. When the buzzer sounds, release the vacuum, and remove and examine the sample. The dental lab technician can verify the quality of the finished product for you. If the quality is poor and the calibration of the oven is in question, you need to recalibrate.

Use pure metals with known melting points to calibrate the muffle. Place the metal flake on the sagger tray and insert the tray into the furnace. Set the temperature control at the melting point of the metal used and adjust the current to achieve the 90° – 100° F rise per minute. Observe the metal until it melts; check the pyrometer. If the temperature is lower than that for which the control was set or if the metal has not melted, calibrate the furnace. The screw for this adjustment is located on or near the temperature control knob. Using a small screwdriver, turn the screw until the pyrometer agrees with the temperature control. Cool the furnace down slowly with the door closed to prevent muffle cracks, and then repeat the procedure to check the calibration.

The porcelain furnaces operate at high temperatures. Use safety equipment and be careful how you handle the hot items.

Fixed prosthetics burnout oven

In the process of forming or creating dental appliances for a patient, the mold or cast must eventually be fired in the burnout oven. There are usually several of these burnout ovens located in the dental lab.

Clinical application

Electric furnaces are used for wax elimination, preheating, and heat treatment of the dental cast used for the creation of dental appliances. The paramount requirements of a furnace are:

- An accurate pyrometer.
- A method of controlling the rate of temperature rise.
- A positive means of maintaining a constant temperature.

Operational inspection

Ensure the muffle is clean and all debris is vacuumed out. Set the pointer on the dial to the desired temperature. The oven should heat to the preselected temperature, and then remain constant. Never operate the unit at temperatures higher than those recommended by the manufacturer's literature. Do not hit the meter to see whether the needle is moving, as this could cause the face of the meter to break. Once the oven finishes its cycle, allow it to cool with the door closed. Quick cooling may crack the muffle. Quarterly, check the pyrometer by using temperature pills or a pure metal.

You should also check the electrical connections and power cord. This oven draws a lot of current and the cord could become hot, causing rapid deterioration of its exterior material. Ensure the area where the oven is located is uncluttered and clean because there is a potential fire hazard with a unit that can get so hot!

Ticonium super oven

This oven is your bulk burnout oven. It can burn up to 22 cases at one time. It has a spring-loaded door that opens upward.

Clinical application

It is used primarily for burnout of removable partial denture framework molds. Most of the ovens are not operated manually, but have some form of controller that automatically monitors a cycle. The twin controller is an electronic device used to automatically operate the ticonium super oven or a vertical loading oven. When properly adjusted, it activates an oven, maintains a predetermined maximum burnout temperature for specific time periods, and deactivates the oven after the programmed burnout time elapses.

Operational inspection

Visually inspect the physical condition of the power cord and plug. Check the mechanical integrity of all moving parts. Check and carefully replace the door springs as they start to weaken. Inspect the interior of the unit for damage (i.e., cracks), and dirt and dust. Then, proceed with operating the unit.

With the oven at room temperature, turn the unit on. Immediately check the temperature reading to ensure it corresponds with the room temperature. If a discrepancy exists, adjust the indicator. Any difference here will also be present at higher temperatures. After observing the pyrometer, run the temperature up to 1300° F. Check for accuracy with temperature pills. Utilize the manufacturer's literature for equipment-specific adjustments or repairs.

Casting machines

There are several different types of casting machines used in the dental lab. This lesson discusses some of the more important aspects of these units so you can better understand casting procedures.

Clinical application

Casting machines use centrifugal force to cast molten metals. When working with gold, the casting is essentially a holder or arm that rotates due to spring tension. The casting arm is rotated to put tension on the spring and is locked in that position until the metal is molten. When the metal is ready to be cast, the spring tension is released, causing the arm to rotate. The metal is then forced into the mold by centrifugal force. This is a manual method. This type of machine requires an external heat source–

–a gas and air blowpipe—to melt metal. New units use an electric motor to fling the molten metal into the mold.

When working with metals having a relatively low-melting temperature (i.e., gold), an acetylene flame can be used for heat. However, when working with metals having a higher melting temperature (i.e., ticonium), the metals are electrically heated by conduction or induction methods.

The induction type of casting machine is primarily used to cast chromium alloy and remove partial denture framework. It sets up an electromagnetic field around the ingot of metal and melts it through rapid rearrangement of the molecules of metal.

The conduction type of casting machine is used to electronically melt conventional and porcelain fused to metal gold alloys.

Operation inspection

When you work with a manual casting machine, the following simple tips ensure the dental lab staff has an operational machine on which they can rely:

- Ensure the arm is balanced to prevent vibration damage and possible miscast.
- Lubricate with three drops of oil at the base of the rotating shaft after each 200 castings.
- Do not exceed more than four turns in winding the centrifuge arm. Too many turns weaken or break the spring.
- Have the operator keep the machine clean and free of dust by providing a daily/weekly preventive maintenance (PM) checklist.

When you deal with conduction and induction devices, the following suggested guidelines ensure longer life of the equipment:

- Never allow conduction devices to exceed 8 amperes of current to the muffle. This can result in rapid muffle burnout.
- Always turn off the switch on the control panel before releasing the contact block during your PM. Failure to do so causes arcing of the points and quick element burnout.
- Ensure the spring-loaded contact block drops down to prevent interference with the casting arm.
- When lubricating the induction-type assembly rods, use a powdered lubricant (e.g., molybdenum disulfide), and wipe off the excess.
- Once a month, remove the crucible slide arm holder and clean the tracks. Do not neglect to lubricate the two contact fingers on the induction type with powdered lubricant. Ensure these are vertical and tight.

Remember to always use the manufacturer’s literature when operating or performing maintenance on casting machines.

Blasters

Several types are blasters are found in the dental lab. They range in size from small portable systems to large floor-mounted systems, and utilize shells or sand. Each has its own purpose, but, generally, all perform the same actions.

Clinical application

Shell blaster and sand blasters have identical construction characteristics. They differ only in abrasive content and use. The shell blaster uses crushed walnut shells as abrasives. It is used to remove gypsum products from acrylic resin prosthesis during the deflasking operation. Walnut shells do not affect the teeth or denture base.

The sand blaster uses zircon grit as an abrasive. It is used in cast removable partial denture work, or to remove casting investment and surface oxides from the metal framework. Do not use the sandblaster on acrylic or porcelain because it ruins them.

Figure 3–16 shows two sandblaster styles. The one on the left is the floor-mounted style; the one on the right is the portable model. The portable model is used in conjunction with a mini-airbrush unit, to prevent contamination of adjacent laboratory areas by abrasive and investment particles. The airbrush allows finer and more detailed cleaning.

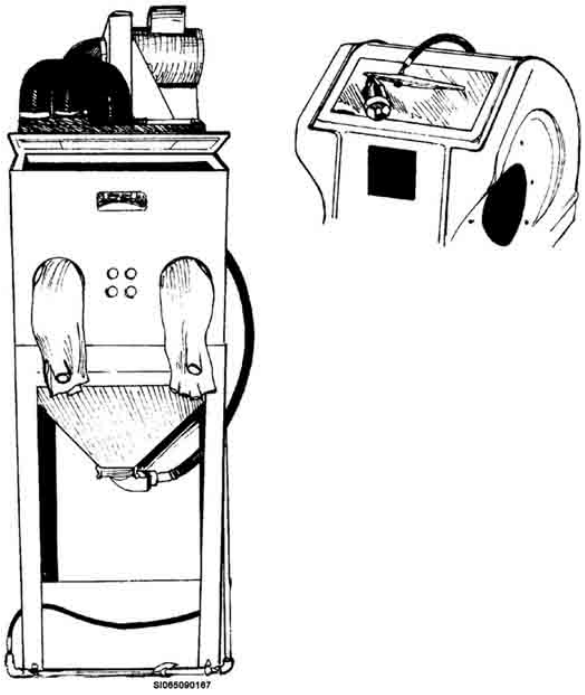


Figure 3–16. Sand and shell blaster styles.

Operational inspection

Verify the rubber gloves are securely attached and have no damage (i.e., tears, cracks, etc.). This is the only protection the operator gets from a lot of static electricity. This static is generated by the blasting and churning of the sand or shells within the confined space. Remove the interior abrasives periodically. Verify the protective viewing shield does not impair vision. If it is abraded, replace it. Check the power cord and plug for defects. Ensure safety glasses or goggles are readily available for the operator. Drain the air line to eliminate condensed moisture. Check air and electrical connections for cuts, wear, or other damage. When you turn the unit on, it will operate at 90 –100 psi air pressure. The nozzle should not be damaged and should emit a stream of blasting material.

Once again, always use the manufacturer's literature for operation and maintenance of blasting units.

Bench engines and lathes

In this section, we discuss bench engines and dental lathes. These pieces of equipment are used in the finishing, grinding, and polishing phases of denture completion.

Bench engines

The dental bench engine is a very simple device and requires relatively little maintenance; however, you must understand some basic uses and principles of bench engines to ensure safe operation and long life.

Clinical application

Many dental lab technicians prefer a bench engine because of its versatility and mobility (fig. 3–17, A). It can be angled to reach awkward areas. The dental engine is used to operate the straight hand piece assembly. These hand pieces are, in turn, used to trim the acrylic and teeth. Dental engines can also be part of older dental operating units used to remove decay or polish teeth.

Principles of operation

The dental bench engine is a series-wound electric motor. You may recall from electronic fundamentals that all electric motors operate on the same principle—a force is exerted between stationary and movable magnetic fields. The stationary field is the field produced by the field windings; the movable field is the magnetic field produced by the armature. The amount and direction of this force, which results from the interaction of the two magnetic fields, determines motor speed and direction of rotation.

Series-wound motors have their windings in series with their armature; thus, any change in armature current is accompanied by a corresponding change in field strength, resulting in a change of speed. The speed is adjusted by controlling the armature or field current.

The direction of rotation for a series motor may be changed in one of two ways: reversing current flow in the field winding or in the armature.

Reversing the power source leads in a DC series motor will not change the direction of rotation, since this action reverses current flow in the armature and field windings. When both currents are reversed, the armature rotation remains the same; therefore, the changing of polarity of the DC does not affect the direction of rotation.

Another characteristic of the series motor to remember is that due to the way a series motor operates, it continues to accelerate unless a load is placed on the motor. The acceleration is limited only by the friction on the armature. Therefore, a load should always be on the motor.

The speed on newer models is changed by varying the amount of resistance in series with the motor, thereby varying the voltage to the motor. A double-pole, double-throw (DPDT) switch reverses the rotation of the armature by reversing the direction of current through the armature.

Lubricate the foot controller every six months since the plates must always have a small quantity of Vaseline on them to avoid excessive wear. To ensure this, the manufacturer placed small round holes in them to hold the Vaseline, so a little is drawn out as the spring brushes pass over them.

Exposure to different degrees of temperature may dry the Vaseline, in time, so examine the plates from time to time. Remove the inside iron plate by taking out the four screws around the edge, but do not touch the center screw that holds the foot lever.

If the plates appear to be sufficiently lubricated, no attention is required. But, if the Vaseline appears dry and hard, or there is none present, carefully clean and brighten the metal with a cloth moistened with alcohol. If any grease is lodged between the plates, scrape it out with a toothpick or wood splinter; never use metal. To apply fresh Vaseline, simply fill the small round holes (not the spaces). If there are no holes, put the Vaseline directly on top of the plates, using a little more than in the above case.

Do not touch the screws that hold the foot lever. If the bars that throw the foot lever to the center show any signs of wear, apply a little Vaseline where they touch.

Other preventive maintenance procedures should include cleaning the armature, checking for worn brushes, lubricating and adjusting engine bearings, and checking for worn belts on the straight hand piece assembly.

Dental lathe

There are three types of dental lathes used in the dental lab: the bench lathe (fig. 3–17, C), floor-mounted lathe (fig. 3–17, B), and high-speed lathe. We will discuss all these types.

Clinical application

The bench lathe and chuck combination is used for a variety of grinding, finishing, and polishing procedures. The Wells Quick Release Chuck (fig. 3–17, D), when correctly installed on a bench lathe, allows the operator to change chucks and burs while the lathe is in motion, which greatly decreases the time spent in the finishing and polishing procedures.

The floor-mounted lathe is equipped with a suction device to draw smoothing and polishing agents away from the operator. It is used for low-speed polishing of cast removable partial frameworks, polishing gold, fixed partial dentures, and for all types of acrylic resin restorations.

The high-speed lathe is used on extremely hard chrome alloy metals and in partial denture construction finishing and polishing. It is not recommended for finishing gold.

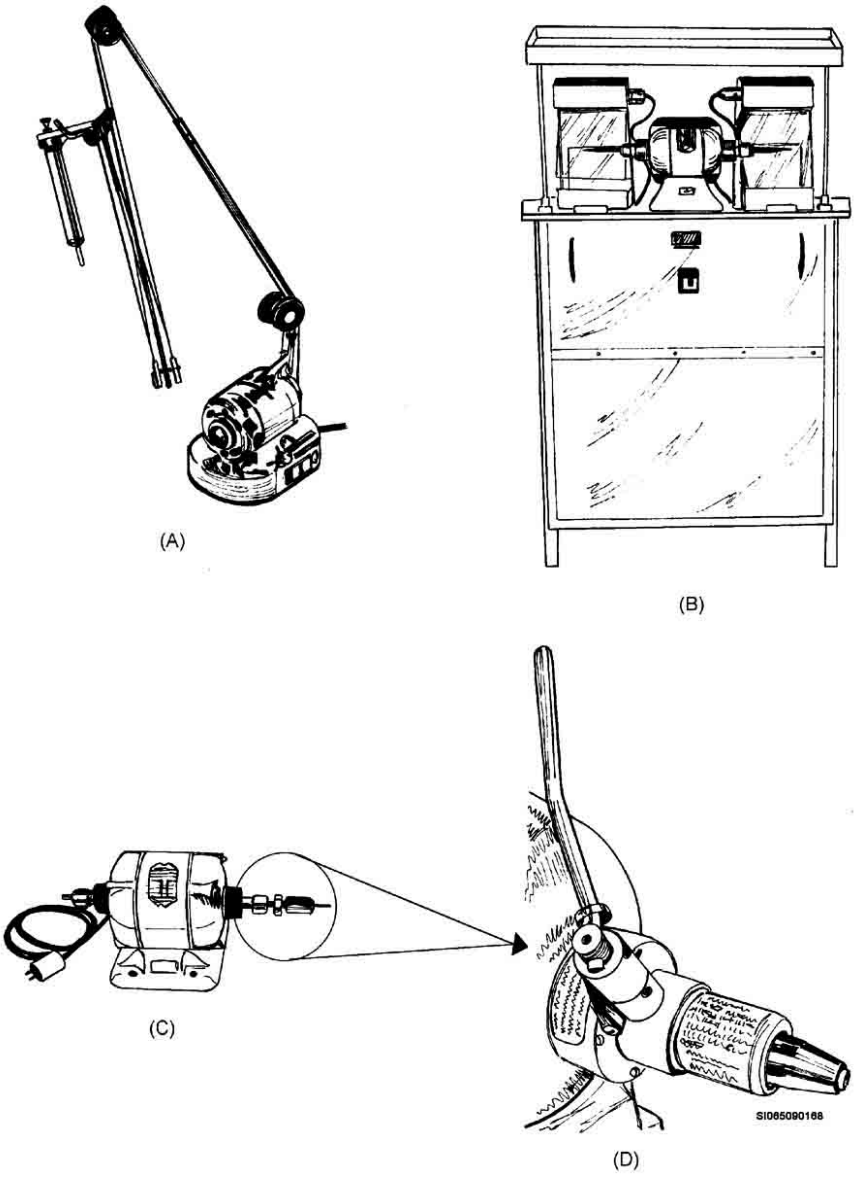


Figure 3–17. Dental engine, floor-mounted lathe, bench-mounted lathe, and quick-release chuck.

Operational inspection

Although the bench lathe is used more than any other item of equipment in the dental lab, the only maintenance required is general operator cleanliness. The bearings are factory sealed and require no lubrication. Cleaning and lubrication of the standard chuck is performed by the operator periodically to prevent rust and ensure smooth operation. If the quick-release chuck is used, there are some simple things to remember:

- Do not attempt to operate the chuck unless it is properly installed on the lathe.
- Never oil or use solvents of any kind on the quick-release chuck.
- Never close the collet without a tool (chuck, bur, etc.) in the collet. Allow the clutch spring to slowly engage the clutch. Never push up on the handle or let the handle snap up.
- Do not remove or attempt to defeat the purpose of the safety strap.

The floor-mounted unit only requires these few simple items:

- Keep the blower motor oil cups filled. Check the manufacturer's literature for the type of oil and frequency.
- Ensure dust is cleaned from motor housing by operators daily.
- Replace filters as required by the manufacturer's literature.

The high-speed lathe has a few different items you must check periodically:

- Oil the motor every 6 months with 3 drops of light machine oil in each oil cup.
- Maintain correct belt tension. If the belt is too loose, the spindle will not turn. Adjust the tension by loosening the screws under the spindle housing and turning the spindle clockwise.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

214. Dental operating system

1. What is the function of the dental chair?

2. What features are necessary for proper patient positioning?

3. How can the pre-position switch be stopped once it is activated?

4. What is the function of the automatic return switch?

5. What will still operate on the chair although the safety stop is activated?

6. What is the difference between an articulating and a horseshoe headrest?

7. Should a request for a conversion of a system from a right-handed dentist to a left-handed dentist be considered routine?

8. What is the clinical application of a dental unit?

9. From what location do the main utilities for the dental unit come into the room?

10. What operations on the dental unit will be inoperable if the H_2O system fails?

11. What provides air to the dental hand pieces?

12. What damage can occur to dental hand pieces as a result of moisture in the air?

13. The compressor tank should be at what pressure range?

14. What should be cleaned if a decrease in vacuum is noticed?

15. What is the procedure for removing gauze pads from the vacuum lines?

16. What is the difference in function of the HVE and saliva ejector?

17. What are the two parts of the hand piece control system?

18. Which feature on the control system turns off the H_2O to all the hand pieces?

19. What is the function of the automatic hand piece holder?

20. What secures the bracket tray in the proper position for use?

21. How are the hand pieces operated by the provider?

22. What is the chip blower used to accomplish?

23. What components on the foot control requires the bulk of maintenance?

24. What three ways may a dental light be mounted?

25. What are the three assemblies of the chair mounted dental light?

26. What must be adjusted if the dental light arm moves too easily or drifts during procedures?

27. What must you do if you accidentally touch the light bulb during replacement?

28. What is used to clean the light shield and reflector?

29. What visual signs indicate the light has been improperly cleaned?

215. Ultrasonic prophylaxis unit

1. How do ultrasonic instruments clean teeth?

2. How fast does the ultrasonic tip oscillate compared to the sonic scalers? What pattern do sonic scalers follow?

3. What comprises an ultrasonic prophylaxis unit?

4. Why is it necessary to allow H_2O to flow through the system after it has sat for a while?

5. Why is air allowed to bleed out of the hand piece?

6. How do you know the hand piece tip is tuned properly?

7. What is the reason for decreased numbers of bacteria in the area that has been ultrasonically debrided?

8. When should the ultrasonic scaler not be used?

9. Why is laminar air flow important in areas where ultrasonic scaling is being performed?

216. Dental lab equipment

1. What is the clinical application of a dental porcelain oven?

2. What is the purpose of preheating the muffle?

3. How many pounds of vacuum should a porcelain oven maintain?

4. What are electric furnaces (burnout ovens) used for in the dental lab?

5. Why should the area around the burnout oven be free from clutter?

6. What is the clinical application of a ticonium super oven?

7. What is the function of the twin controller on the super oven?

8. What is the clinical application of a casting machine?

9. What method is used to force molten metal into the casting mold?

10. On a manual casting machine, winding the arm too many turns will do what to the arm?

11. How are shell blasters and sand blasters used?

12. What type materials should not be sandblasted?

13. What provides the only protection the operator gets from static electricity when using a blaster?

14. What is the air pressure operating range in a blaster?

15. What is the clinical application of a dental bench engine?

16. What type of motor is used on the bench engine?

17. How do you change the direction of motor rotation?

18. What is the clinical application of the dental bench lathe?

19. What is the purpose for having a suction device on the floor-mounted lathe?

20. What is the clinical application of the floor-mounted lathe?

21. The high-speed lathe is used on what type of metals?

22. What metal should not be finished on the high-speed lathe?

3–2. Physical Therapy

The physical therapy clinic within the medical facility provides therapeutic care to patients with injuries to their musculoskeletal system. A doctor refers patients to this clinic with a description of the problem and a recommended course of treatment. Discussed are the various types of equipment found in this area to include ultrasonic therapy, diathermy, and hydrotherapy units.

217. Ultrasonic therapy

Ultrasonic therapy units are utilized primarily in the physical therapy department of your facility. Ultrasonic units operate along the same basic principles as many of the other physical therapy devices we discuss.

Principles of operation

Ultrasonic therapy, commonly referred to as ultrasound (US) diathermy, is the therapeutic application of a form of acoustic vibration at frequencies too high to be heard by the human ear. The sound waves spread through the tissues, where they are absorbed and converted into heat. This type of heating is by conversion. Conversion is just that—heat transferred when energy penetrates into deep layers of the body tissue where it is converted into heat. The following features of ultrasound are to be considered:

- Acoustic vibrations below 20,000 Hz are called sound.
- Acoustic vibrations above 20,000 Hz are called ultrasound. This frequency is inaudible.
- The physics of ultrasound is the same as audible sound, except for the differences in frequency.
- For therapeutic purposes, the ultrasound frequencies range from 0.8 to 1 megahertz (MHz).

Circuits

There are three circuits generally found in all therapeutic ultrasound devices:

1. Power supply circuit – transforms the alternating wall current into a high voltage DC, and a low-voltage AC for the oscillating circuit. The power supply circuit is constructed so the 110V, 60 Hz, AC line current does not noticeably modify the steady output of the power supply circuit.
2. Oscillating circuit – produces an AC having a high frequency of about 0.8 MHz to 1 MHz. The frequency of the oscillating circuit equals the mechanical frequency of the crystal in the transducer. It is possible to adjust the frequency of this AC by tuning unless the manufacturer installed a device for controlling the oscillating frequency. The oscillating circuit is also referred to as the generator.
3. Transducer circuit – is where the high-frequency AC produced by the oscillating circuit is supplied to a crystal. This crystal converts the electrical current into mechanical (acoustic) vibrations. This conversion happens by a reversal of the piezoelectric effect. The transducer circuit is also known as the transducer, applicator, or sound head, and is attached to the machine by a coaxial cable. This coaxial cable transmits the high-frequency AC from the generator to the crystal housed within the sound head (transducer circuit).

Clinical application

Before we discuss some of the applications of ultrasound, let's examine the two techniques for administering therapeutic ultrasound to the patient. The two types developed for applying ultrasound diathermy are the direct and indirect method:

1. For direct contact, a viscous fluid is used as a coupling agent between the applicator and skin. Mineral oil or an aqueous gel are the most frequently used coupling agents. The direct contact method is used to apply ultrasonic energy to areas of the body that are relatively smooth and have few bony prominences.

2. The indirect method utilizes H_2O as the coupling agent between the applicator and skin. The applicator is held ½ to 1 inch away from the skin with the transducer and body part submerged in H_2O. This is the ideal way for applying ultrasonic energy to irregular surfaces and bony prominences.

During ultrasonic therapy treatment, clinically we cannot measure the parameters that determine the biologic response to ultrasound: temperature obtained in the tissues, duration of the temperature elevation, and rate of temperature rise within the tissues. We can, however, measure the amount of energy entering the tissues and duration of the application of ultrasonic energy.

Measurement of energy (intensity) is expressed in terms of watts per centimeter squared (W/cm^2), which refers to the average intensity of the field. On most ultrasound machines, this information is obtained from the meter on the panel. The intensities of ultrasound for therapeutic purposes range from 0.5 to 4 W/cm^2. For most applications, the duration varies from 3 to 10 minutes for each field in the area of application.

Ultrasound is an effective deep-heating agent. It is possible to produce higher temperatures in bone than either the fatty or muscular tissues even when the bone is covered by more than 6 centimeters (cm) of soft tissue. Unlike the other diathermics, ultrasound can be used safely in the presence of metal implants. The metal implants have a very high thermal conductivity so the heat is removed from the area more rapidly than it is absorbed.

Ultrasound is applied to heat joints covered with a thick layer of soft tissue, such as the hip joint. Other modalities, even shortwave diathermy, cannot heat these deeper structures to a therapeutic level producing results comparable to ultrasound.

Ultrasound selectively heats denser structures permitting an increase in their extensibility. For this reason, it is very effective when applied to a joint with limited mobility just prior to range of motion or “stretching” exercises. The denser structures that are selectively heated by ultrasound are joint capsules, ligaments, and tendons.

Ultrasound may also be used as a heating agent over nerves. The heating effect may reduce the irritability of the nerve, and relieve the pain and spasm effects of the nerve root irritation.

Physiological effects

Most of the physiological effects that are of potential therapeutic value are a result of the increase in tissue temperature resulting from the absorption of ultrasonic energy. The following table lists the local and systemic effects that occur:

Local Effects	Systemic Effects
Increased tissue temperature.	Sedation.
Increased tissue metabolism.	Increased cardiac output.
Increased blood flow.	Increased pulmonary ventilation.
Increased clearing of metabolites and heat.	
Increased supply of oxygen, nutrients, antibodies, and leukocytes.	
Analgesia.	
Increased phagocytosis.	

Some precautions you must be aware of when working around ultrasound equipment are:

- Do not apply ultrasound to the eyes, ischemic areas, malignancies, or a pregnant uterus, or to a patient with predisposition to hemorrhagic disease.

- Apply ultrasound with caution to areas of sensory impairment.
- Observe the patient during treatment for signs of possible tissue damage due to heat.

Operational inspection

Be aware of the sources of information that are helpful in understanding and complying with safe operating techniques before we discuss some of the operational aspects of an ultrasound unit. Again, your best source of operational guidance is the manufacturer's literature furnished when the equipment was purchased. A source of information you should also be familiar with the Code of Federal Regulations (CFR) Title 21, Food and Drugs, Chapter I, Food And Drug Administration Department of Health And Human Services, Subchapter J, Radiological Health, Part 1050, Performance Standards for Sonic, Infrasonic, and Ultrasonic Radiation-Emitting Products, Section 1050.10, Ultrasonic therapy products. This CFR contains definitions applicable to ultrasonic therapy. It also contains performance requirements, such as treatment time, labeling requirements for the manufacturer, and guidelines for manufacturers.

If for any reason the unit does not appear to be operating properly, a simple test to check for normal output from the transducer is:

1. Wrap a piece of 1-inch adhesive or masking tape around the front edge of the transducer to form a cup.
2. With the transducer head in the inverted and vertical position (fig. 3–18), pour approximately ¼" H_2O into the cup formed by the tape.
3. Operate the machine in the normal manner, slowly increasing the intensity control from zero to maximum output.
4. As the intensity is advanced, the H_2O forms a small cone; at full output, it forms a sharp peak and shows violent agitation.

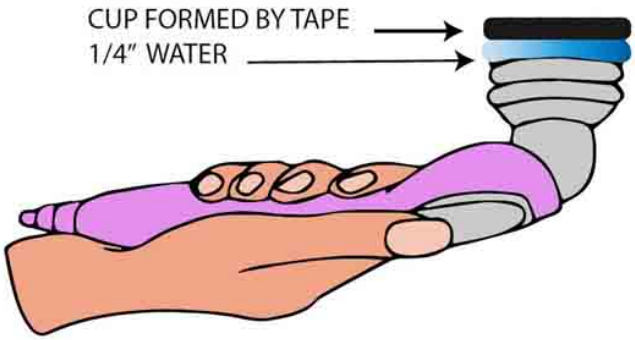


Figure 3–18. Transducer test.

The test can also be performed in a tank of H_2O of sufficient depth to accommodate the transducer, with the transducer free in a horizontal position, about ¼" below the surface.

If you discover you have little or no activity shown by the preceding tests, this indicates improper unit operation, or possibly transducer cable or head problems.

The transducer assembly and cable can be spot-checked rather quickly by removing the whole assembly and taking an X-ray of it to detect possible breaks in the cable wiring. Another method, depending on availability, is to swap out the transducer and cable assembly with another unit manufactured by the same company. Emphasis here is on the word "same;" never attempt to use another manufacturer's parts on the unit you are servicing. Severe damage may occur to the unit or component parts being trouble shot, resulting in two units being unserviceable instead of one. Also, there is a possibility of creating an electrical shock hazard endangering you, the operator, or the patient.

Ultrasound wattmeter

The ultrasound wattmeter, or power meter is designed to measure the ultrasonic power output of therapeutic transducers up to 30 W using the radiant force method. It uses a positioning clamp to hold the transducer in degassed water above a conical target. The ultrasonic energy passes through the water to reflect off the target and is then absorbed by the rubber lining. The radiant power is directly proportional to the total downward force (weight) on the target. This force is then transferred through the target support assembly to the electromechanical load cell inside the meter. The meter processes and digitizes the data to display an accurate measurement of grams or Watts, selectable by the user.

Water as a measurement medium

Ultrasound propagation in water closely approximates ultrasound propagation in tissue. Large areas in the body can consist of low attenuating material such as urine and amniotic fluid. Other areas of the body, such as the liver, contain higher attenuating materials. Water is used as a lower limit of the attenuation encountered in the body. This allows measurements to represent the highest possible intensities that might be encountered in the body. Degassed water is the widely accepted test medium for ultrasound transducers.

Degassed water

Ultrasound power measurement accuracy is affected if the water contains more than 5–10 parts per million (PPM) of air. To degas, boil distilled water for 30 minutes, then seal the container tightly and place it in a refrigerator. An alternate method of degassing water is to heat the water to the boiling point, then pull a vacuum on it for 5 to 10 minutes. The degassed water storage container should be made of glass or plastic. Polystyrene containers should not be used since they allow oxygen to permeate and degrade the water quality. Any unsealed degassed water will absorb oxygen and affect measurement accuracy, therefore a change of degassed water is recommended before each test. Water temperature also affects accuracy. It is recommended to use an ambient testing temperature of 24.0 ±3.0° C (75.2 ±5.4° F). Sonic energy agitates the water surface through heating and scattering. Prolonged testing, particularly at higher power levels, will show visible signs of air bubbles on the transducer, target, and tank lining. Replace the tank's degassed water before each test.

Testing

After filling the tank with degassed water, set up the unit under test by securing the transducer firmly into place using the handle clamps on the tester. Submerge the transducer head under the water medium and position it directly over the target. Allow the water to stabilize before beginning measurements. Once the setup is complete, power on the unit, zero out the readings and select the desired measurement units (grams or Watts). Simply apply ultrasonic power from the unit under test and record the readings as applicable.

218. Neuromuscular stimulator

Another staple of the physical therapy department is the neuromuscular stimulator. These units are small and simple in design, yet play a big part in recovery functions. Let's discuss some of the type and uses of stimulators.

Types and functions of stimulation

Neuromuscular stimulation devices, also known as neuromuscular electrical stimulation (NMES), are medical devices that transmit an electrical impulse, which mimics the action of the central nervous system. The NMES device encompasses a portable stimulator with electrodes, placed on the skin over a targeted muscle or muscle group. The current passes through the electrodes into the body stimulating the motor nerves, causing a muscle contraction as a form of physical therapy or exercise. The intensity and frequency of stimulation can vary based on the level of muscular function and response to treatment. The ramp time is the amount of time it takes the unit in each cycle to reach maximum intensity. The on time is the time that the intensity is on in each cycle, while the off time is

the amount of time the unit is off in each cycle. These cycles continually repeat, which causes a muscle to slowly reach contraction (ramp on), stay contracted for a short period of time (on time), slowly release the contraction (ramp off) and then rest before the cycle repeats (off time). The timing options make it possible for the muscle stimulator to do a "pseudo exercise" for the weak muscle.

NMES units are often confused with transcutaneous electrical nerve stimulation (TENS) units. While both are similar in size and concept, the difference is in their functions. The key here is the nerve. Distinctly different from NMES, TENS therapy uses electric current to stimulate nerves rather than muscles. They are similar in that they deliver electrical current via electrodes attached to the skin, but the difference is in the waveforms they output. TENS units typically moderate the electrical pulse's intensity, width, and frequency in order to suit the individual and unique needs of each user. Each unit has a different waveform and the muscle stimulator has timing options, whereas the TENS unit does not. While TENS by broad definition refers to the complete range of transcutaneously applied currents for excitation of the nerves, it is more commonly used to describe the actual TENS units that deliver the pulses. Although these units have generally been two separate medical devices, some manufacturers have begun to combine these two distinct functions into one device with separate modes and setting ranges.

Clinical application

As a form of both muscle training and electrotherapy, NMES are a treatment modality for disuse muscle atrophy due to a condition such as limb casting or hip replacement surgery, where the nerve supply to the muscle is intact. NMES devices are generally regulated into two broad categories by the United States Food and Drug Administration (FDA): prescription and over-the-counter. Prescription NMES devices can only be purchased with a medical prescription and are solely intended for use under the direct supervision of an authorized healthcare practitioner. Over-the-counter NMES devices are exclusively intended for the use of muscle toning, and can be purchased without a prescription.

NMES therapies have shown great promise in relaxing chronic or acute muscle spasms, enhancing the circulation of blood, re-educating muscles and regaining muscle memory, increasing or maintaining range of motion, the prevention of retardation of disuse atrophy, and the prevention of venous thrombosis (through post-surgical stimulation of the calf muscles) following surgery.

TENS units, on the other hand, are "pain blockers." The buzzing sensation is thought to block the pain signal from the nerve to where it is perceived in the brain as pain. TENS units are also thought to aid in the release of endorphins, which are the body's natural pain fighting mechanism. These devices serve as a form of pain management as well as for prevention of muscle atrophy, and help strengthen muscles, maintain or gain range of motion, and temporarily reduce spasticity.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

217. Ultrasonic therapy

1. What is the term used to describe the heating of tissue by sound waves?

2. What are acoustic vibrations below 20,000 Hz called?

3. What are acoustic vibrations above 20,000 Hz called?

4. What is the major difference between acoustic vibrations above and below 20,000 Hz?

5. What is the frequency range for therapeutic ultrasound?

6. What are the three circuits commonly found in all therapeutic ultrasound devices?

7. The high-frequency AC produced by the oscillating circuit is supplied to a crystal located in what circuit?

8. What distance should the transducer be from the surface of the skin when using the indirect method using H_2O as the coupling agent?

9. For what type of body surface is the indirect method ideally suited?

10. What three factors cannot be measured in determining the biologic response to ultrasound?

11. Name three denser structures that can be heated selectively with ultrasound.

12. What are three local and one systemic physiological effects associated with ultrasound therapy?

13. What areas of the body should not receive ultrasound therapy?

14. What is the procedure for checking normal output from the ultrasound transducer?

15. What is an alternative method to check out the transducer's operation?

16. What two quick check methods can be utilized when the transducer head output is in question?

17. What is the power output rating that an ultrasound wattmeter is designed to measure using the radiant force method?

18. What is used as the highly accepted test medium for ultrasound transducers?

19. What effects power measurement accuracy?

20. What is the recommended ambient water testing temperature for ultrasound power measurements?

218. Neuromuscular stimulator

1 What is the function of a NMES device?

2. What causes the intensity and frequency of stimulation to vary?

3. What is ramp time?

4. Explain the difference between the intended functions of a NMES versus a TENS unit?

5. Describe the clinical application of a NEMS unit.

6. What are the two broad categories of NMES devices?

7. Explain the clinical uses of a TENS unit?

3–3. Ventilator and Anesthesia Equipment

We begin this section by introducing ventilators—types, phases, and inspection requirements. Once you understand how the breathing circuits work, we will introduce the concept of anesthesia. From there you can begin to concentrate on the most misunderstood piece of surgical equipment—the anesthesia machine. This machine has a direct impact on the patient's life. This fact sometimes

creates concern in an otherwise confident BMET, thus unnecessarily leading to a maintenance contract for these machines.

219. How ventilators work

Ventilators breathe for or assist a patient in breathing when there are apnea problems. You will find ventilators in surgery, the intensive care unit (ICU), and any respiratory therapy section within the hospital. We will cover the different types of ventilators and how they are classified, but first, you need to know a little about spontaneous breathing as compared to controlled ventilations.

Spontaneous vs. controlled ventilation

During a spontaneous inspiration, the diaphragm contracts and moves downward. At the same time, the rib cage swings outward and elevates the sternum. This maneuver enlarges the volume in the thoracic cavity and expands the lungs. As the lungs expand, the pressure within them becomes less than atmospheric, and gas is drawn down the airway and into the lungs. Inspiration continues until lung pressure rises to equal atmospheric pressure.

Because the lungs and thoracic wall contain elastic tissue, exhalation is passive. When the diaphragm and the muscles of the rib cage relax, the lungs and thoracic cage recoil to their original size. As this happens, the volume of the thoracic compartment reduces, the pressure within the lungs becomes slightly greater than atmospheric pressure, and gas moves out of the lungs until alveolar pressure and atmospheric pressure are again equal.

The lungs never completely empty; the volume that remains in the lungs at the end of a quiet, spontaneous exhalation is the functional residual capacity (FRC).

During the inspiratory phase of controlled ventilation, the lungs expand because of positive pressure applied from within. As the lungs expand, the rib cage is forced upward, and all the intrathoracic structures are compressed. This action causes the following (use fig. 3–19 as you read this list):

1. Intrapleural pressure rises to a positive value and returns to its normal subatmospheric pressure level only during the quiescent part (expiratory pause) of the exhalation phase, if lung pressure is allowed to reach atmospheric level.
2. The rise in intrathoracic pressure to above atmospheric levels nullifies the action of the thoracic pump mechanism, and venous return falls.
3. The expanding lungs squeeze all structures within the mediastinum, especially the heart, between the lungs and cardiac output falls. The effects are similar to a cardiac tamponade.
4. The positive pressure also compresses the small pulmonary vessels, especially those in direct contact with alveolar pressure. This impedes pulmonary blood flow and increases the work of the right side of the heart.
5. During positive-pressure ventilation, as the central venous pressure (right atrial pressure) rises, venous return to the heart falls.

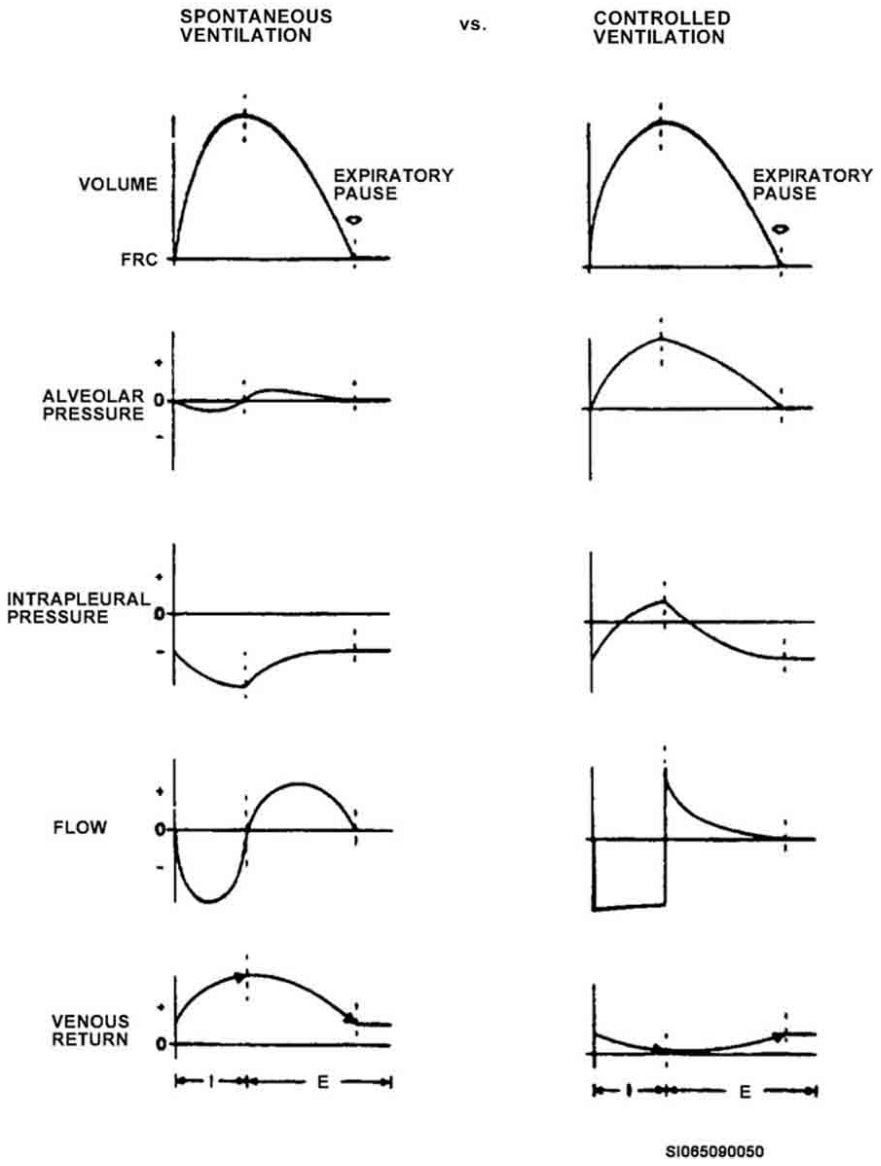


Figure 3–19. Physiologic differences between spontaneous and controlled ventilation.

Although the effects of these responses are not uniform, the reduction in the right heart output can lead to a reduction in systemic blood pressure in the hypovolemic patient (a patient with abnormally low circulating blood volume). In others, the blood pressure is normally maintained by a compensatory mechanism with effects that include the development of issues such as tachycardia, vasoconstriction, an increase in systemic vascular resistance, or peripheral shunting of blood away from the kidneys and lower extremities.

Ventilator/breathing pressures

The ventilator is capable of displaying all pressures developed during the inspiratory and expiratory phases, and the mean airway pressure (mean airway pressure of the respiratory cycle). These pressure displays are also found in modern ventilators that have spontaneous modes, whereby the patient is allowed to breathe through the ventilator with or without assistance. Understanding the significance of each pressure reading is necessary in the evaluation of the patient's lung mechanics, and to minimize cardiovascular and pulmonary side effects of ventilatory support.

Peak inspiratory pressure

Figure 3–20 is a simplified waveform of the pressure that you can observe on the ventilator's manometer during the respiratory cycle. Peak inspiration is the highest pressure developed during the inspiratory phase. If this pressure is measured before the humidifier, the level will vary with changes in the:

- Resistance of the ventilator circuit, which includes the humidifier.
- Compliance of the ventilator, which includes the circuit and the humidifier.
- Patient's airway resistance, which includes the endotracheal tube.
- Patient's compliance (total compliance).

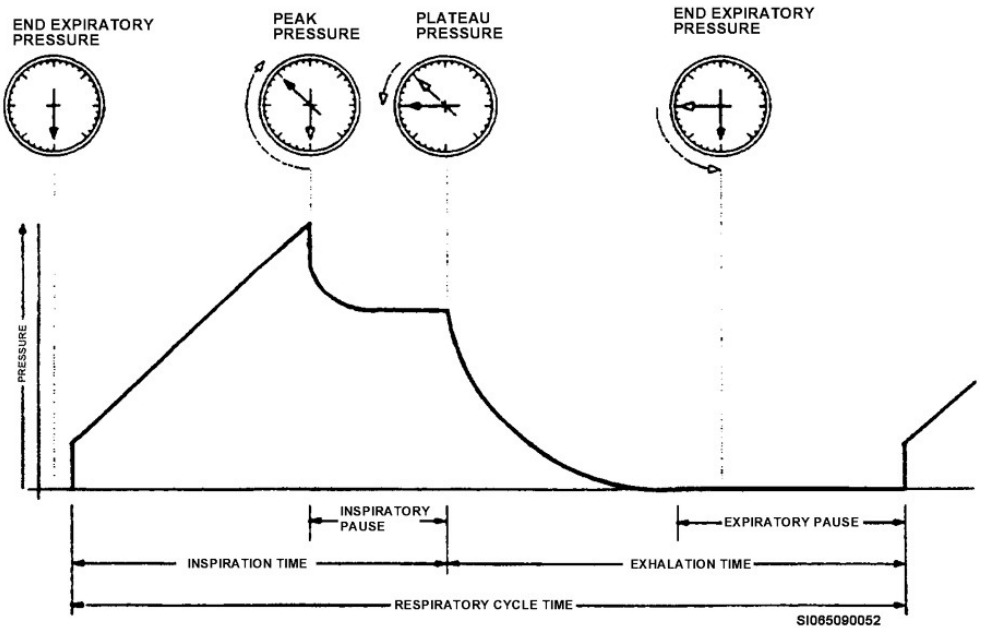


Figure 3–20. Common pressure levels during the respiratory cycle on controlled ventilation.

If the pressure sampled is the proximal airway pressure, then the level will vary with all of the listed factors, except the resistance of the ventilator circuit. The proximal airway pressure is an integral tool in establishing the patient's airway resistance.

Plateau pressure

Once the peak pressure is reached, the pressure in the patient circuit is normally released (exhalation valve opens) and the lungs are allowed to empty to atmospheric pressure. A plateau pressure is established when a volume has been delivered from the ventilator, but the exhalation valve remains closed for a predetermined time. At the onset of this mode, a drop in pressure from the peak is observed; it results from the distribution of gas from the upper airways to the lower airways. When the plateau pressure is perfectly flat, the pressure displayed is the actual pressure in the lungs and ventilator circuit. The plateau pressure, measured proximally or distally, is unaffected by the resistance of the ventilator or the patient's airway resistance. However, the level of the plateau pressure will vary with changes in the ventilator, circuit compliance, and patient's compliance. At the bedside, the proximal peak inspiratory pressure and plateau pressure are used to estimate the patient's total airway resistance; the plateau pressure alone is useful in approximating the patient's static lung compliance.

End-expiratory pressure

The end-expiratory pressure is the pressure maintained in the lungs during the expiratory pause. The lungs normally empty to atmospheric pressure. However, the pressure can be clinician-selected to below-atmospheric pressure (negative end-expiratory pressure [NEEP]) or above-atmospheric

pressure (positive end-expiratory pressure [PEEP]). The use of NEEP during positive-pressure ventilation has been abandoned, but the use of PEEP is widespread in contemporary respiratory care.

Mean airway pressure

The instantaneous values for positive pressure measured at the mouth and those measured intrathoracically are not the same quantitatively. They relate in that a change in the mean mouth pressure (more precisely mean airway pressure [MAP]) indicates a change in the mean intrathoracic pressure. Since the intrathoracic pressure mediates venous return to the heart, understanding the concept of MAP is essential. MAP is defined as the area under the pressure curve for the duration of one respiratory cycle. Any ventilator parameter that alters the area under this curve translates as a change in MAP. Since the contour of the airway pressure curve varies during the respiratory cycle, and also with the type ventilator used or waveform selected, the manual calculation of MAP is tedious and not always practical. Fortunately, microprocessor-controlled ventilators make this information readily accessible.

Now that we've discussed the various pressures monitored and ways they are monitored, let's take a closer look at the ventilator itself.

Drive mechanisms

This subject is important because the pattern of pressure generated by the drive mechanism determines the waveforms of pressure and flow entering the lungs, and the classification of the ventilator in the inspiratory phase. The ideal pattern would mimic the normal physiological breath in barotrauma and adverse cardiovascular effects would not occur. Unfortunately, the search for that pattern continues today. However, with the advent of microprocessor technology, the cumbersome and complicated plumbing that once was associated with the generation of a specific waveform is no longer necessary. The microprocessor-controlled ventilator can produce any waveform with only one simple drive mechanism. Generally, there are seven types of drive mechanisms (fig. 3–21):

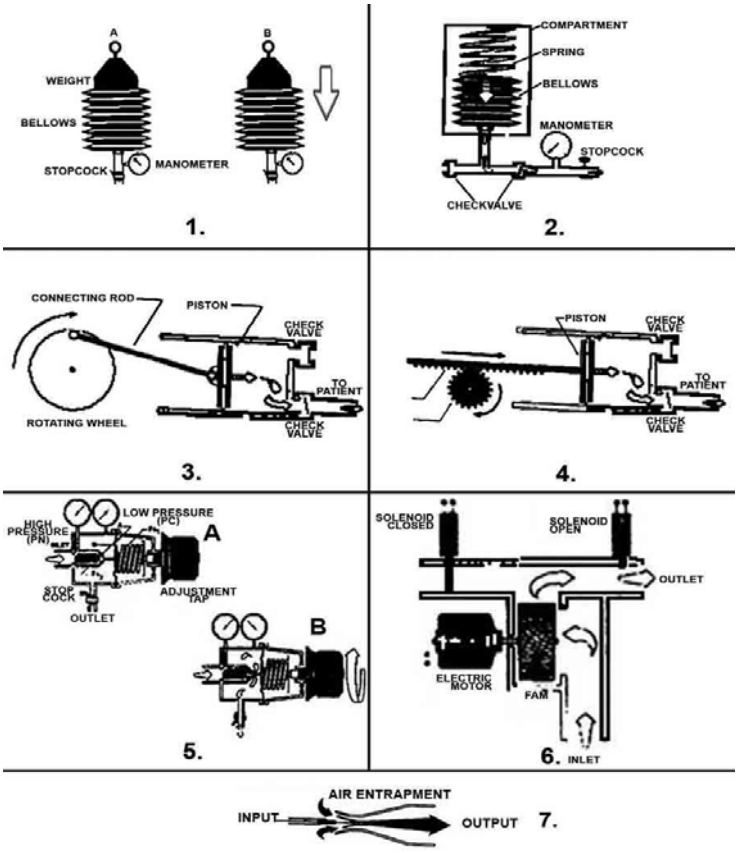


Figure 3–21. Ventilator drive mechanisms.

1. Weighted bellows – The simplest method of generating pressure is with the use of a weighted bellows, see figure 3–21 (1). Since pressure is defined as force per unit of area, the pressure generated within the bellows is a function of weight (force) acting on the cross-sectional area of the bellows. The greater the weight, the greater the pressure generated. When the stopcock opens, the downward force of the weight causes the bellows to empty. As the bellows empties, the pressure within it remains unchanged because the factors that determine original pressure in the bellows—force and area—have not changed. Consequently, the pressure generated by this drive mechanism is constant.
2. Spring loaded bellows – Lung inflation can also be achieved with the use of a spring-loaded bellows. In figure 3–21 (2), the tension of a spring applies a continuous downward force at the top of an expanded bellows. The amount of pressure generated is a function of the force of the spring and the cross-sectional area of the bellows, similar to the weighted bellows mechanism. The greater the force of the spring, the greater the pressure generated. When the stopcock of the spring-loaded bellows opens, the force of the spring causes the bellows to empty. However, unlike the weighted bellows drive mechanism, as the bellows empties, the spring relaxes; the pressure within the bellows does not remain constant, but decreases. Although the pressure progressively decreases as the spring expands, the tension of the spring is such that enough pressure is generated to inflate the lungs before the spring is fully relaxed. The action of a microprocessor-controlled valve compensates for the reduction of pressure and flow.
3. Non-linear driven piston – In figure 3–21 (3), a constant-speed electric motor (not shown) rotates a large wheel attached to a connecting rod and piston. The arrangement causes the piston to travel in a reciprocating motion in the cylinder, and positive pressure is generated during the forward stroke of the piston. However, because the connecting rod is attached off-center to the large wheel, the piston does not move in the cylinder at a constant speed. Consequently, the pressure and flow developed by this drive mechanism vary with the motion of the piston.
4. Linear driven piston – Figure 3–21 (4) demonstrates the one method of generating pressure that uses an electric motor and piston. In this figure, the center of a circular gear connects to the shaft of the motor (not shown). A series of cogs connects to the center of the piston rod along the bottom of the rod. When the cogs of the rod engage with the gears of the wheel, linear motion is transferred to the piston, and positive pressure is generated during the piston's forward stroke. This drive mechanism was popular for use in an electronic pediatric ventilator.
5. Pressure-reducing valves (PRV) – PRVs, like the one shown in figure 3–21 (5), are probably the most popular type of drive mechanism and are used extensively in microprocessor-controlled ventilators. As the name implies, a PRV reduces a high-pressure input to a lower constant output pressure. The high input pressure may originate from high-pressure cylinders, in which pressure in excess of 2,000 pounds per square inch gauge (psig) is common, or from hospital outlet stations, where pressure is normally maintained at 50 psig. Regardless of the input pressure, the output pressure from the PRV becomes the generated pressure. Some PRVs have their output as high as 50 psig; in others, you can adjust the pressure to only a few centimeters of H_2O. PRVs may be adjustable or preset. The main difference between the two is in the former, the tension of the large spring (FS1) can be regulated externally to adjust output pressure. A sealed spring (FS2) prevents source pressure from entering the PRV when the adjusting spring (FS1) is fully relaxed. In the preset PRV, FS1 cannot be adjusted externally, and the output pressure is preset from the manufacturer. Some ventilators do not have PRVs built into them and connect directly to the hospital station outlet. In these instances, if the ventilator does not have a built-in device capable of further modifying the pressure, the station outlet pressure becomes the generated pressure of the ventilator.

6. Blowers – In figure 3–21 (6), an electric motor connected to a series of fan blades rotates at a high, constant speed. This arrangement propels the gas forward and generates a constant level of pressure. As long as no other device capable of modifying the pressure from the drive mechanism is present, the pressure developed by the blower is the generated pressure of the ventilator. With this drive mechanism, the motor runs continuously; but the patient only connects to the blower during inspiration. During exhalation, pressure from the blower vents to the atmosphere through a series of electrically operated switches. This type of drive mechanism was common in early electronic ventilators. It has regained popularity in the modern ventilator as a backup air compressor (air source) for the PRV drive mechanism.
7. Injectors – Injectors, often called venturis, are drive mechanisms normally powered by PRVs or blowers. The main function of the injectors is to increase the overall flow rate capability of the ventilator. In figure 3–21 (7), a high, constant pressure is applied to the jet of the injector, and gas leaves the jet nozzle at a high velocity. This causes the pressure nearest the high velocity of gas to drop below atmospheric pressure. It also causes atmospheric gases to be drawn in around the jet of gas. A well-designed injector captures more flow than the flow driving it. The result is an increase in the total flow rate at the outlet of the injector.

Ventilator circuits

A ventilator may be classified as having a direct-acting or indirect-acting drive mechanism. If gas from the drive mechanism is used directly as the source of pressure for lung inflation, the ventilator is considered to be direct-acting. Ventilators having a direct-acting circuit are also called single circuit ventilators. An indirect-acting circuit is one that uses the direct-acting drive mechanism to operate another circuit. Ventilators having an indirect-acting circuit are called double circuit ventilators. Any drive mechanism can power the secondary circuit, which may consist of a bag or bellows. However, when the secondary circuit comprises a bag, it is customary to have the secondary circuit powered by a nonlinear-driven piston (fig. 3–22). When the secondary circuit contains bellows, the primary drive mechanism may be a PRV, blower, or injector. The primary reason for the development of a double circuit ventilator is it provides a reliable method for the delivery of predictable tidal volumes. Today, ventilators have returned to the single circuit mechanism, but now incorporate electronic measuring devices that can detect and respond to minute changes in pressure, flow, and volume.

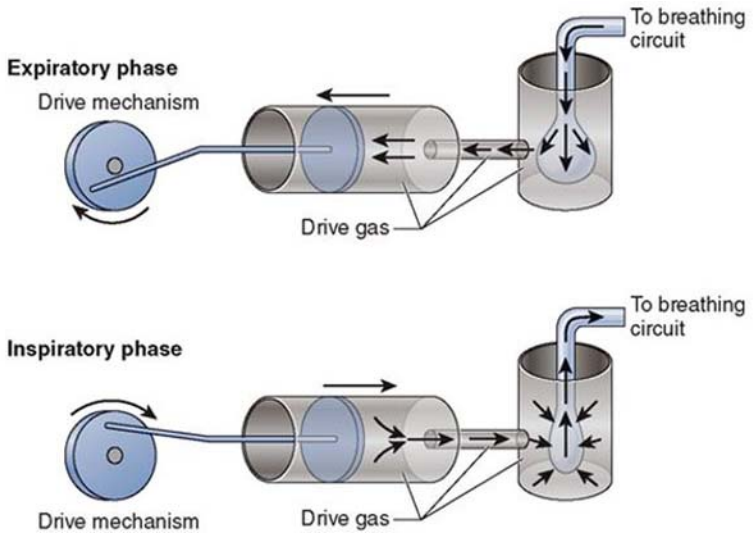


Figure 3–22. Indirect acting ventilator.
(Reproduced by permission courtesy of McGraw-Hill Companies, Inc.)

High-frequency ventilators

High-frequency ventilation is used when the natural breathing frequency must be exceeded with small tidal volumes. In other words, it produces breathing patterns at higher frequencies than conventional

ventilators can provide. The primary use of these units is on infants with underdeveloped lungs, patients with air leaks in lungs, older patients with lung injuries, and any patient who is difficult to ventilate with conventional methods. The two most common forms of high-frequency ventilation in use today are the high-frequency oscillatory ventilation (HFOV) and high-frequency jet ventilation (HFJV).

Settings

High-frequency ventilators have three settings:

1. MAP – This measurement is similar to peak airway pressure in conventional ventilation. This is usually set approximately 2 cm H_2O above the MAP setting for a conventional ventilator. The actual setting is dependent on the equipment used and condition of the patient.
2. Frequency – This measurement is the rate of delivery and is measured in Hz. The setting for this measurement is dependent on the size of the patient and his or her medical condition. High-frequency ventilators are capable of delivery at rates of 5 to 25 Hz.
3. Amplitude – This is the most important setting on a high-frequency ventilator. It is set by observing chest movements. The technician usually adjusts the amplitude in 1–2 cm H_2O increments until reaching the desired setting.

HFOV

The HFOV is a volume-delivered, pressure-limited device. The HFOV employs a piston or diaphragm to provide bi-directional gas flow. MAP is generated when gas is sent through a low-pass filter that acts as a resistor. This high-frequency, low-amplitude gas is usually delivered at a rate of 5 – 15 Hz, an inspiratory time of 33 percent of the oscillatory cycle, and a 1:2 inspiratory-to-expiratory ratio. HFOV provides a continuous flow of fresh gas that provides inspired gas and the clearing of CO_2.

HFJV

The HFJV is a time-cycled, pressure-limited device. This ventilator has a constant gas flow interrupter and is used in parallel with a conventional ventilator. It uses a tube to dispense a high-pressure jet stream into the lungs. The tube consists of a distal airway pressure port, jet side port, and connections for conventional ventilators. The operator is able to adjust the settings for peak inspiratory pressure for the jet and conventional breaths, as well as frequency.

220. Classification and maintenance of ventilators

Now that you know the different types of ventilators, you're ready to learn how they are classified into phases. At the end of the lesson, we briefly discuss the inspection process and related test equipment.

Breathing phases

When looking at a breathing cycle, you find it has four distinct phases: the initiation of inspiratory phase, the inspiratory phase, the change over from inspiration to expiratory phase, and the expiratory phase. Each phase requires the ventilator to do something different, so let's talk about the options at each phase. Refer to the following table throughout this discussion:

Initiation of inspiratory phase	Inspiratory phase	Changeover from inspiration to expiratory	Expiratory phase
• Patient cycling • Time cycling • Manual cycling	• Constant pressure generator • Constant flow generator • Nonconstant flow generator • Nonconstant pressure generator • Decreasing pressure generator • Decreasing flow generator	• Pressure cycling • Flow cycling • Time cycling • Volume cycling • Inspiratory adjuncts	• Constant atmospheric pressure generator • Constant negative pressure generator • Constant positive pressure generator

Initiation of the inspiratory phase

The ventilator can cycle into the inspiratory phase in three ways: by an inspiratory effort of the patient, after a predetermined time has elapsed, or manually. Therefore, the changeover from the expiratory phase to the inspiratory phase happens through patient cycling, time cycling, and manual cycling. Although only one cycling mechanism is necessary, modern ventilators may have all three.

Patient cycling

Patient cycling implies the ventilator responds to an attempt at inspiration by the patient and delivers a controlled breath. This mode is also called assisted ventilation. To accomplish patient cycling, the ventilator must have an assist mechanism. If the mechanism is not present, the patient cannot initiate the inspiratory phase and the ventilator is thus classified as a strict controller.

Two parameters are evaluated to establish the performance of the assisted mechanism—sensitivity and response time. Sensitivity determines the inspiratory effort required to trigger the ventilator. Normally, when the patient inhales a small volume of gas from the ventilator circuit, the corresponding drop in pressure activates the assist mechanism, which delivers a controlled breath. Some mechanisms may respond to volume or flow instead of pressure. The sensitivity is usually set by a knob or menu settings on the ventilator. In its most sensitive position, the ventilator requires only a small inspiration effort of the patient to trigger the controlled breath. The least sensitive position never allows the ventilator to cycle because no amount of inspiratory effort by the patient will produce a controlled breath. Once the inspiratory effort has been made, the ventilator should respond and deliver a breath within a reasonable time. Response time is the time lag between the initial inspiratory effort and the moment the controlled breath reaches the patient airway. The factors affecting the response time are the length of the ventilator circuit and the characteristics of the assist mechanism.

Ideally, the ventilator's response time should not exceed more than 10 percent of the patient's inspiration time. For example, given a ventilator response time of 0.08 seconds (80 ms) and an inspiration time of 1.5 seconds, the response time ratio would be 5 percent and, therefore, would be adequate for this patient. The situation changes drastically when you use the same ventilator on an infant having an inspiration time of 0.5 seconds. Since 16 percent of the infant's inspiration time is wasted in triggering the ventilator, the response time is no longer considered adequate. This is where you would use a ventilator designed for the high respiration rate and short inspiratory time of a pediatric patient. These are high-frequency or pediatric ventilators (discussed in the previous lesson).

Time cycling

The ventilator is classified as being time cycled when the changeover from the expiratory phase to the inspiratory phase is achieved through a timing mechanism, completely independent of the patient. The timing circuit may be pneumatic, electronic, or a combination of both. A strict controller is a time-cycled ventilator that has no assist mechanism.

Manually cycling

The changeover from the expiratory phase to the inspiratory phase is manually cycled when the expiratory phase ends by the action of the operator. In some ventilators, an external means of cycling the ventilator is possible. Activating this mechanism overrides and resets all other cycling options, delivering a controlled breath.

Inspiratory phase

The only function of the ventilator in the inspiratory phase is to move the gas into the lungs. For the gas to move from one area to another, a pressure gradient must exist between two points of the conducting system. In mechanical ventilation, this pressure gradient exists between the generated pressure of the ventilator and the alveolar pressure. The conducting system involves two components—the ventilator circuit and the patient's airway.

Based on the magnitude of the generated pressure, a ventilator is classified as a pressure or flow generator. A pressure generator is a ventilator that generates a fixed pattern of pressure at the mouth regardless of lung conditions, while the flow waveform is free to vary. A flow generator is a ventilator that generates a fixed pattern of flow regardless of the lung conditions, while the mouth pressure waveform is free to vary. For each type of generator, there is a further sub-classification. This sub-classification depends entirely on the pattern of pressure and flow developed during the process of lung inflation.

Constant-pressure generator

For a ventilator to have a constant-pressure generator classification, the drive mechanism must meet two specific conditions. First, it must generate a constant pattern of pressure; that is, it must generate a level of pressure that does not vary from the beginning to the end of the inspiratory phase. Examples of such drive mechanisms include the weighted bellows, PRV, blower, injector, and linear-drive piston. Second, the pressure generated by the drive mechanism must be low enough to allow equilibrium between the pressure generated and the alveolar pressure. Any one of the drive mechanisms mentioned can perform this action. A microprocessor-controlled ventilator can make a waveform or pattern that matches the conventional ventilator, but it handles lung compliance very differently. That is why mechanical ventilators still exist.

Constant-flow generator

A constant-flow generator creates a flow rate that remains constant from the beginning to the end of the inspiratory phase. A ventilator holds a constant-flow generator classification when the pressure generated by the drive mechanism is at least five times the maximum pressure developed at the mouth. Any generator that falls short of that is nothing more than a pressure generator. When the level of pressure generated by the drive mechanism is far beyond the pressure required in the alveoli to accomplish the desired volume exchange, the ventilator must provide a means to control the flow to the lungs. In conventional ventilators, the placement of a high series resistance—known as a flow rate control—between the generated pressure and the patient will accomplish this. All ventilators must provide a cycling mechanism to terminate the inspiratory phase. Without this mechanism, the alveolar pressure will continue to rise to the generated pressure; the flow rate control merely determines how long the process will take to get there.

Nonconstant-flow generator

This ventilator uses a non-linear drive mechanism. Because of this, the flow rate developed during the forward stroke cannot maintain at a constant level. In fact, the motion generates a flow waveform that assumes the shape of a half sine wave. Because of this flow pattern, the pattern of pressure that develops during lung inflation is sigmoid in shape. Since the wheel rotates at a constant speed and is totally uninfluenced by changes in lung conditions, the pattern of the drive mechanism's speed must also be constant. Furthermore, because the motion of the drive maintains regardless of lung condition, the volume dispersed must also be constant. If the volume delivered into the lungs is constant, then any changes to the lung compliance will have an effect on the mouth pressure waveform. Any change to the airway resistance while maintaining the pattern of flow must also affect the mouth pressure.

A flow generator is a ventilator that generates a fixed pattern of flow into the lungs regardless of lung conditions, while the mouth pressure is free to vary. From this definition, we conclude the ventilator described here is indeed a type of flow generator. However, what type is it? Certainly, it is not a constant-flow generator because the flow rate does not remain constant for any definite period. However, the pattern of flow holds constant. In a situation where the drive mechanism generates a pattern of flow that assumes the shape of a half sine wave, and the pattern of flow repeats regardless of lung conditions, the ventilator is classified specifically as a nonconstant-flow generator.

Nonconstant-pressure generator

The main difference between pressure and flow generators is the generated pressure. Therefore, it is possible to transform a nonconstant-flow generator into its equivalent nonconstant-pressure generator by providing a means of reducing the generated pressure. This method involves the placement of a low parallel resistance in the circuit of the ventilator. The parallel resistance allows most of the flow to vent to the atmosphere; the pressure drop across the resistance generates the pressure necessary for lung inflation. The pressure generated by the drive mechanism is low. Because of this, the flow rate into the lungs does not remain constant, but decreases as the lungs fill. However, the pattern of pressure generated at the mouth remains constant regardless of lung condition. Therefore, we must regard the fundamental action of the ventilator as a pressure generator. Since the mouth pressure does not hold constant, but the pattern of the mouth pressure waveform repeats within every stroke, the ventilator is classified as a nonconstant-pressure generator. This is seldom a primary source for lung inflation, but more as the primary circuit in a double circuit ventilator.

Decreasing-pressure generator

The simplest mechanism that operates as a decreasing-pressure generator is the spring-loaded bellows system. In such a system, the volume present in the bellows and the tension of the spring govern the pressure generated. Here the decay in flow rate comes from not only to the buildup in alveolar pressure, but also to the generated pressure. The generated pressure does not remain constant, but decreases as the bellows empties. In a situation where the pattern of the mouth pressure waveform decreases from an initial level as the lungs fill and the pattern of pressure repeats regardless of lung conditions, the ventilator is classified as a decreasing-pressure generator.

Decreasing-flow generator

To transform a decreasing-pressure generator into a decreasing-flow generator, we must provide a means of increasing the generated pressure. This is as simple as adjusting the tension on the spring in a spring-loaded bellows drive mechanism. Once again, you increase the flow through an adjustment, but the flow rate does not remain constant. The pattern of flow remains constant and repeats within each respiratory cycle, regardless of lung conditions. Therefore, a decreasing-flow generator is a ventilator whose flow rate does not hold constant, but whose flow pattern remains constant regardless of changes in lung conditions

Changeover from inspiratory to expiratory phase

As the process of lung inflation continues, a mechanism built within the ventilator must "decide" when to end the inspiratory phase and begin the expiratory phase. The ventilator may end the inspiratory phase in four ways. Although only one method is necessary, modern ventilators may have as many as three. This is known as mixed cycling. Here are the four ways to cycle a ventilator.

Pressure cycling

A ventilator is pressure cycled if the inspiratory phase ends when a pressure-sensing mechanism, built within the ventilator, reaches a predetermined value. At the moment of cycling, the volume delivered, time taken to deliver the volume, and flow rate may all vary from one respiratory cycle to the other. The only nonvariable is the preset cycling pressure.

Pressure-cycling mechanisms may be pneumatic, electronic, or a combination of both. Fluid logic devices, commonly abbreviated "fluidics," represent the latest pneumatic mechanism involved in pressure cycling. In such ventilators, fluidic devices use gas under pressure as an operating medium and can perform all cycling functions of electronic ventilators.

The most important characteristic concerning the use of pressure-cycled ventilators is tidal volume will vary with changes in lung characteristics, regardless of the generated pressure. Reductions in lung compliance or increases in airway resistance will cause a reduction in tidal volume and inspiratory time. When changes in lung conditions occur, the primary control that you can adjust to recover the volume is the cycling pressure. Once the tidal volume is restored, the length of the inspiratory phase may be affected, the extent of which depends entirely on the generated pressure. When inspiration time is affected, the flow rate control can correct the situation.

Flow cycling

A ventilator is flow cycled if the inspiratory phase ends when the flow of gas through a flow-sensitive valve decreases to a critical level. At the moment of cycling, the pressure and volume in the lungs, along with inspiration time, may all vary from one respiratory cycle to the other. The only nonvariable is the terminal flow rate.

The flow-sensitive valve cannot compensate for changes in lung compliance and, in this respect, behaves similarly to the pressure-cycled ventilator. With a reduction in the lung compliance, the volume in the lungs and inspiration time decrease. To compensate, the generated pressure increases until the volume is restored. However, the maneuver does not restore the length of the inspiratory phase, which remains shorter than originally observed. In the simplest form of a flow-cycled ventilator, nothing can be done to correct for inspiration time. In a more sophisticated version, however, a variable series resistance (peak flow control) resides downstream to the flow-sensitive valve and provides more control over flow rate and the length of the inspiratory phase.

The flow-cycling mechanism reacts favorably to changes in airway resistance. With increases in airway resistance, the valve automatically compensates by decreasing the flow rate. Although complete compensation is theoretically impossible, the reduction in flow rate allows more of the generated pressure to reach the alveoli and minimizes large fluctuations in tidal volume. That means with changes in airway resistance the valve will attempt to maintain alveolar pressure at the expense of inspiration time. With minor increases in airway resistance, the increase in inspiration time may not be clinically significant. However, in the simplest form of the ventilator, the operator has no control over flow rate, and the length of inspiratory phase cannot be fully corrected. Some control is available with the placement of a peak control valve, as mentioned. However, with pronounced increases in airway resistance, inspiration time can never completely restore.

Volume cycling

A ventilator is volume cycled if the inspiratory phase ends at the moment a predetermined volume has been delivered into the patient circuit. At the moment of cycling, the flow rate, time taken to deliver

the volume, and pressure developed in the patient circuit may all vary from one respiratory cycle to another. The only parameter remaining constant is the volume preset on the ventilator.

The length of the inspiratory phase depends entirely on the level of pressure generated by the drive mechanism and the patient's lung characteristics. When the drive mechanism generates a fixed pattern of flow, inspiration time is not affected, and the pressure developed during the process of lung inflation is related to the lung characteristics of the patient. In conventional ventilators, when the generated pressure is not high enough to maintain a constant pattern of flow, decreases in lung compliance or increases in airway resistance cause an increase in the length of the inspiratory phase. In such instances, inspiration time is restored by increasing the flow rate.

Microprocessor-controlled ventilators can generate any flow waveform, unlike the constant-volume or nonconstant-volume ventilator.

Time cycling

A ventilator is time cycled if the changeover from the inspiratory to expiratory phase occurs at the moment a timing mechanism built within the ventilator reaches a predetermined value. At the moment of time cycling, the flow rate, volume, and pressure in the lungs may all vary from one respiratory cycle to another. The only parameter remaining constant is the preset inspiratory time. The inspiratory timing mechanism may be pneumatic, electromechanical, or electronic. The length of the inspiration phase may be controlled directly by a simple inspiration timer or indirectly by setting the rate and keeping the inspiration-to-expiration ratio (I:E) constant, or by varying the I:E ratio and percent inspiration time.

Time-cycled ventilators do not control volume directly, but deliver a volume proportional to the product flow rate and inspiration time. Therefore, the volume in the lungs will remain constant as long as the generated pressure is great enough to maintain a constant pattern of flow throughout the inspiratory phase. For this reason, the ideal time-cycled ventilator is one that operates as a flow generator.

When a time-cycled pressure generator is used, the flow pattern will not remain constant, but will decrease with changes in lung conditions. Therefore, the volume in the lungs will vary from one respiratory cycle to the next.

Since the inspiration timing mechanism is completely independent of the patient, the time-cycled ventilator will always appear to operate normally, even during adverse lung conditions. Only by measuring the tidal volume will the clinician know whether a reduction in tidal volume has taken place. Therefore, frequent monitoring of the patient's tidal volume is absolutely necessary in ventilation with a time-cycled pressure generator.

Expiratory phase

The only function of the ventilator during the expiratory phase is to allow the lungs to empty, and the ventilator has a few ways in which to do that. Just like the inspiratory phase, it is also possible to classify the ventilator during the expiratory phase. The three most common classifications are:

1. Constant atmospheric pressure generator.
2. Constant negative pressure generator.
3. Constant positive pressure generator.

Constant atmospheric pressure generator

During the expiratory phase, this ventilator allows the lungs to empty passively to atmospheric pressure. Because no positive pressure remains in the lungs during the quiescent portion of the expiratory phase, the ventilator is said to provide zero end-expiratory pressure (ZEEP).

Constant negative pressure generator

A ventilator is classified as a constant negative pressure generator when subatmospheric pressure is applied to the airway from the beginning of the expiratory phase. During the quiescent portion of the expiratory phase, lung pressure is held below atmospheric pressure. We often use the term NEEP to describe this mode of therapy. The original use of NEEP was to reduce the cardiovascular effects of controlled ventilation, but its use has been associated with air trapping, which led to abandoning the practice.

Constant positive pressure generator

In contrast to the negative pressure generator, a constant positive pressure generator is one in which the lung pressure is held above atmospheric pressure throughout the respiratory cycle. There are four specific types of constant positive pressure generators:

1. PEEP maintains positive pressure in the lungs throughout the respiratory cycle during controlled ventilation.
2. Continuous positive airway pressure (CPAP) maintains positive pressure in the lungs during spontaneous ventilation, and lung pressure never reaches atmospheric pressure. However, the ventilator does not deliver controlled breaths during the entire session.
3. Expiratory positive airway pressure (EPAP) is similar to CPAP in that the patient breathes spontaneously while positive pressure is applied to the airway. However, during EPAP therapy, positive pressure is maintained in the lungs during exhalation only. During inspiration, the patient must inspire to atmospheric pressure.
4. Intermittent mandatory ventilation (IMV) and PEEP are a combination of CPAP and PEEP in that positive pressure is maintained in the lungs and the patient receives controlled breaths intermittently between spontaneous breaths.

That completes the expiratory phase, and so the cycle begins again with the initiation of the inspiratory phase.

Understanding the various phases of respiration and how the ventilator you are looking at is set to react to each phase, will allow you to more effectively troubleshoot the ventilator system. It is much easier to determine which stage is not acting properly and the circuitry that controls it, as opposed to tearing a ventilator apart trying to figure out what is malfunctioning.

Clinical application

We often use an automatic ventilator to sustain life when a surgical procedure or patient condition depresses or paralyzes the patient's respiratory system. Ventilators also help sustain respiration when a condition hinders a patient's ability to breathe fully on their own.

Operational inspection

Each ventilator has its own requirements and, perhaps, special instructions for the operation and care of the system. Therefore, you must always use the manufacturer's literature when performing any kind of maintenance or inspection. Another important provision is personal safety (i.e., body fluids may be present so use infection control precautions). Finally, use the following generic list of checks recommended by the ECRI Institute to ensure a properly working ventilator:

1. Inspect the mechanical integrity of the housing, chassis, strain relief, line cord, AC plug, connectors, and fittings.
2. Ensure the circuit breaker moves freely and the fuse is the correct size.
3. Inspect the mechanical integrity and operation of all controls and switches to ensure they are properly positioned for operation.
4. Inspect indicators, alarms, displays, interlocks, audible signals, meters, gauges, and lights for proper operation.

5. Inspect mechanical components for wear, and lubricate, if necessary or as called for in the manufacturer's literature.
6. Ensure warning labels and index tags are present and legible.
7. Clean the interior and exterior of the unit, fans, and filters.
8. Check the function of all modes of operation (i.e., control, control/assist, IMV pressure support, and CPAP/PEEP).
9. Ensure breathing circuits are properly assembled.
10. Check the operation and accuracy of ventilation controls.
11. Check alarms for accuracy (generally within 10 percent of the set point).
12. Ensure humidifiers, nebulizers, and absorbers work properly.
13. Perform an electrical safety inspection according to applicable standards.

Gas flow analyzer

The gas flow analyzer is a key piece of test equipment for most ventilator products. This unit serves functions for multiple equipment items requiring flow measurements, but is most known for its ventilator applications. We will use the Fluke VT Plus gas flow analyzer to illustrate concepts for the purpose of this lesson. See figure 3–23 for a unit layout.

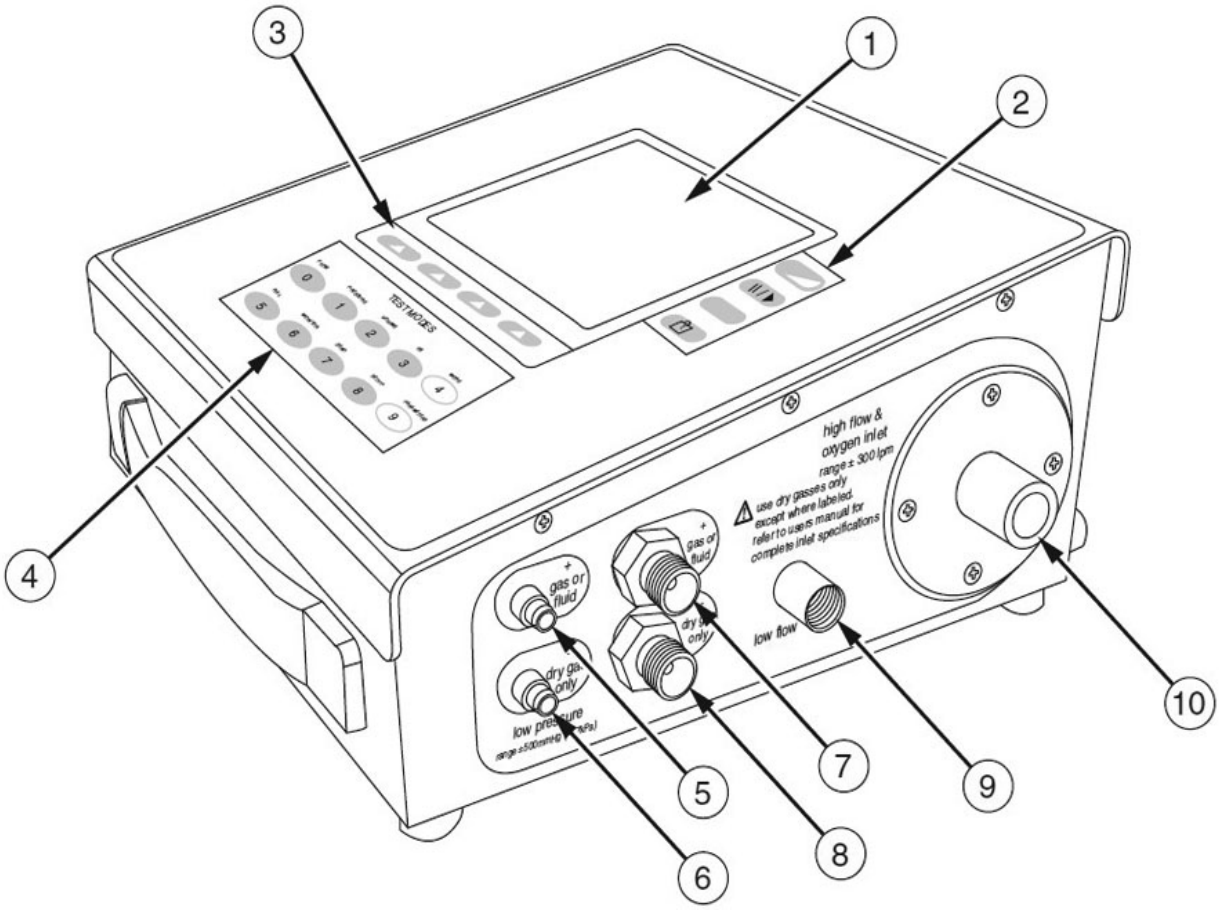


Figure 3–23. Gas flow analyzer.
(Reproduced by permission courtesy of Fluke Biomedical)

Front Panel		Right Panel	
Label	Description	Label	Description
1	LCD Display	5	Low Pressure (+) Gas Or Fluid Port
2	Contrast, Pause/resume, print, and help keys	6	Low Pressure (-) Dry Gas Only Port
3	Soft keys	7	High Pressure (+) Gas Or Fluid Port
4	Test Mode keys	8	High Pressure (-) Dry Gas Only Port
		9	Low Flow Inlet
		10	High Flow And Oxygen Inlet

The Analyzer measures high flow, low flow, airway pressure, low pressure, high pressure, barometric pressure, oxygen concentration, and calculated breath parameters. Let's discuss these in more detail.

High flow

The analyzer has a high-flow (±300 liters per minute [L/min]), bi-directional flow measurement. Flow measurements can be either static flows (no breath variations) or ventilator waveforms (i.e., both an expiratory and an inspiratory phase). The flow measurement uses a differential pressure drop across a resistive screen mesh. This flow measurement can be used for pediatric/adult ventilators or for determining the performance of many types of flow meters. Valves switch between the low-flow and the high-flow measurements depending on the range selected in the display flow screens.

Low flow

The analyzer also performs a low-flow ±25 L/min, bi-directional flow measurement. Similar to high flow, the flow measurements can be either static or ventilator waveforms, and use a differential pressure drop across a resistive screen mesh. The low-flow signal is used for infant/neonatal ventilators or for determining the performance of many other types of flow meters. Valves switch between the low-flow and the high-flow measurements depending on the range selected in the display flow screens.

Airway pressure

The airway pressure measurement comes from a tap off the proximal (near the exhaust port) of the flow sensor housings. This tap connects to a ±120 centimeters of water (cmH_2O) pressure sensor that generates the airway pressure signal. Valves switch between the low-flow and the high-flow measurements. When selecting the low-flow port, you can measure the airway pressure off the low-flow port. Likewise, when selecting the high-flow port, you can measure the airway pressure off the high-flow port. Using a range function, you can select which flow port (high or low) airway pressure is measured from.

Low pressure

This is a dual-port connection consisting of a (+) positive and a (-) negative pressure port. The differential pressure range is ±500 millimeters of mercury (mmHg). This pressure measurement can be used for any pressure differential or gauge pressure in the given range. The transducer is capable of measuring fluid pressure on the (+) positive port as indicated on the label**.**

High pressure

The high-pressure measurement is taken from a dual-port connection consisting of a (+) positive and a (-) negative pressure port. The differential pressure range is ±100 psi. This pressure measurement can be used for any pressure differential or gauge pressure in the given range. Like the low-pressure transducer, it is also capable of measuring fluid pressure on the (+) positive port as indicated on the label.

Barometric pressure

The analyzer can measure barometric pressure for reference. The barometer can read absolute pressures from 8 to 18 psia. The barometer function provides automatic conversions for flow and volume measurements. The barometric pressure signal can also be fine-tuned.

Oxygen concentration

Oxygen concentration is measured through the high-flow port of the system on the rear panel bulkhead fitting. An integrated sensor measures the oxygen percentage of the gas in the high flow channel of the analyzer. The range for this sensor is 0 percent to 100 percent. The oxygen cell mounts inside the enclosure on the rear bulkhead for the high-flow circuit. The fuel cell requires replacement approximately once a year. Oxygen readings compensate for airway pressure.

Calculated breath parameters

From the primary flow and pressure measurements, the analyzer is designed to calculate breath rate, leak percentage, and base flow. A breath detection algorithm determines the various phases of a ventilator breath and calculates the parameter.

Additional features

In addition to the measurements above the gas flow analyzer can also perform circuit leak tests, operate in high-frequency mode for use with high-frequency ventilators, or remote mode for use with a computer.

Leak test

The analyzer allows the user to test the leak rate of a sealed vessel or test lung. A leak test can be done using the high pressure, low pressure, or airway pressure signals to measure the leak rate of a sealed vessel or test lung. The analyzer can emulate RT200 serial port communications. This mode allows the use of some automated ventilator test procedures.

High-frequency oscillator mode

The analyzer can test high-frequency flow and airway pressure. The high-frequency oscillator (HFO) mode samples flow and airway pressure at a much faster rate (5x) than the analyzer does in normal operation. It is useful for monitoring the function of extremely high-frequency breath rates, up to 800 breaths per minute (bpm). In HFO mode, the analyzer collects two seconds worth of data at a time. It processes the data to calculate parameters, and plots the first half-second of data on the display.

It calculates the mean, minimum, and maximum values for both pressure and flow signals. These values apply to the entire two seconds of data, not just the half-second that is plotted. The breath rate is calculated and displayed in both bpm and Hz. The inspiratory time and tidal volume are also calculated.

Remote mode

The analyzer can run from software via a remote computer. The two must be connected properly, with the appropriate software installed on the computer. Once the computer establishes communication with the analyzer, remote operations can begin.

Ventilator tester

While similar in functions to the gas flow analyzer, some ventilators have their own test equipment for automated multi-parameter testing of the device. The main difference between the gas flow analyzer and the ventilator tester is that the analyzer is passive while the tester is active. The analyzer is generally a manual diagnostic device that reads inputs from the device under test, while the ventilator tester controls the functions of the ventilator and provides feedback on performance values.

This is the case with the remote calibration system (RCS) designed for the Impact 731 series transport ventilator found within the patient movement items (PMI) inventory. We will use the RCS for the

purpose of this lesson. This ventilator tester has a unique flow module and sensors designed for use with the 731 series ventilator. It also includes a laptop and software used for automated remote testing, as well as appropriate pneumatic tubing, restrictors, adapters, filters, and communication cables for interfacing with the control computer.

This calibration kit performs similar tests to that of the gas flow analyzer, but it is designed to function solely with its specific device. The ventilator tester provides calibration testing of flow, pressure and gas mixing of the internal air compressor, as well as the O_2 supply. It also provides a means of function testing for flow performance, supply pressures, leak tests, and valve functions. The software on the laptop controls these automatic tests. The software has the ability to download error logs, clear runtime hours, and save calibration files for documentation of services performed. Be sure to follow the manufacturer's guidelines and tolerances when using a ventilator tester. Figure 3–24 illustrates a standard calibration test setup for the RCS ventilator tester components.

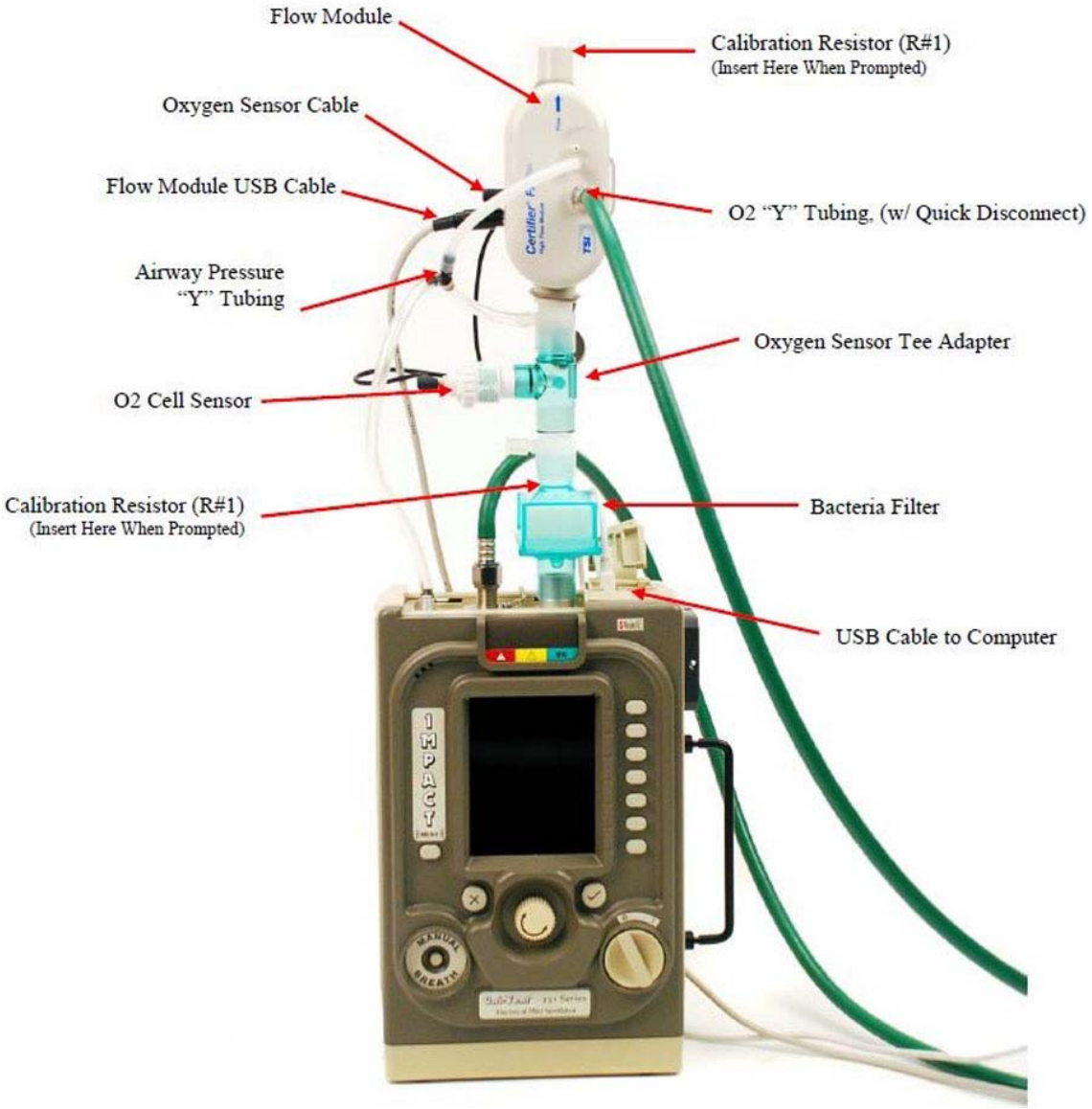


Figure 3–24. 731 ventilator tester calibration setup.

221. Fundamentals of anesthesia

Anesthesia brings a loss of the feeling of pain, touch, or other sensations—allowing a surgeon to operate on the patient. In this lesson, we briefly describe the two types of anesthetics and the stages a body passes through while administering anesthesia. Let's start at the beginning.

History of anesthesia

The Egyptians and Arabians were among the first to use what was then called hemp, and is now called hashish. The Greeks in the first century discovered that by boiling the root of the mandrake plant in wine they could make a crude anesthetic. In the late 1700s, a man by the name of Priestly discovered O_2 and nitrous oxide (N_2O). The first significant advance in anesthesia came when Dr. Morton discovered "ether" in the mid–1800s. This ether was used as the first general anesthetic at the Massachusetts General Hospital. The Johnson brothers in the late 1800s provided the first application of O_2 and N_2O in cylinders. In the 1930s, divinyl ether, cyclopropane, and triclorethylene were discovered. Twenty years later, the declassification of the Manhattan Project brought with it information on fluorine chemistry. This information led to new anesthetics, such as fluomar, halothane, and methoxyflurane. From the 1950s to the present, many different types and uses of anesthetics have been developed. Let's examine some of them.

Types of anesthetics

There are two types of anesthesia in use today—local and general. We define each one, and then look at the different physiological stages and planes of anesthesia, and its effect on the patient.

Local anesthesia

This procedure affects a limited area of the body's sensory system, blocking pain impulses to the brain. Local anesthesia may be induced by novocaine or procaine injections into the area you want to anesthetize. Ethyl chloride or the application of cracked ice is also a form of local anesthesia.

General anesthesia

This procedure affects the body's entire sensory system, blocking all pain impulses to the brain. General anesthesia may be introduced by oral, rectal, subcutaneous, intramuscular, or intravenous (IV) administration, and by the inhalation of gases. We focus our discussion on the inhalation of gases.

Stages the body passes through

It is important to understand the various stages and planes the body passes through as it reacts to the anesthesia. Understanding these processes will assist you when relating to the professional staff and help you enormously in communicating with them about the operation and repair of their anesthesia devices.

First stage

The first stage, also called the state of analgesia, is the period that extends from the beginning to the point of loss of consciousness. There is a progressive loss of pain to the point of complete abolition, just before consciousness is lost. The point of pain abolition is known as total analgesia; the approach to this is known as relative analgesia. This stage of analgesia is virtually limited to obstetrics.

Second stage

This stage, also referred to as the state of delirium, is the dream stage of anesthesia. It represents the period from loss of consciousness to the beginning of regular automatic breathing of the third stage. The second stage is a potentially dangerous stage in every form of general anesthesia. The dangers of this stage are physical injury (patients may become violent) and cardiac ventricular fibrillation, which is the unsynchronized contraction and relaxation of muscle fibers, resulting in no circulation of blood. Operative procedures or preparations are not attempted during this stage.

Third stage

The third stage, referred to as the surgical stage, is characterized by regular automatic breathing. This is the operative stage and is further subdivided into four planes, with muscular relaxation increasing with each plane.

In the first plane, there is full rhythmic respiration with increased volume, and eyelid and swallowing reflexes are abolished. In the second plane, respiration shows no particular change in character. Eyeball activity ceases and pupils begin to dilate.

In the third plane, depth of respiration is reduced, and there is a further dilation of the pupils of the eye in this plane. In the fourth plane, respiratory volume is markedly decreased, pupils are widely dilated, and cessation of respiration marks the passage of anesthesia out of the fourth plane of the third stage into the fourth stage.

Fourth stage

The fourth stage represents the period beginning with central respiratory paralysis and ending with cardiac failure and death. Artificial respiration must be given, and the anesthetic must be discontinued. Prolonged depression in this stage may cause circulatory collapse and, for this reason, operative procedures are not performed in this plane.

NOTE: During recovery, the patient goes through the same planes and stages in the reverse order.

222. Safety, operation, and inspection of anesthesia equipment

The anesthesia machine is a direct link to the patient during surgery. This machine uses different types of gas, which are inhaled by the patient, producing an anesthetizing effect. Some of those gases are combustible, so let's begin with a review of safety considerations when working with gas cylinders.

Safety considerations

There are many safety precautions you must take when using gas cylinders. These precautions apply to the handling, color coding, and pin index systems as set by the Department of Transportation (DOT), the Compressed Gas Association (CGA), and the National Fire Protection Association (NFPA). You can enjoy a safe working environment for yourself and staff personnel by having a good working knowledge of cylinder safety.

Handle cylinders properly

Here are some of the key points to remember to prevent fire or possible explosion due to improper handling:

- Never permit oil, grease, or combustible material to come in contact with cylinders, valves, regulators, gauges, or fittings. Oil may react with O_2 or N_2O with explosive violence.
- Never lubricate regulators, fittings, or gauges.
- Open the high-pressure valve on the cylinder before connecting the apparatus to the patient. This removes any foreign matter or dust that may contaminate the system.
- Open cylinder valves slowly, with the face of the gauge on the regulator pointing away from personnel. This prevents possible eye injuries.
- Never drape a cylinder with sheets, hospital gowns, masks, or caps. This material is combustible and, in an O_2-enriched atmosphere, can be a very unsafe condition.
- Never use gas fittings, valves, regulators, or gauges for service other than for the purpose intended.

- Never mix gases in cylinders; never refill cylinders.
- Always use a pressure regulator when using O_2 from a cylinder.
- Do not use regulators in need of repair or cylinders with valves not operating properly.

Many have lost their lives by ignoring safety principles relating to cylinder operation. Always maintaining a healthy respect for the possible dangers is the wise choice. Your maintenance shop should have an operating instruction dealing with handling medical gases.

Use built-in safety features

Not only must the gases and cylinders be handled properly, but you must ensure the proper gases are delivered and hooked up correctly. There are two safety features built in to the design of the system to help you with this: color coding and pin indexing. You learned about both of these features in the 4A251A set, so we will just briefly review the concepts here.

Color coding

A color coding system was designed so medical gases could be identified immediately by the external color of the cylinder, instead of having to read a stenciled name on the side. This is a universal system within the US and can be applied at any hospital you are involved with. It is very important to know how to identify the type gas you are working with. The table below provides specific information on the more common gases:

GAS	SYMBOL	CYLINDER COLOR	PIPING COLOR
Oxygen	O_2	Green w/white shoulder	Green
Nitrous Oxide	N_2O	Blue	Blue
Carbon Dioxide	CO_2	Gray	Gray
Nitrogen	N_2	Black	Black
Helium	He	Brown	Brown
Medical Air	-	Yellow	Yellow

Pin index system

The pin index safety system (PISS) was designed to prevent accidental interchange of medical gas cylinders. The system is built around the matching of pins and holes. For each gas there is only one combination of holes and pins. Unless the proper cylinder is used, the pins and holes of that cylinder and the yoke assembly will not match, and the cylinder gas will not be allowed to discharge into the wrong plumbing system.

Operation – gas flow through the major assemblies

Now we're ready to look at a typical anesthesia unit. Figure 3–25 shows an anesthesia unit. The major components you studied in technical school are identified for familiarization.

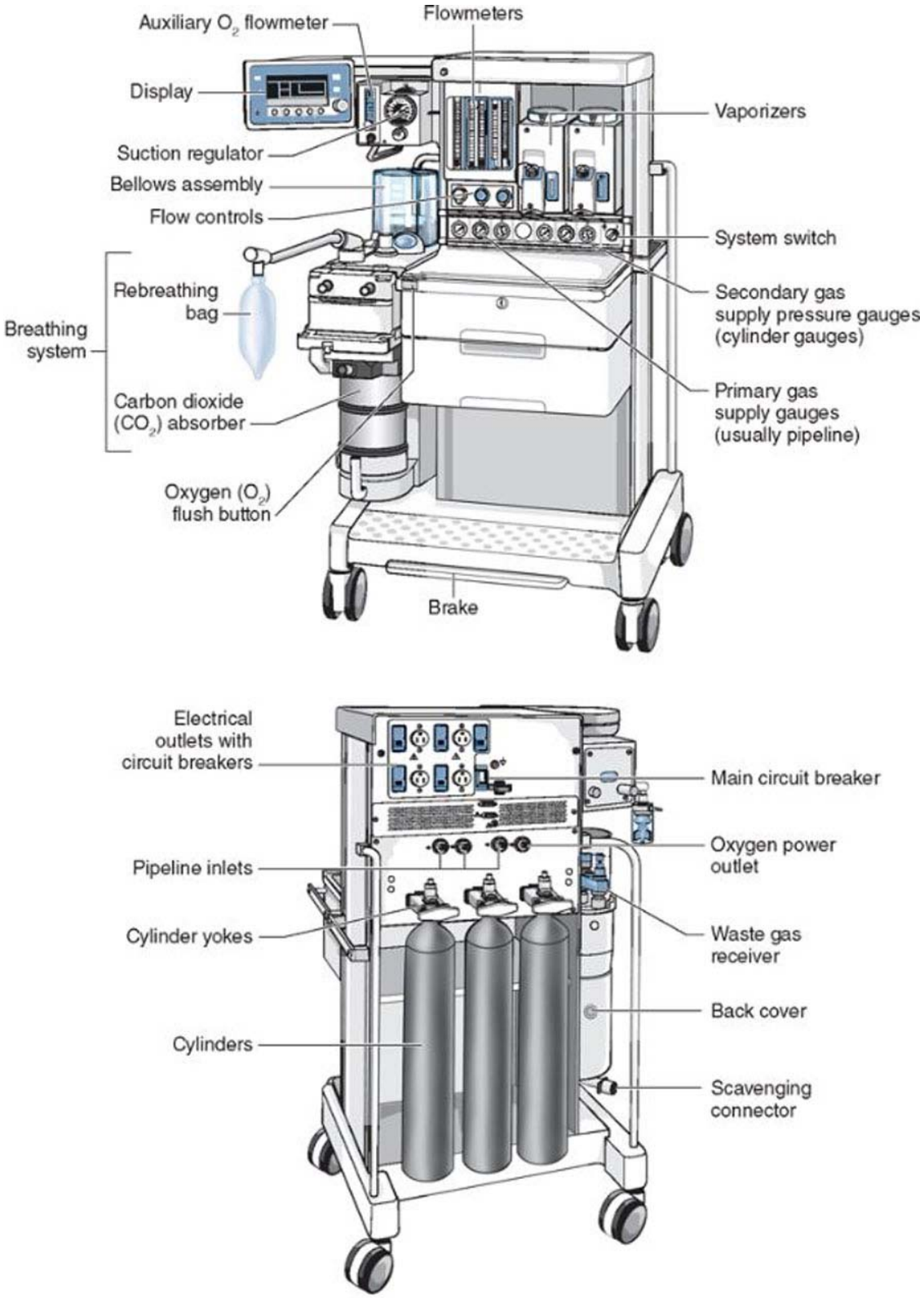


Figure 3–25. Basic anesthesia system.
(Reproduced by permission courtesy of McGraw-Hill Companies, Inc.)

You can learn about the operation of a typical anesthesia unit by following the path of the support gases and anesthetics as they pass through the various components that make up the unit on through to the patient. There are two configurations in which the anesthesia machine with ventilator can be

used: manual and automatic. Once you understand the properties and functions of various gases and anesthetic agents, we will break out into the similarities and differences of these modes. Use figure 3–26 for the following discussion.

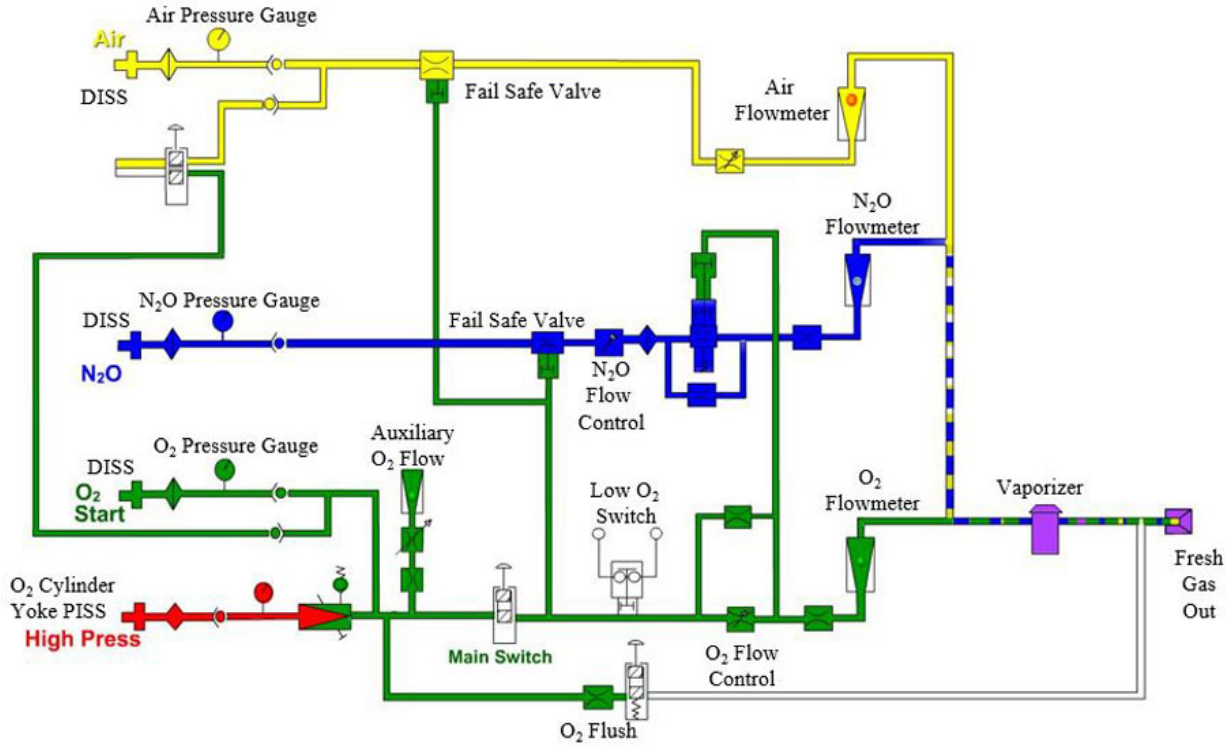


Figure 3–26. Gas path for anesthesia system.

Support gases and anesthetic gases enter at the service inlets. There are two methods of delivery—the central wall or ceiling facility system, or the attached cylinder system. The cylinder system is generally used as a backup in the event there is a failure of the primary system. The figure shows O_2, N_2O, and air entering the system. These gases are considered carrier or support gases since they themselves do not provide total analgesia for surgical procedures.

Types of support gases

There are several gases that fall into this carrier or support gas class. You may be familiar with these more popular types: O_2, helium (He), CO_2, and N_2O.

O2

O_2 is the most vital substance required for sustaining life and the hardest to store in the human body. Lack of O_2 for more than a few minutes is fatal or extremely damaging to the body organs. A cylinder of O_2 must be available with every gas anesthesia apparatus. In addition to supplying O_2 (together with the anesthesia agent) for sustaining life, it is just as vital for resuscitation (artificial respiration) when the procedure is indicated. No matter what technique the anesthetist uses when administering anesthetics, there must always be 20 percent O_2 delivered to the patient. O_2 is a colorless, tasteless, nonflammable gas. Keep in mind that it readily supports combustion.

He

He is a nonflammable, inert gas used to dilute other gases or relax muscular spasms. It is also used in breathing mixtures to reduce their density and allow easier flow through obstructions in the breathing passages.

CO2

CO_2 is a nonflammable gas that is the normal stimulus to breathing. It is sometimes added to inspired atmospheres to stimulate a depressed respiratory center. This is its most important function and is considered a support gas in anesthesiology.

N2O

N_2O is a colorless, tasteless gas that is nonflammable, but supports combustion. This gas is widely used as an analgesic, usually in combination with O_2. The absence of side effects of N_2O makes this gas as close as or closer than any other gas or volatile liquid to the so-called ideal agent. This gas is being used probably more than any other agent, despite the fact that the highest concentration of N_2O that can be given safely for maintenance of anesthesia ranges from 75 to 80 percent. These concentrations will not anesthetize a fit subject; however, lack of potency is overcome by the addition of certain drugs. These are normally administered by prior intramuscular injection, followed by intermittent intravenous use. N_2O is also used to calm a fit patient and prepare him or her for inducement by a stronger inhalant.

When N_2O tanks are used, a pressure gauge gives the operator a visual indication that the cylinders are maintaining the proper pressures. You may recall O_2 is filled at 2,200 psi and N_2O is filled at 750 psi. The gas flows through a pressure regulator designed to do just what its name implies—regulate the high-pressure inlet gas coming from the cylinders to a safe operational pressure of 50 psi. When the central or ceiling facility system is used, the pressure is already regulated at 50 psi.

Fail-safe valve

The gas now flows on to the fail-safe valve (fig. 3–27). Before this valve was widely used, it was a risky situation at best if a sudden loss of O_2 occurred. The main purpose of this valve is simple; to prevent the flow of all gases to the patient if the unit loses O_2 supply. If the central O_2 system or cylinder should fail during a procedure, the unit discontinues all other gases after a short period of time. When the presence of O_2 is felt on the valve, it opens and allows gas to safely flow through. Since the O_2 pressure is the switch mechanism for the value, without its presents the valve remains closed for patient safety. As you recall, O_2 is a support gas that must be maintained at a 20 percent level, or the patient will be in serious trouble. Today, all anesthesia units have a fail-safe valve or its equivalent installed.

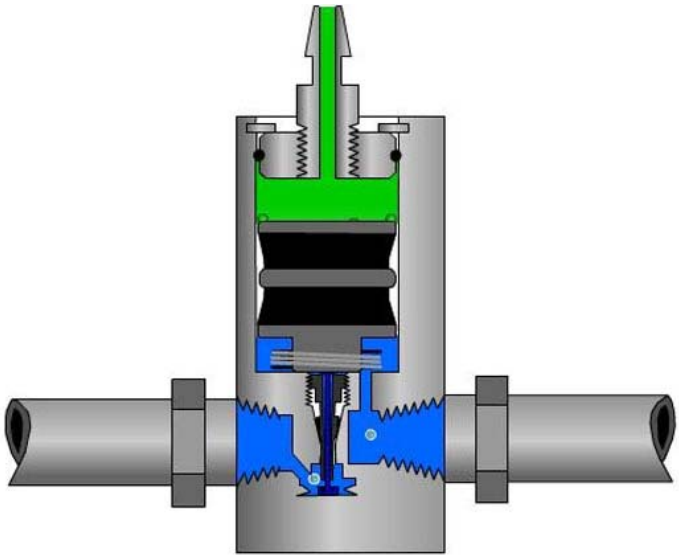


Figure 3–27. Oxygen fail safe valve.

Flowmeters

Before gas enters the flowmeters, it goes into the needle valve. This valve has a silver seat that can easily be damaged, so be careful not to over tighten this valve during operation. This valve is used to regulate the gas being delivered to the flowmeters and can be adjusted to the desired setting by the operator. There is a needle valve for each flowmeter.

NOTE: Should this valve or seat require replacement, the metal or silver seat is considered a precious metal, and you should read the standard hospital regulation covering precious metal harvesting or consult your precious metals monitor.

The gas then enters the unit's flowmeters. The flowmeters are precision, hand-calibrated, cone-shaped glass tubes. They contain a float (ball) that can be used to read the scale located directly behind the glass tube. The newer flowmeters have the scale painted directly onto the glass tube. The flowmeter is used to assist the operator in determining the amount of gas passing through the needle valve.

Vaporizers

The gas now enters the calibrated vaporizers. The vaporizer's main function is to control the rate of evaporation of a given liquid anesthetic and introduce a precise volume percentage of that anesthetic vapor into the carrier gas stream. The vaporizers provide a concentration of anesthetic that is agent specific. You can see two vaporizers on our anesthesia unit (fig. 3–25); each vaporizer has a different agent in it. There are many different agents used in the vaporizers, but let's discuss a couple of the more familiar types that you might see in an Air Force facility.

Isoflurane

Isoflurane is a chemical isomer of previously used enflurane. It also has a pleasant odor, and a rapid induction and recovery time. It is a bronchodilator with excellent muscle relaxation capabilities. The cardiac rhythm remains stable, and isoflurane can be used with epinephrine. It is nonflammable and nonexplosive. It totally eliminates the muscle spasms encountered with enflurane.

Desflurane

Is a highly fluorinated methyl ethyl ether used for maintenance of general anesthesia. It has lower blood and body tissue solubility therefore its uptake and elimination from the body is faster. It undergoes minimal metabolism and should have low potential for toxic effects.

Sevoflurane

Sevoflurane is the preferred agent for mask induction due to its lesser irritation to mucous membranes. Along with desflurane, it is replacing halothane and forane. Like the other halogenated ethers, it is administered in a mixture of nitrous oxide and oxygen. The U.S. Environmental Protection Agency (EPA) has classified sevoflurane as a greenhouse gas. Desflurane and sevoflurane are the most commonly used agents for human applications.

Figure 3–28 is a cut-away view of a vaporizer. Let's trace the flow of carrier gas through the vaporizer. When the vaporizer's concentration dial is in the "0" (zero) position, the internal on/off switch is closed. In this position, the fresh gas enters the vaporizer through the inlet port, flows through the on/off switch, and travels to the outlet port without entering the interior of the vaporizer. When the concentration dial rotates to any concentration above 0.2 percent, the on/off switch automatically opens and directs the carrier gas flow into the interior of the vaporizer. When the gas enters the interior of the vaporizer, it encounters the temperature-compensating bypass. This bypass divides the carrier gas into two streams. The majority of the fresh gas flows through the bypass and exits the vaporizer without interacting with any agent. The remainder of the carrier gas enters a pressure compensator. The pressure compensator eliminates pressure fluctuations in the vaporizing chamber.

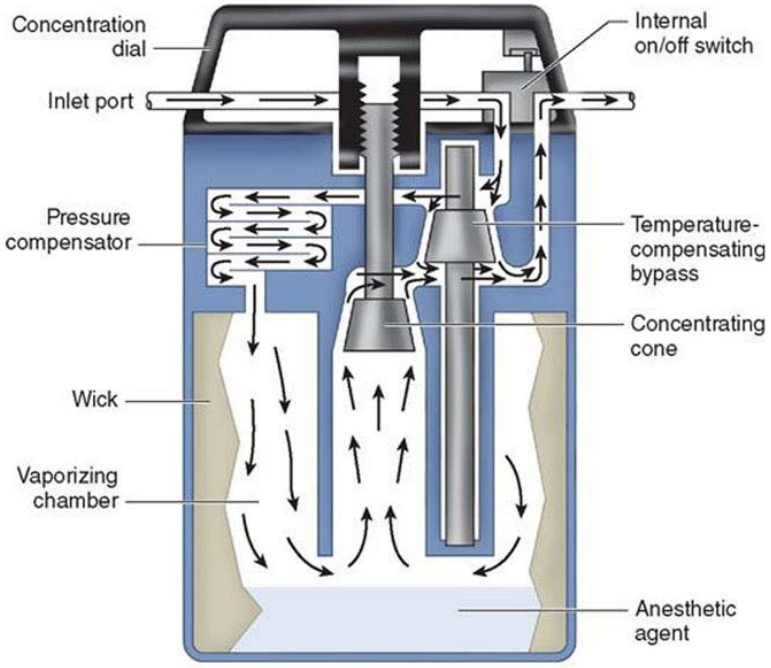


Figure 3–28. Cut-away view of a vaporizer.
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The carrier gas stream moves through the vaporizing chamber and becomes partially saturated with anesthetic agent as it flows over the wick. The carrier gas/agent mixture then leaves the vaporizing chamber via the control cone, which is actuated by the concentration dial. As the concentration is increased or decreased, the space between the control cone and the cone housing increases and decreases, allowing more or less of the gas mixture to leave the vaporizing chamber. After traveling through the control cone, the gas mixture meets up with the carrier gas that bypassed the vaporizing chamber. The reunification of the gas/agent mixture and the carrier gas results in the final percent volume concentration that goes to the patient breathing circuit.

The temperature-compensating bypass corrects for temperature variations by altering the ratio between the two streams of gas. If the temperature decreases in the vaporizing chamber (due to an increased rate of evaporation), the bypass cools, contracts, and moves downward. This action allows more carrier gas to travel through the bypass, thus decreasing the amount of carrier gas that combines with the anesthetic agent. With less carrier gas available for the evaporation process, the final percent volume concentration drops until thermostability is re-established in the temperature-compensating bypass. The opposite happens if the temperature in the vaporizing chamber increases (due to a decrease in the rate of evaporation). Ultimately, the amount of anesthetic carried by the carrier or support gas is determined by the selected concentration at the on/off switch.

There is a safety feature called an exclusion or lock-out system built into the anesthesia vaporizer assembly. This feature allows the anesthesiologist to select only one of the vaporizers during a procedure. The exclusion system will lock out the other vaporizers so the anesthesiologist cannot accidentally mix the inhalant anesthetic.

Inspiratory and expiratory valves

From the vaporizer, the gas passes through an inspiratory valve, which assures the gas flows to the patient's lungs, and then on to and through the expiratory valve. The inspiratory and expiratory valves are unidirectional, allowing the gas to flow in only one direction through the breathing circuit. During inspiration, there is a certain amount of back pressure to the vaporizers and flowmeters because there is not a check valve prior to gas delivery to the patient breathing circuit. The main purpose of the

unidirectional valves is to ensure exhaled gases are forced to flow through the CO_2 absorber before being rebreathed.

O2 sensor

The O_2 sensor is usually mounted on the inspiratory valve. It provides a constant monitoring of the percent of O_2 being delivered directly to the patient. There are two types of commonly used O_2 sensors: galvanic cell and polargraphic.

Galvanic cell sensor

An O_2 galvanic cell sensor is an electrochemical device that converts the energy from a chemical reaction into an electrical signal. Output voltage is proportional to the O_2 pressure in the breathing circuit. The galvanic sensor has also been called a microfuel cell. Figure 3–29 shows the necessary components of a galvanic cell sensor.

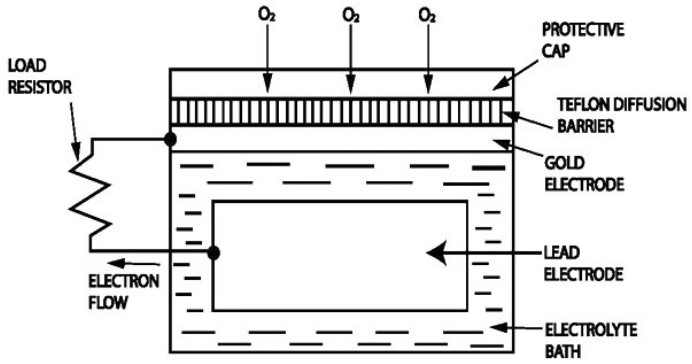

Figure 3–29. Oxygen galvanic cell sensor.

The sensor contains two electrodes, a lead anode and a gold cathode surrounded by an electrolyte bath of cesium hydroxide (C_SOH) or potassium hydroxide (KOH). O_2 molecules diffuse through a Teflon membrane and are reduced at the gold cathode to hydroxyl ions. The hydroxyl ions react with the lead anode to form lead oxide and, in the process, release electrons. The output voltage is created by the electron flow through the external load resistor connecting the lead anode and gold cathode, which, in turn, is dependent on the partial pressure of the O_2 at the Teflon membrane.

O_2 galvanic cell sensors have a reaction time of 15 to 20 seconds to bring about 90 percent of the total change in O_2 concentration. Life expectancy depends on the percentage of O_2 and CO_2 the sensor is exposed to. If the sensor is placed at the inspiratory valve and is only subjected to 21 percent O_2, it will last 12 to 15 months. If it is exposed to 100 percent O_2 when located in the same place, it will last only 2 to 3 months. If the sensor is placed in the expiratory valve where it is subjected to CO_2, its life expectancy will be greatly reduced. Simply removing the sensor and covering it each day with the protective cap will greatly aid in extending its life.

Numerous safety features can be built into an O_2 monitor. Some of these features are:

- Each monitor can be equipped with identical independent sensor cells that detect O_2 simultaneously and allow a sensor error detection signal to alert the operator should the difference between the two signals exceed a predetermined percentage. The second sensor cell can continue to analyze the O_2 content until the failing sensor is replaced.
- High and low alarms can be preset by the operator so the monitor will alert the operator if the O_2 concentration exceeds the minimum or maximum requirements.
- Autocalibration, which establishes zero and scaling constants for 12 hours, allows the anesthesiologist to calibrate the machine once in a normal day.
- Stainless steel shielding on the outside of the monitor will limit the radio-frequency (RF) interference created by equipment in the operating room.

Polargraphic O2 sensors

Polargraphic O_2 sensors depend on the chemical reduction of O_2 at an electrode surface. O_2 molecules must first pass through a Teflon membrane and into an electrolyte solution of potassium chloride (KCl). Electrolysis occurs at the polarized surface of the platinum cathode electrode. A reference silver anode electrode provides a fixed potential. The cathode is polarized negatively between –0.5 and –0.8 volts with respect to the anode. Reduction of the dissolved O_2 to hydroxyl ions at the cathode produces an electric current directly proportional to the tension of the O_2 in the electrolyte solution.

The polargraphic O_2 sensors are capable of rapid responses, but the faster the response, the shorter the sensor life. The electrode response time is not limited by the electrode chemical reaction time, but by the diffusion time of O_2 through the membrane and electrolyte. A rapid response should make the electrode ideal for anesthesia. However, the polargraphic analyzers are not widely used because of the demands for daily check-up procedures and extensive maintenance. Many technical problems associated with the polargraphic analyzer have made the slower, but more stable galvanic sensor cell the most popular analyzer.

Polargraphic sensors are stable in storage due to the slow diffusion rate of the electrolyte through the Teflon membrane. Once the sensors are committed to regular use, the electrolyte gel requires regular changing. The Teflon membrane also requires occasional replacement. The sensors can be used for a long time if the proper maintenance is done. There are disposable polargraphic sensors, but their life expectancy is limited to six months.

Anesthesia ventilators

Now, this is where manual and automatic operations differ. In manual, the expired gas fills the breathing bag. When the patient needs to inspire again, the breathing bag is squeezed. Notice the automatic pressure limiter (APL) valve located near the bag (fig. 3–30). It is set so excess pressure from the squeezed bag will be vented to the scavenger system. If the APL valve is not set properly, the patient's lungs could be over inflated. The gas mixture leaves the breathing bag and passes through the CO_2 absorber. All CO_2 is filtered out of the previously exhaled gas, and then it is mixed with fresh new gas and anesthetic agent for inspiration. Once again, the patient exhales and the breathing bag fills. Of course, the anesthesiologist can get tired squeezing this bag throughout the procedure, so the ventilator has the capability of being placed into automatic operation.

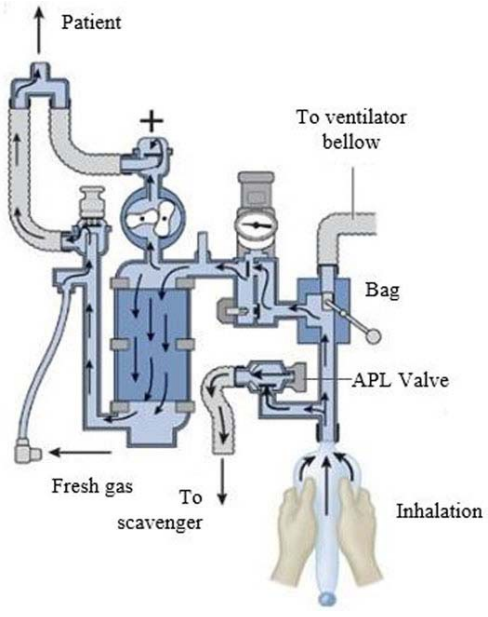

Figure 3–30. Manual ventilator operation gas path.
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Placing the unit in automatic mode (fig. 3–31) adds the bellows assembly to the circuit, while eliminating the breathing bag and APL valve. When the patient exhales, the gas collects inside the bellows assembly. The volume of gas allowed within the bellows assembly is predetermined by volume and is adjusted from the top. The bellows in the figure are ascending, which means they raise up as they are being filled and compress downward when the patient is inhaling. The area between the bellows and the glass is a mixture of fresh air and O_2. This mixture applies pressure to the bellows assembly and forces it to compress. As it descends, the gas mixture is forced through the CO_2 absorber and intermixed with fresh carrier gas and anesthetic. It then goes through the one-way inspiratory valve and into the patient's lungs. Once the bellows assembly is compressed, the air-O_2 mixture between the bellows and glass is evacuated, creating a vacuum that forces the bellows to ascend. As it ascends, gas is drawn from the patient's lungs through the expiratory valve and into the bellows assembly. Once the bellows are filled to the preselected volume, all excess gas passes through the relief valve and into the scavenging system. An air-O_2 mixture is then injected into the space between the bellows and glass, and the process starts over again. That is how a ventilator is incorporated into an anesthesia machine.

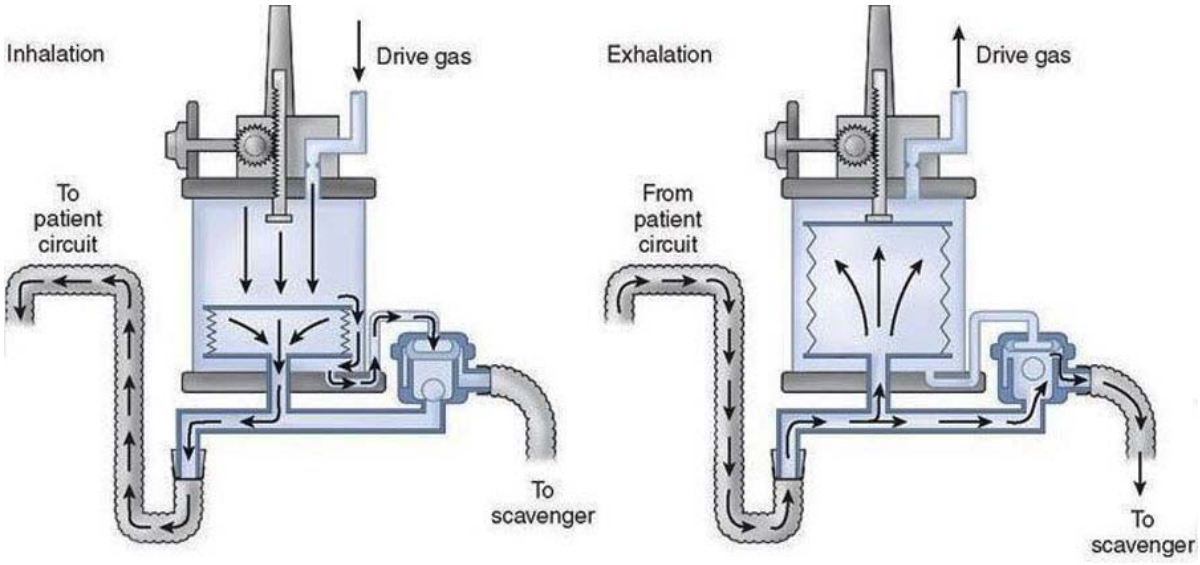

Figure 3–31. Automatic ventilator operation gas path.
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Scavenger system

The final major assembly for the anesthesia machine is the scavenger system. All scavenger systems have four basic components:

1. An exhaust hose from the pop-off or APL valve or ventilator.
2. An interface.
3. A gas disposal tube or hose.
4. An exit mechanism for the gas from the operating room.

The most complex part is the interface, which is what directs the flow of waste anesthetic gas from the breathing circuit and ventilator to the hospital disposal system. Each interface should have two relief valves to minimize the effects of excessive resistance or excessive suction on the breathing circuit. The negative pressure valve opens automatically when the waste gas flow is less than the vacuum capacity. Thus, the vacuum sucks in room air instead of withdrawing anesthetic gas from the breathing circuit. There is a second negative pressure valve set for a little higher negative pressure than the first. If the first malfunctions, the second valve will perform in its place. Increased pressure in the scavenging system can occur when the flow of the waste gas exceeds the capacity of the vacuum and reservoir bag. A positive relief valve vents the gas and prevents pressure build-up in the

breathing circuit. The scavenger needle valve adjusts the rate of the vacuum, and thus controls the volume of the reservoir bag. Repeated adjustment is required since the fresh gas flow to the breathing circuit is frequently changed. Once the fresh gas flow stabilizes, you can tighten the lock nut, if present, to maintain the needle valve setting. The reservoir bag can absorb short bursts of increased volume from the breathing circuit and contain the increased volume until the evacuation system can eliminate it. It is recommended the reservoir bag be a different color than the rebreathing bag for manual breathing.

Clinical application

The main application of an anesthesia unit is to accurately deliver measured concentrations of anesthetic gases, support gases, and vapors into a patient's breathing circuit. This gas, in turn, anesthetizes the patient in preoperatory preparations. This system is normally found in surgery, or labor and delivery. If the patient happens to be an animal, the system is found in the veterinary clinic, or the animal research and development laboratory. The anesthesia machine can be used in all applications of surgery where you would want total, general analgesia for the patient.

Operational inspection

Normally, you will perform a visual inspection of the unit to ensure mechanical integrity. Remove the reserve cylinders and ensure the pin index pins are not broken off or bent, which could possibly allow the wrong gas to be carelessly attached to the wrong yoke. It is a good idea, but not mandatory, to have another BMET or technician standing by while you perform your inspection. The reason for this is the anesthesia unit may have developed a faulty valve, regulator, or line that would cause a gas leak. An undetected situation like this could go unnoticed until you find yourself feeling lightheaded or dizzy. You could even lose consciousness before you realize what is happening. Although the possibility of this happening may be remote, use a backup to be extra safe.

Next, remove the top and inspect the plumbing. Use some form of a leak detector to verify there are no leaks in the system. This detector should be used around all fittings and connectors in the system.

Check the operation of the needle valves to ensure they open and close easily, and verify the flow of gas by observing the flowmeter. By increasing or opening the needle valve, you should get a corresponding increase in height of the float assembly in the glass tube. Decreasing or closing the needle valve should conversely allow the float to return to the bottom of the glass tube.

As mentioned earlier, the flowmeter tube assembly is calibrated by hand. If for some reason an accident should break the tapered glass, then the glass, float, and scale must be replaced as a complete set. If you do not do this, your unit will not deliver proper gas quantities to the patient's breathing circuit, resulting in obvious problems for the operator and jeopardizing the safety of the patient.

Sometime during the operational inspection, shut off the O_2 supply to see if the fail-safe valve is functioning. If it is, it will shut down all other gases you may have on; if not, immediate attention should be given to this problem and the unit taken from service until corrected. Consult your unit's manufacturer's literature for the fail-safe valve response time after the shutdown of O_2.

Operate the flush valve. This valve is used to bypass the flowmeters to deliver immediate large amounts of O_2 directly to the patient if the case arises. The flush valve does not affect the operation of the flowmeter settings. Figure 3–32 shows the route the O_2 flush would take. The O_2 flush button is used to provide pure O_2 to the patient during a procedure. It must be selected by the anesthesiologist. It is usually a button located on the front of the anesthesia unit.

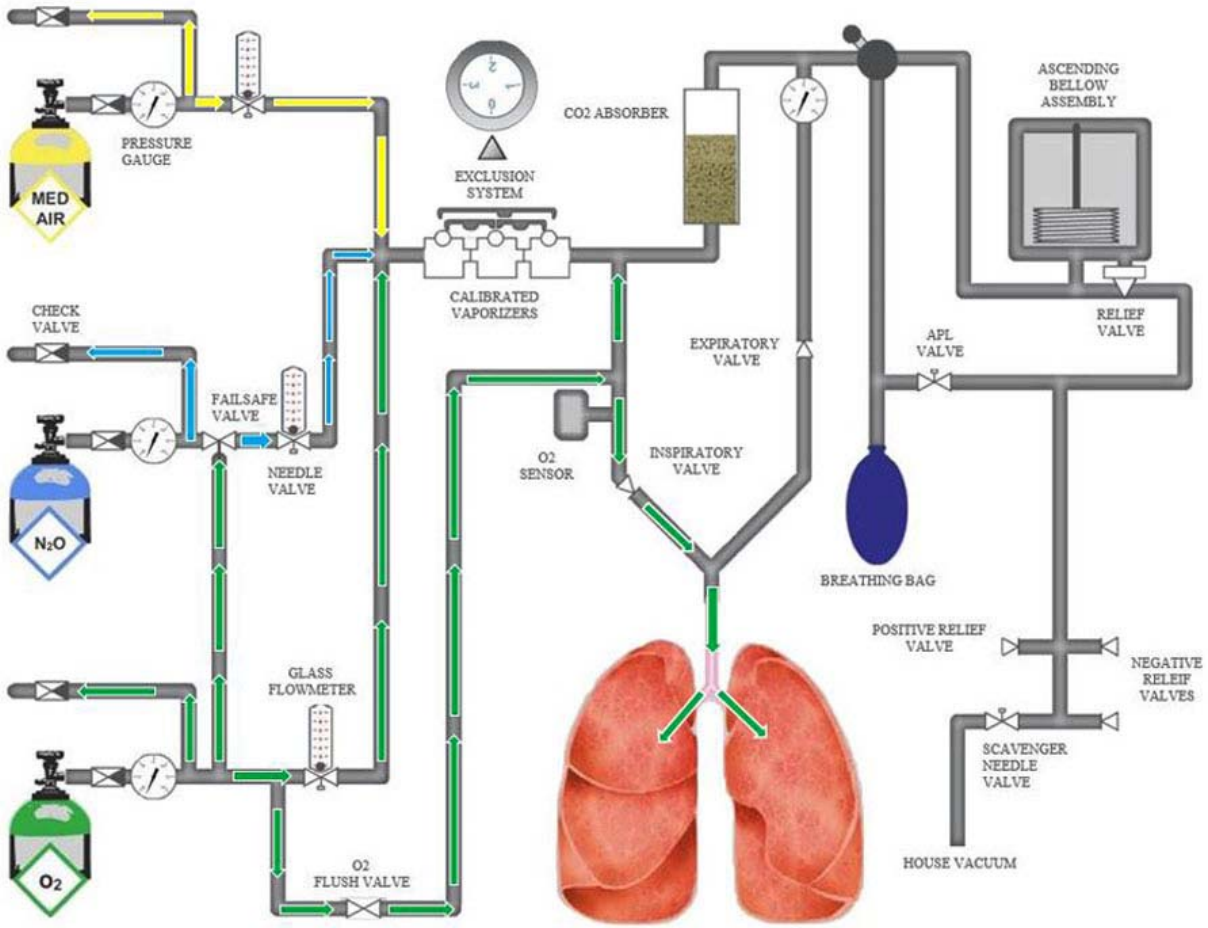

Figure 3–32. Gas path for oxygen flush.

The O_2 sensor should be out of the circuit and capped when not in use. When the O_2 sensor is mounted, ensure it enters the breathing circuit from the top. If the sensor enters the unit from the bottom or side, condensation can build up on the sensor's Teflon face. That buildup acts as a diffuser to O_2, thus inhibiting the proper O_2 concentration from being reported. Usually, the O_2 monitor will reflect less O_2 concentration than is in the circuit. If your O_2 sensor is the polargraphic type, ensure the electrolyte and membranes are being changed regularly.

At this time, it would be a good idea to look carefully at the CO_2 absorber canister, noting the color of the lime crystals. Some crystals turn a bluish color, and some may turn a pinkish color, when saturated. Once the crystals change in appearance from their normal color, they require replacement with new crystals. Ensure there is a good seal if you do open the canister for crystal replacement; this is needed for gas-tight operation. Many users replace the crystals in the CO_2 absorber themselves. If that is the understanding in your hospital, then you should verify the task is properly completed.

Finally, inspect the scavenger system. This system is very important to the operation of your anesthesia unit. If the system is not functioning properly, then the technicians and staff could inhale the unit's anesthetic gases. These gases are harmful to specific body parts with long-term exposure.

Remember, the particular manufacturer's literature is your best source for specific information for the safe operation and maintenance of your anesthesia equipment.

223. Anesthesia monitoring systems

As the anesthesia process can be one of the most dangerous parts of surgery, it requires continuous monitoring and recording throughout the procedure. We monitor both the safe operation of the

machine as well as the physiological status of the patient. Let's take a look at the gas monitoring aspect as well as patient monitoring and recording.

Gas monitoring

The multigas monitor is a compact, microprocessor-controlled, multigas instrument for use in surgical operating rooms or special care units where the monitoring of respiratory gases is critical. These can be standalone units or integrated within the anesthesia machine.

Components

It features CO_2 and N_2O concentration measurement using infrared absorption techniques and a fast paramagnetic O_2 analyzer. This unit also has the ability to monitor concentrations of anesthetic agents and saturation of peripheral oxygen (SpO_2). The measurement of the anesthetic agents is based on the absorption of infrared light by anesthetic agents similar to the CO_2 and N_2O concentration measurements.

Figure 3–33 shows a typical multigas monitor and its functions. Some functions include:

- A digital display that shows a breath-by-breath chart of inspiratory and expiratory CO_2 concentrations. The alarm settings for CO_2 are also displayed when the alarms are activated.
- End-tidal CO_2 as a percentage or partial pressure in mmHg.
- Respiratory rate.
- Inspiratory O_2 percentage.
- Inspiratory N_2O percentage.
- SpO_2 measurements.
- Anesthetic gas percentage.
- Setting control nob and soft touch keys used for calibration and alarm settings.
- H_2O trap for H_2O separation from measured gases.

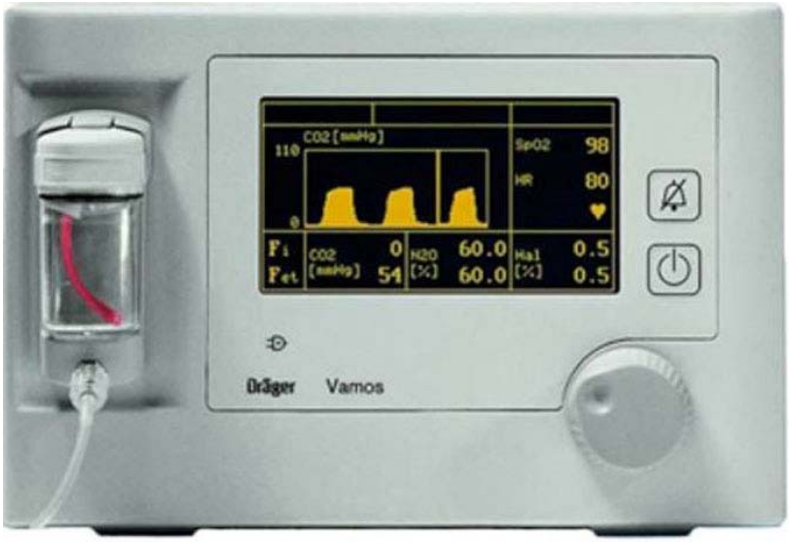

Figure 3–33. Multigas monitor.
(Reproduced by permission courtesy of Draeger Inc.)

The unit contains a small pump to maintain a constant flow of 200 millimeters of mercury (mmHg) for the sample gas. The sensor is placed in the "Y" of the patient breathing circuit where it can directly measure the concentrations of gas being inhaled and exhaled by the patient. If the multigas monitor has the capability to monitor O_2 concentrations, the anesthesiologist may choose to eliminate the O_2 sensor located at the inspiratory valve. However, the anesthesiologist may decide to keep the

redundancy in the circuit because of the critical nature of the system. You may see the multigas monitor as a module that can be added to a system, as opposed to the stand-alone model we showed you. All of these choices should not throw you off the main point. This system is used to monitor the concentrations of gases being inhaled and exhaled by the patient.

Preventive maintenance

The following are general maintenance procedures for a multi-gas monitor. Please refer to the manufacturer's service manual for specific instructions.

- Examine the condition of the monitor housing, power cord, printer, and all connectors.
- Replace the membrane filter if necessary.
- Replace all tubing, filters, and O-rings normally provided in the preventive maintenance kit.
- Perform functional tests for the modules installed on the unit.
- Perform a check to ensure the system is properly measuring gas agents. Ensure the proper amount of calibrating gas is available and the room is well ventilated.
- Perform an electrical safety check.

Anesthetic gas analyzer

The anesthetic gas analyzer is a portable measurement tool used to measure the concentration of anesthetic agents. While the anesthesia gas monitor is a feedback system used to rely system parameters of the anesthesia machine, the gas analyzer is a tool that BMETs use to validate accuracy of the concentration of anesthesia agents against the gas monitor. This unit provides rapid and accurate measurement and automatically makes all calculations and adjustments for range, anesthetic and conversion factors. These units are generally hand held and have a direct digital readout, selectable anesthetic gas and base gas (air or O_2), as well as an electric sample pump. The pump has a flow rate of 0.4 L/min and can measure 4 different anesthetic gases (sevoflurane, isoflurane, desflurane, halothane).

Patient monitoring and recording

Aside from monitoring the gas output and feedback, another major aspect is patient parameter monitoring. This concept is a diagnostic function, which we will cover more in-depth in volume 3 of the 4A251B set, so here we will just touch on the basics of the anesthesia monitoring and recording systems.

Clinical application

The purpose of the anesthesia monitoring and recording system is to provide a distributed solution that permits comprehensive data management for the anesthetist. These systems capture and manage anesthesia vital signs information in the operating room (OR) environment. The systems automate and integrate critical modules in the OR. The reporting modules provide efficient data access and collection and automate the procedures for required data fields, time stamps and electronic signatures, providing a comprehensive record. This makes it much easier for a MTF to illustrate regulatory compliance. They also establish and maintain a master record of all the critical activity within the OR environment.

These systems collect personally identifiable information (PII) about the patients to include: name, social security number (SSN), truncated SSN, citizenship, legal status, gender, race/ethnicity, date of birth, home telephone number, cell telephone number, mailing/home address, spouse information, and medical information. Each workstation supports automated acquisition of patient vital signs from monitoring devices (e.g. monitors, anesthesia machines, gas analyzers) via serial port connections. This PII is retained within each MTF and is only accessed by authorized care providers. The system does not collect PII directly from the patient—it is not the source system. PII is obtained from sources

such as the Composite Health Care System (CHCS) and is manually entered into the system, or downloaded through the Surgical Scheduling System (S3) connection.

Operational maintenance

Anesthesia recording and monitoring systems are essentially networked information collection, storage, and transfer systems. As such, they would follow the same maintenance principles that you learned in 4A251A volume 4. System maintenance generally falls under a 3rd party maintenance contract, your local information technology (IT) systems team, or the in house BMETs (given the proper training, certifications and network permissions). Be sure to always follow your local network policies and manufactures requirements for system maintenance. Below are some of the actions commonly performed on anesthesia monitoring and recording systems.

Frequency	Maintenance Actions
Daily	• Check the free disk space on all servers.
	• Verify that all case data was copied to the server database.
	• Monitor the windows event logs.
	• Verify that the database backups ran properly.
	• Visually inspect the server hardware.
Weekly	• Archive the database backup and log files.
	• Update the Anti-Virus and host intrusion detection system (HIDS) definitions.
	• Apply approved software updates.
	• Perform disk management.
Monthly	• Change the windows administrator passwords.
	• Move the archived log files and backups to off-system storage.
	• Update, disable, or delete the accounts having expired passwords.
Quarterly	• Start the test database service.
	• Delete the restored databases created during your test.
Annual	• Update the domain service accounts.
	• Update the local service accounts.
	• Update the application accounts.
	• Update third party application accounts.
	• Verify that the anesthesia recording and monitoring system is fully functional.

After you update all of the application and service passwords, monitor the system logs for a short period to verify that the system is fully functional.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

219. How ventilators work

1. What are the compensatory mechanisms the body uses in reaction to controlled ventilation?

2. How is plateau pressure measured?

3. List the seven types of drive mechanisms.

4. What is the main function of the injectors?

5. When is high-frequency ventilation used?

6. What are the two most common forms of high-frequency ventilation in use?

220. Classification and inspection of ventilators

1. What are the four phases of the breathing cycle?

2. What are the three ways the inspiratory phase can be initiated?

3. What is the function of the ventilator during the inspiratory phase?

4. Describe the two classes of generators used during the inspiratory phase.

5. Name the four ways in which a changeover from the inspiratory cycle to the expiratory cycle can occur.

6. What does the length of the inspiratory phase depend on in a volume-cycled ventilator?

7. What is the ventilators function in the expiratory phase?

8. Describe four specific constant positive pressure generators.

9. Name two clinical applications of a ventilator.

10. What are the two types of high flow measurements of a gas flow analyzer?

11. What is the barometric pressure range of a gas flow analyzer?

12. What is the function of the gas flow analyzers breath detection algorithm?

13. What is the main difference between the gas flow analyzer and the ventilator tester?

221. Fundamentals of anesthesia

1. What are two types of anesthesia in use today?

2. How is local anesthesia introduced?

3. Briefly describe the four stages of general anesthesia.

4. Why is the fourth stage of anesthesia not used in surgical procedures?

222. Safety, operation, and inspection of anesthesia equipment

1. Briefly describe the two safety features built into the anesthesia system design.

2. Which gas must be maintained at the minimum of 20 percent when delivering anesthesia to a patient?

3. What does the pressure regulator do on an anesthesia machine?

4. What is the purpose of the fail safe valve?

5. What is the main function of a vaporizer?

6. What safety feature is built into the anesthesia vaporizer assembly?

7. Where is the O_2 sensor usually located?

8. What is the difference between automatic and manual ventilation during an operative procedure?

9. Name the four components of the scavenger system.

10. Why should anesthesia machine inspections be performed by two BMETs?

11. What makes the flush valve so important that it must be checked during an operational inspection?

223. Anesthesia monitoring systems

1. When is a multigas analyzer used?

2. Where is the gas monitoring sensor placed in the patient breathing circuit?

3. What items are normally found in a PM kit?

4. List the four different anesthetic gases measured by an anesthetic gas analyzer.

5. What is the function of the patient monitoring and recording system?

6. What maintenance actions are performed annually on a patient monitoring and recording system?

3–4. Surgery and Inpatient Care

In the surgical and inpatient care area, you are likely to encounter other equipment, such as the electrosurgical unit, hypo/hyperthermia device, and pneumatic tourniquet. You may also encounter infusion devices, laser units, and dialysis equipment. In this section, we will describe these pieces of equipment, as well as others you may be responsible for as a BMET.

224. Electrosurgical unit

An electrosurgical device is used in a surgical environment to cut tissue and coagulate (stop the flow of) blood. Electrosurgical units (ESU) range in complexity from very simple wall-mounted or portable units used for minor surgery, to very complex portable units used in the most delicate surgical procedures.

The first electrosurgery units were developed in an era when the electrical spark gap circuit was the only means for generating significant amounts of RF. The main differences between the modern solid-state devices and older spark gap devices lie in the ability of a spark gap generator to develop higher peak powers, which results in a lower duty cycle for the same average power. The lower duty cycle waveform results in less cutting or dissolution in the coagulation (COAG) mode. The spark gap generator can also produce higher open circuit voltages, which result in a better ability to fulgurate (i.e., destroy living tissue by electrical sparks generated by a high-frequency current).

Although the makes and models of electrosurgical units you will probably encounter in Air Force hospitals are numerous, the basic principles of electrosurgery apply to any type, make, or model.

Principles of operation

An electrosurgery unit is an AC source that operates at certain RFs. Typical electrosurgery devices operate in the range of 500 kilohertz (kHz) for cutting to 4 MHz for coagulation. Figure 3–34 illustrates the basic principle behind electrosurgical devices. There are two electrodes connected to the RF power generator. One electrode is called the active electrode and has a cross-sectional area that is very small. This electrode is hand held by either the surgeon or technician, and is used for active actions such as cutting and coagulating. The other electrode, referred to as the dispersive electrode or passive electrode, has a much larger area than the active electrode. The dispersive electrode uses the patient as part of the circuit, and provides the ground or return of the active electrode. This dispersive electrode is made of metal and is often called the patient plate. It is positioned beneath the buttocks or thigh. State-of-the-art technology now offers a disposable electrode pad that can be attached to the patient's thigh with an adhesive side and the patient plate in the center. Regardless of the type of passive electrode, the operating principle remains the same. The current flowing into the patient plate is the same as the current flowing into the active electrode. Since the active electrode has a much smaller cross-sectional area than the passive electrode, the current density in amperes per square meter is far greater. As a result of the difference in current density between the two electrodes, the tissue underneath the passive electrode is heated slightly, while the tissue underneath the active electrode is significantly heated, destroying tissue.

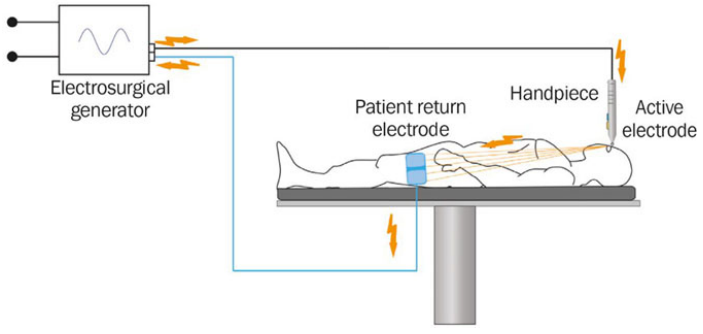

Figure 3–34. Basic electrosurgical method.
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The active electrode is used by inserting it into the insulated hand piece. This insulation prevents accidental burns to the patient's surrounding tissues. The electrode itself remains cold and the high-frequency current creates an incising (incision) or coagulating effect at the point of contact between the electrode and tissue. Burns may also appear at inappropriate points on the body due to a damaged or misapplied patient plate. To decrease the likelihood of burns to the patient, an electroconductive gel or paste is normally used. This gel is smeared over the surface of the patient plate that comes in contact with the patient's skin and is similar to the gels and pastes used in electrocardiograph and defibrillator electrodes. Up to this point we have been talking about a biterminal procedure. Now let's look at another procedure called monoterminal.

In a monoterminal procedure, the patient is not incorporated into the circuit. Since the patient is not grounded to the unit, an increase in voltage is necessary to offset this loss. Biterminal and monoterminal should not be confused with the terms monopolar or bipolar, which refer to an electrode with one or two tips projecting from the active electrode hand piece. As a BMET, you should be aware of these basic principles to ensure a safer operating environment during electrosurgical applications.

Clinical application

The primary application of electrosurgery is to arrest bleeding by closing off blood vessels. The electrosurgical unit, as previously mentioned, provides a continuous RF current for cutting tissue and a burst wave RF for coagulation. These two currents can be combined in a homeostasis mode of operation to produce a cutting and coagulation action concurrently, called blended. Figure 3–35 shows examples of the waveforms used for various applications. The current that passes through the body causes no neuromuscular reactions because of the higher frequency. Neuromuscular reactions do, however, occur at approximately 60 Hz, which is too low for electrosurgery.

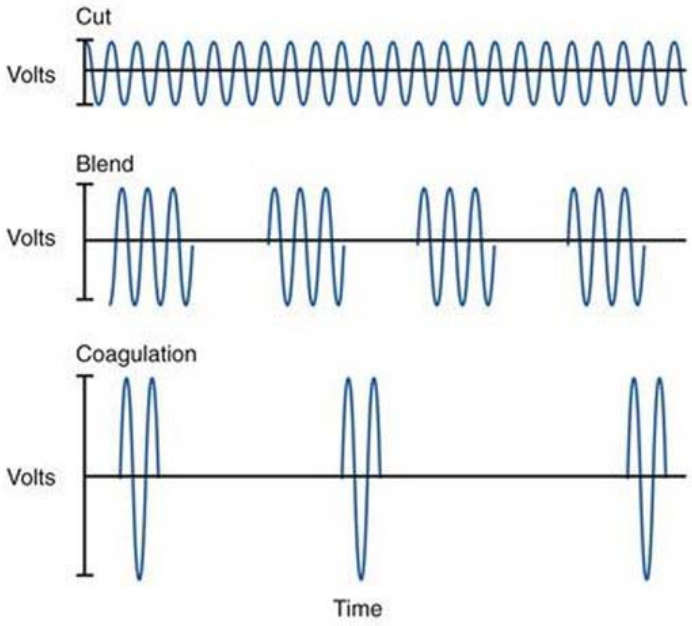

Figure 3–35. Electrosurgical output waveforms.

The various applications of electrosurgery fall into the categories of electrosection, electrocoagulation, electrofulguration, and electrodessication. Follow along with figure 3–36 as we discuss these categories.

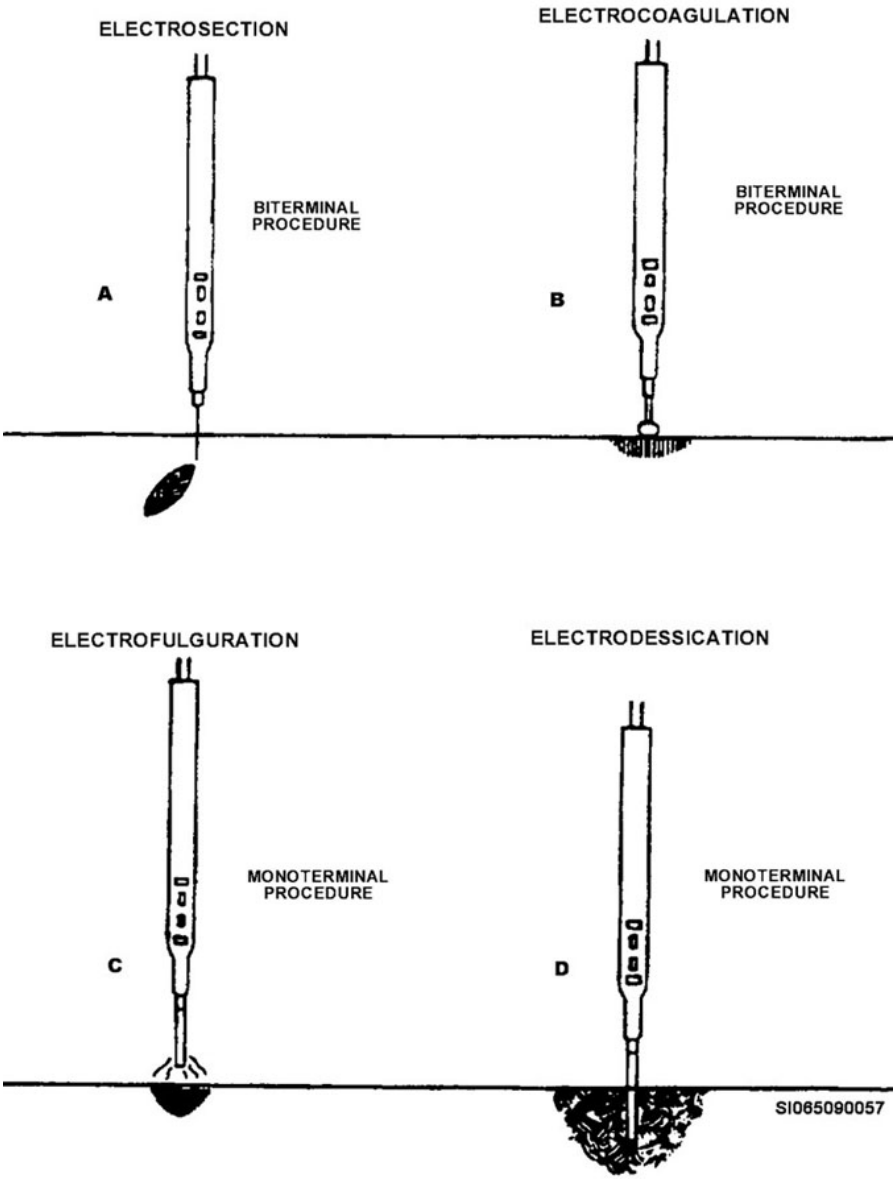

Figure 3–36. Applications of electrosurgery.

Electrosection

Electrosection or incision mode (fig. 3–36, A) is accomplished by the concentration of high-frequency energy at the tip of the active electrode. The incision or cutting is actually achieved as the individual cells of the tissue "explode" and are destroyed by the current passing through them. The "blade" of the hand piece is not sharp and does not cut; it is used merely to guide the electrical current on the desired path. Electrosection applications provide clean, bloodless, and sterile incisions. Electrosection may be accomplished without the use of the dispersive electrode (monoterminally), but this would require the use of more energy and the heat effects would be increased.

Electrosection is the most frequently used modality in electrosurgery. It is accomplished through the use of wire electrodes of various shapes. The tip of the electrode is held above the tissues when the current is turned on because of the initial power surge. After the current is on, the necessary procedure may be performed.

Electrocoagulation

Electrocoagulation (fig. 3–36, B) is performed biterminally. The term "coagulation" refers to the process of causing a liquid to turn to a soft semisolid mass or clot. Electrosurgical units are used to accelerate the natural process of blood clotting to minimize blood loss. During the procedure, a ball electrode is placed in contact with the tissues before activating the current. The current is then activated, dehydrating and coagulating the cells, which decrease or stop the hemorrhage. This allows the surgeon to have a clean work site, and the decrease in blood loss decreases the risk to the patient. Several applications of the ball electrode may be necessary to achieve the desired effect; an interval of 5 to 10 seconds is suggested between applications to allow for dissipation of heat. In the past, electrocoagulation technology hemostats (clamps) were used to close off blood vessels, but now the overall effect of electrocoagulation is much like welding the open end of a pipe shut. It should be mentioned this procedure only works on small vessels, usually no larger than $^{1}/_{16}$ inch in diameter.

Electrofulguration

Electrofulguration (fig. 3–36, C) is a procedure applied monoterminally, which you recall requires more power. The electrode is held above the tissues, and the current is transmitted by an electrical arc (sparking) to the tissues. The arcing effect, when applying this method, produces a dehydration and superficial destruction (carbonization) of the tissues, depending on the amount of energy used. Electrofulguration is used to destroy fistulous tracts, tabs of tissue, and surface tissues following biopsy.

Electrodesiccation

Electrodessication (fig. 3–36, D) is also a monoterminal procedure. The needle of the electrode is inserted into the tissues and held motionless while the current is turned on. The electrode remains cold, but, as a result of the tissue's electrical resistance, a high local heat is produced as the current flows. The result is cellular dehydration and desiccation (destruction), which often extends deeply into the tissues. Desiccation can be used in the treatment of a disease or tumor by drying up the tissue in and around the area.

Modes of operation

Using the information that you have learned, the following table will break down some general ESU modes and their associated characteristics.

Mode	Effect	Waveform	Voltage	Power	Crest Factor
Monopolar					
Cut	Pure incision plus slight hemostatic effect	Continuous unmodulated sine wave to lightly modulated sine wave	Low	High	~1.41 to 2
Coagulation	Desiccation or fulguration	Burst of damped sine wave	High	Low	~9
Blended	Cut and coagulation	Burst of medium duty factor sine wave	Medium	Medium	Between cut and coagulation
Bipolar					
Coagulation	Desiccation	Continuous unmodulated sine wave	Lowest	Lowest	1.41

225. Maintenance and testing of electrosurgical units

Electrosurgical units are designed to cut and destroy tissue in a safe and controlled manner. It is essential to ensure the safe operation of any equipment that has the potential to cause harm to a

patient. We do this through periodic maintenance and testing at established intervals. This lesson will discuss some of the preventive maintenance tasks and related test equipment associated with electrosurgical units.

Preventive maintenance

The following are some general preventive maintenance guidelines to follow before taking any measurements.

- Inspect unit housing for physical damage.
- Check that all receptacles are clear of obstruction or damage before plugging in accessories.
- Inspect bipolar/monopolar hand pieces, patient return electrode, footswitches, cables and power cord for damage.
- Ensure there is a secure connection between the accessories and the unit before applying power.
- If unit is attached to an electrosurgical cart, inspect casters and brakes.
- Remove fuse and verify correct voltage and current rating.
- Ensure unit completes appropriate power up self-tests including illumination of visual indicators and audible tones.
- Verify that the unit detects the correct hand pieces and patient return electrodes as applied.

Electrosurgical analyzer

The electrosurgical analyzer verifies the performance of an electrosurgical unit. The analyzer measures specific performance parameters and provides a safe output of RF measurements into a physiological load. This unit prevents burns and electrical shocks to the equipment maintainers.

There are two main modes of operation on an electrosurgical analyzer—manual and auto. Within each mode, the analyzer measures generator output and RF leakage. The generator output test allows an isolated load value to be assigned by the user in increments from 10 to 5,200 ohms. The RF leakage test measures current through a leakage path to ground usually set at 200 ohms. The leakage path runs through either the dispersive or the active electrode.

Generator output

In the manual mode, the user selects the available isolated load setting to allow the measurement of the following:

- Peak-to-peak voltage (KVpp).
- Crest factor (CF).
- Current in milliamps.
- Power (measured in watts).

Setup

The setup of and ESU to ESU analyzer can appear confusing considering the amount of cables, accessories, and various setups for different tests. Always consult both the analyzer and unit manuals for the proper configurations. Most analyzers that you will see are color coded according to the cables in order to prevent harm to the user or damage to the unit. Although you will see many different analyzers over your career, which may differ in process or function, for the purpose of this lesson we will use the Fluke QA-ES III to illustrate the concepts. Figure 3–37 shows an example of a common setup for a generator output test using a monopolar configuration.

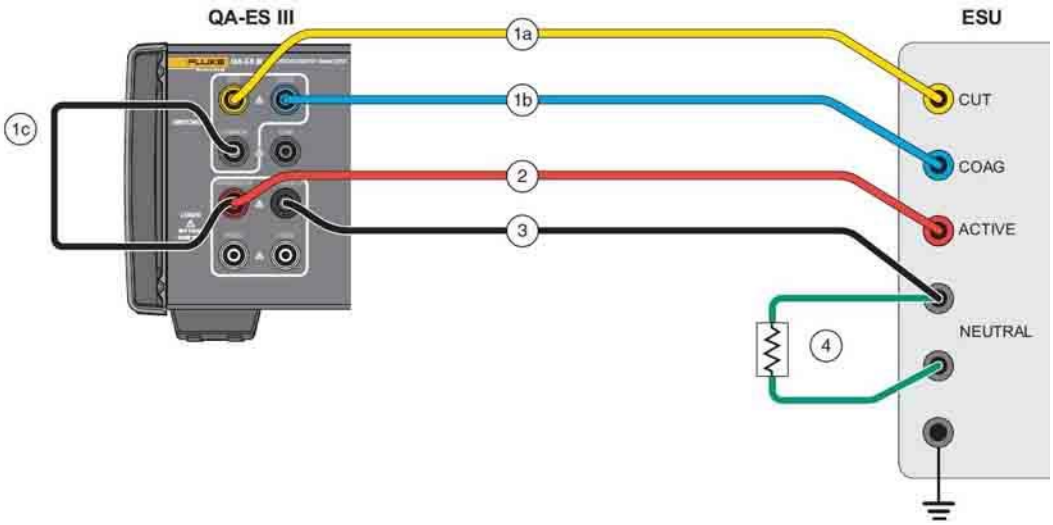

Figure 3–37. ESU analyzer monopolar setup.
(Reproduced by permission courtesy of Fluke Biomedical.)

1. If using the footswitch, make these connections:

   a. Connect the ESU CUT switch to the CUT (yellow) jack on the unit.

   b. Connect the ESU COAG switch to the COAG (blue) jack on the unit.

   c. Use a stackable jumper to connect the footswitch COMMON (gray) jack to the VARIABLE HI jack (red).

2. Connect the ESU active electrode to the VARIABLE HI (red) active electrode on the unit.
3. Use a stackable connector to connect one of the ESU neutral electrodes to the VARIABLE LO (black) jack on the unit.
4. Connect the shorting leads between the neutral connections on the ESU.

Measurement

Utilizing the Fluke QA-ES III, as mentioned above, follow these steps to perform a generator output test:

1. Push F1 from the Top Menu 1.
2. Use the rotary knob to set the Load resistance.
3. If using the footswitch, push F1 and use the rotary knob to set the Delay.
4. Make the test connections, as outlined above.
5. If using the footswitch, select CUT or COAG.
6. Push F3 to start a single measurement or push F4 to start continuous measurement.
7. Push F3 to stop the measurement.

RF leakage

RF leakage, also known as high-frequency leakage, refers to the current flowing from either the active electrode to ground or the return electrode to ground when activating the ESU output. Ideally, the amount of leakage current should be zero. However due to the nature of the high frequency, a significant amount of capacitive leakage current will flow between the electrodes and ground. During this test, the BMET can select the active or dispersive electrode and the desired load value.

Auto mode

In the auto mode, the BMET can select from any of the autosequence programs loaded in the analyzer. Generator output and RF leakage are measured during these auto sequences, and the analyzer can be set up to measure in monopolar, bipolar, or micropolar output. The analyzer in auto mode can measure pure cut, coagulation, and blend all at different power levels.

Return fault test

Many electrosurgical units continuously monitor the current between the active and dispersive electrodes to ensure it is not excessive. This current can cause burns to a patient; a return fault test on the analyzer ensures return fault monitoring is working properly on the unit.

Safety precautions

Safety precautions when using these units include:

- Ensure the tests are performed with the test leads supplied with the unit.
- Ensure the electrodes are isolated from each other and do not come in contact with conductive surfaces during testing to prevent shock and damage to equipment.
- Never touch, connect, or remove the test leads while the unit is in operation.

226. Infusion devices

Infusion devices serve two main functions: to provide an open line to the body for the administration of drugs and provide fluid to the body for hydration.

We have come a long way since the early techniques tried by the Egyptians and Romans, who believed that blood was a life-giving tonic and was given orally. Today, infusions and transfusions alike take on a wide variety of applications. Infusion devices are being used quite often to administer IV fluids in areas such as the emergency room, labor and delivery, surgery, intensive care units (ICU), critical care units (CCU), and in neonatal and pediatric departments to name a few. These devices fall into three categories: gravity feed systems, infusion pumps, and infusion controllers.

Gravity-feed system

A typical gravity-feed system (fig. 3–38) consists of the appropriate IV solution prescribed by the physician, and the administration set, which has a drip chamber and, in this case, a piggyback configuration. This piggyback configuration allows for the administering of more than one IV solution at a time. Each line has a clamp to start and stop the solution flow, plus a “back check valve,” which keeps each solution from backing up into the other IV bottle. A roller clamp is used to shut off both flow rates, and a flow rate valve is used to adjust the flow rate by visually observing the solution dripping in the drip chamber. This setting is adjusted and maintained by a nurse according to the physician’s instructions.

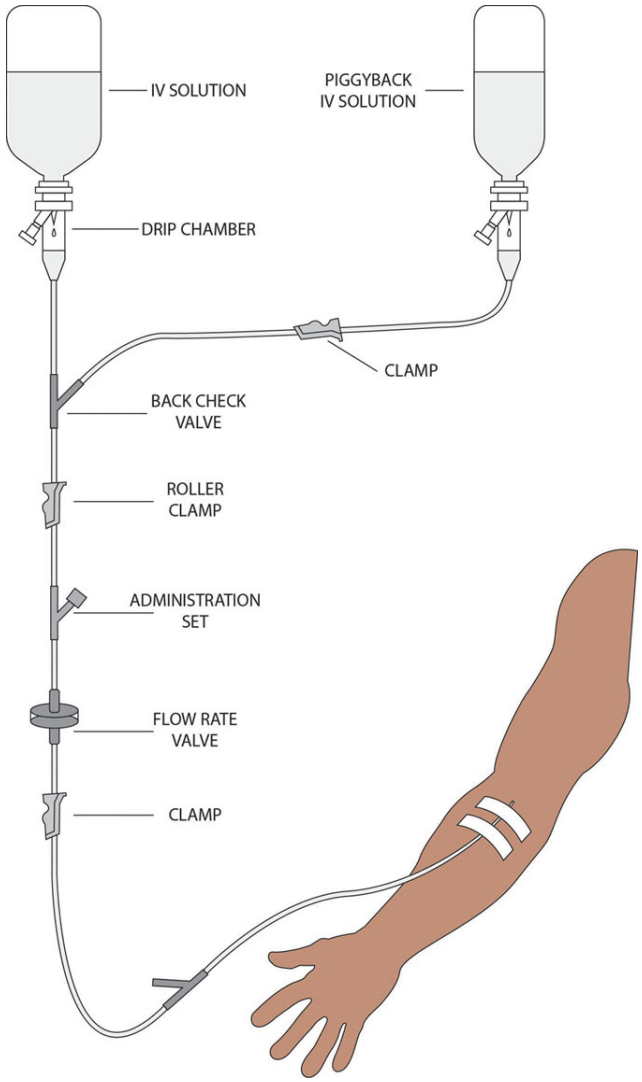

Figure 3–38. Gravity feed system.

Advantages

Gravity-feed systems are simple and are familiar to hospital personnel. They use readily available, standard medical supply components and are adequate for most IV purposes. Gravity-feed systems require no power or electrical safety checks, and few, if any, in-service training sessions by BMETs to the staff personnel. Hence, gravity-feed systems are considered to be cost effective.

Disadvantages

Gravity-feed IV systems need frequent readjustments to maintain a steady flow rate because the plastic tubing and clamps change gradually with time. Also, the flow rate varies with changes in the opposing venous pressure as the patient shifts position, suffers extreme anxiety or temperature changes, cries vigorously, or even breathes deeply. Since the infusion pressure in a gravity system is limited by the height of the IV bottle above the injection site—and is further diminished as fluid flows through the clamped portion of the tube—the flow may actually cease at times when the venous pressure rises to the level of the infusion pressure. Flow is also diminished when filters are used to screen out contamination and air. Improved clamps can and have minimized the frequency of accidental openings that overload the patient with fluid or drugs. Flow monitors also can provide a continuous measure of the volume of fluid administered, but they cannot eliminate the flow rate fluctuations inherent in gravity-feed IV systems.

Gravity-feed systems are also restricted in the range of flow rates attainable. At low flow rates (below about 10 milliliters [mL] per hour), clamping almost completely occludes the IV tube, reducing the infusion pressure and risking blood backing up into the cannula and possible clotting.

High flow rates are erratic because the gravity-derived delivery pressure cannot maintain a constant flow against fluctuations in venous pressure. When a small volume of a drug must be administered over a long period of time by gravity feed, the drug must be diluted with larger volumes of IV fluid. This involves additional cost, increased opportunities for contamination, and extra stress on the patient's capacity for fluid intake. A microdrip IV apparatus has finer bore tubing, hence smaller drops, and allows giving smaller quantities of medication with little or no dilution. However, the cost of microdrip sets is higher than that of standard sets, and their accuracy is inferior to most infusion pumps.

Infusion pumps

Figure 3–39 illustrates a typical setup for the infusion pump method. This particular setup includes the IV solution, plus an additional piggyback solution prescribed by the physician, standard "back check valve," pump (in line with the setup tubing), and in-line filter. The pump now takes the place of the manual roller clamp and is adjusted by the nurse according to instructions from the physician.

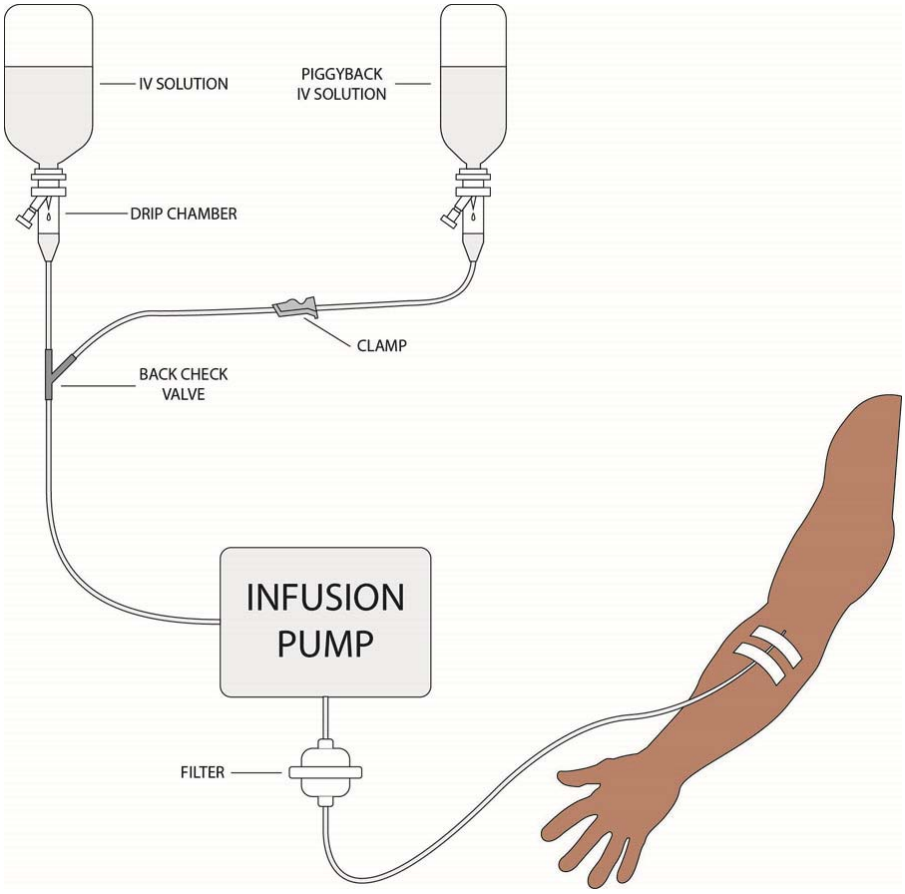

Figure 3–39. Infusion pump system.

Advantages

The electronic infusion pump offers the ability to infuse large volumes of fluid, which usually includes an alarm to warn of problems. Infusion pumps can be used with any type of IV solution containers and for intra-arterial infusions. They reduce such complications as restarts, infiltration, and runaways. Their main advantage is delivering precise amounts of prescribed fluids.

Disadvantages

The Air Force, as well as the civilian hospital administrative process, is concerned with many of the same budget restraints, and one proven disadvantage of electronic infusion pumps is their high cost, initial and continuing. The continuing cost comes from such items as special sterile tubing sets that are disposed of after each use, and the ongoing requirement for maintenance and in-service training to staff.

Types of infusion pumps

Let's now look at the methods used to pump fluids accurately through IV tubing: peristaltic and piston-cylinder devices.

Peristaltic

This method moves fluid by exerting externally applied forces on setup tubing. Figure 3–40 illustrates the linear and rotary methods used by various manufacturers.

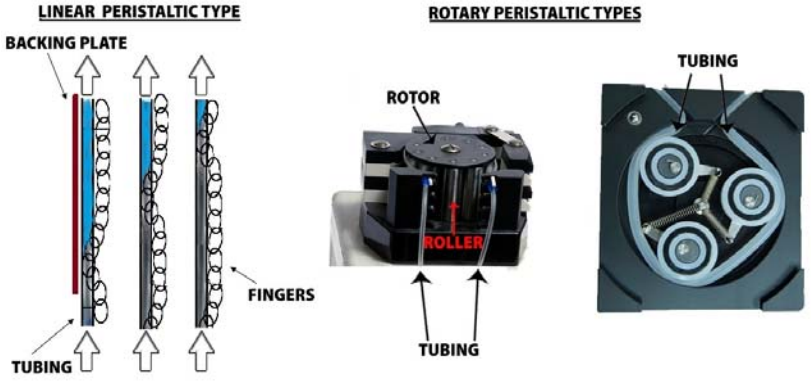

Figure 3–40. Peristaltic pumps.

Piston-cylinder

A piston-cylinder device exerts pressure on fluid in a cylinder by the pumping action of a piston. Two methods that use the piston-cylinder principle are the syringe and volumetric pump. The syringe method uses a motor-driven device in which a plunger is depressed at a constant preset rate to eject medication. Figure 3–41 shows a volumetric pump. The chief advantage of the piston-cylinder principle pump is most models will not pump air, a safeguard against air emboli.

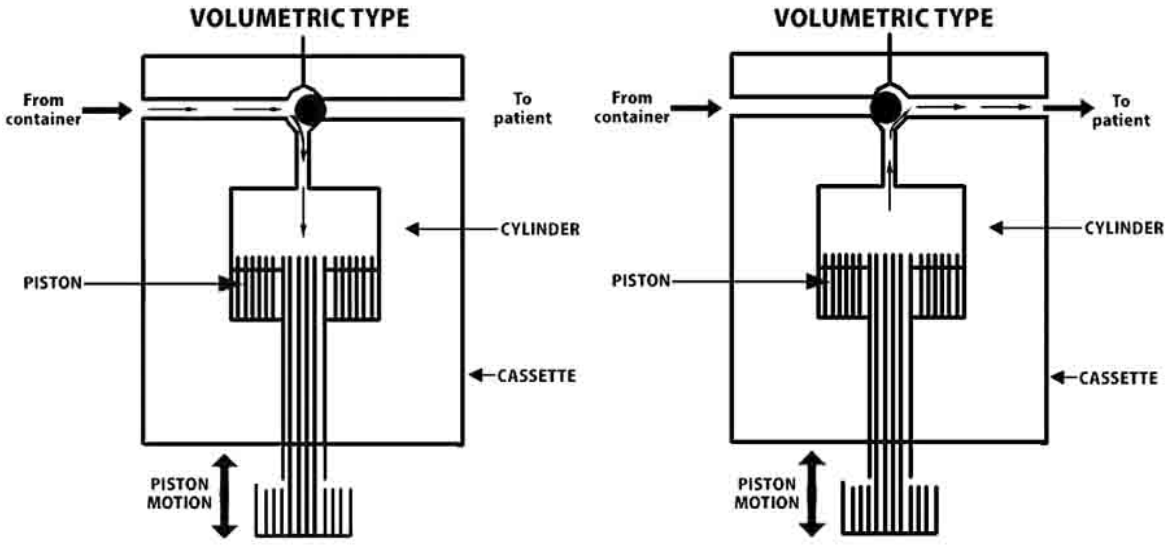

Figure 3–41. Operating principles of volumetric pumps.

Infusion controllers

The last infusion device we are going to discuss is the infusion controller (fig. 3–42). This device is much simpler than an infusion pump and is an enhancement to the gravity-feed system. It eliminates one of the major gravity-feed systems disadvantages—it allows you to accurately monitor and control the amount of fluid entering the patient. The controller automatically monitors the fluid flow through a gravity-fed IV line by electronically counting the drop rate. Although this setup may not be widely used throughout your facility, it normally takes the place of an infusion pump. It requires thorough training for proper use, but it can be a substantial improvement over the manual flow clamps of the gravity-feed system. It also can provide adequate control of many critical infusions at a savings to your facility over infusion pump setups.

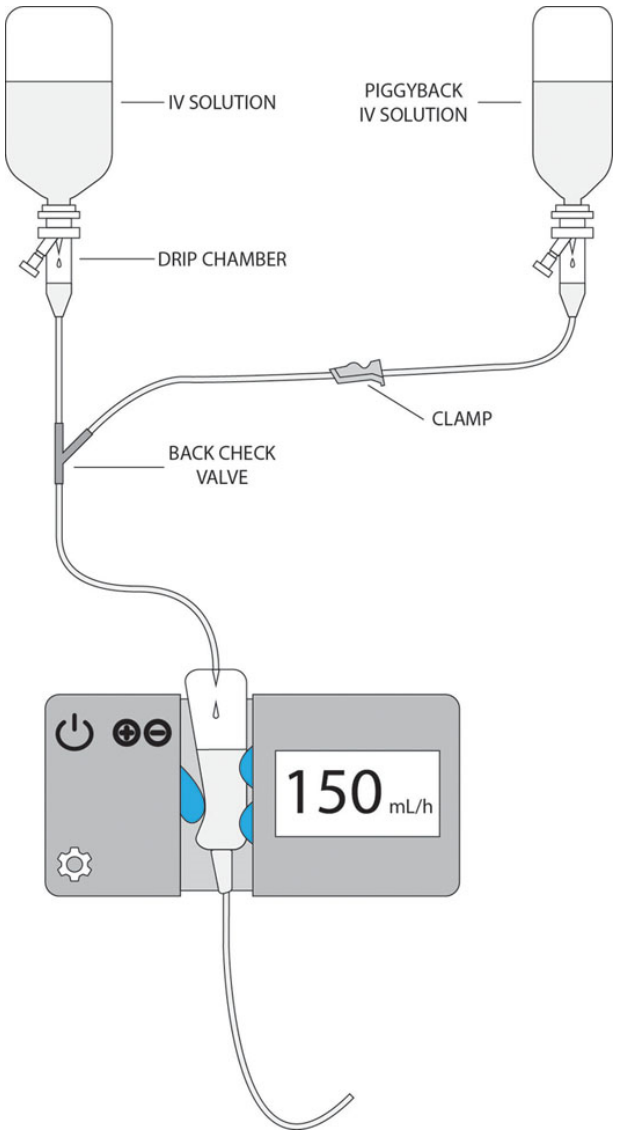

Figure 3–42. Infusion controller.

Clinical applications

The primary uses of controllers and infusion pumps generally fall into two categories: hyperalimentation and drug therapy.

Hyperalimentation

Hyperalimentation is provided parenterally (via the vascular system) or enterally (into the digestive tract). Parenteral solutions include amino acids, sugars, vitamins, minerals, and trace elements to meet specific nutritional needs of each individual patient. The purpose of total parenteral nutrition (TPN) or hyperalimentation is basically to achieve or maintain tissue synthesis; produce structural weight gain and growth; and produce a positive nitrogen balance in the patient. Flow rate accuracy is most important in hyperalimentation—if the patient was to receive significantly less than the prescribed volume, weight gain may be less than anticipated. However, a flow rate significantly higher than prescribed may cause acute diabetic symptoms and even seizures in infants from hyperglycemia (high blood sugar).

Accuracy and safety requirements are more stringent for parenteral hyperalimentation than for enteral feeding because the fluid is infused directly into the blood stream. Formulas used for calculating IV flow rates can be found in the manufacturer's operating literature. It may be helpful in determining correct flow rates of various infusion devices. For most patients, a flow rate accuracy of 10 percent is generally acceptable; however, some patients may require an accuracy of 5 percent.

TPN solutions tend to be more viscous than other parenteral fluids and are often infused at rates in excess of 100 mL per hour. In-line, small-pore micron filters are often used to remove particulate matter, bacteria, and most viruses that can cause phlebitis and septicemia.

Internally administered hyperalimentation solutions may require a pump to maintain flow through small-bore nasogastric tubes. Flow rate accuracy is not as critical since the rate of absorption of nutrients by the bloodstream is buffered by the digestive tract. Internal feeding does not require all the safety features critical for intravenous and arterial infusions.

Drug therapy

The other primary application for pumps and controllers is drug therapy. Drugs are usually administered intravenously, although arterial lines are sometimes used.

Drugs commonly administered by continuous infusion include some antibiotics, bronchodilators, chemotherapeutic agents, heparin, insulin, antiarrhythmic agents, and vasoactive drugs (those affecting blood pressure). They are generally diluted with general-purpose solutions, such as 5 percent dextrose in H_2O (D5W), or normal saline to facilitate controlled administration and minimize local tissue reactions. Flow rates range from less than 1 mL per hour to approximately 100 to 125 mL per hour, depending on such factors as drug type and concentration; patient age and fluid tolerance; and individual variations in drug response.

In drug therapy, rate consistency and the relative accuracy at each setting are more important than volume accuracy. The potency of some drugs can vary as much as 10 percent due to lot variations and age. Neglecting to account for the overfill of the solution container in which the drug is diluted can introduce an additional negative error in drug concentration of up to 10 percent. Thus, the strength of the drug solution cannot be accurately determined. In addition, response to a given dosage rate can vary tremendously among patients. A physician generally begins administration with a standard dosage rate based on body weight, and then "titrates" the patient, adjusting the rate, often dramatically, to achieve the desired physiologic effect. Once the proper rate is determined, however, the physician needs consistent control to assure subsequent changes in the patient's condition are not due to significant deviations in flow rate.

227. Maintenance and testing of infusion devices

Infusion devices are life safety units that require periodic maintenance and can contribute to a large portion of your workload. Infusion devices are one of a handful of units that you are most likely to see an incident investigation conducted on over the course of your career. Careful attention to detail and flawless record keeping are cornerstones of a medical maintenance program. Just remember, if it was not documented…it did not happen!

Preventive maintenance

PMs for an infusion device are relatively simple. Ensure the unit is clean and free of contaminants prior to beginning an inspection.

Inspect the following items for damage (if applicable):

- Exterior surfaces.
- Module connectors and pins.
- Keypad.
- Screen.
- Mechanical parts (e.g. pump doors, syringe drive mechanisms).
- Membrane assemblies.
- Cables (e.g. power cord, bolus cables).
- Pole clamps.

- Inspect the following functions for proper operation (as applicable):
  - Displays – Including liquid crystal display (LCD) screens or 7-segment displays. Check contrast and pixel functions.
  - Keypad – Most units will have a button test. Ensure each keystroke registers.
  - Alarms – Including lights and audible tones. Check occlusion and air-in-line alarms.
  - Doors – Including door sensors, latch functions, or locking mechanisms for medication syringes.

Some units require periodic spare parts replacements including items such as main batteries, internal memory batteries, or various sensors. Follow the manufactures recommendation for parts and replacement intervals. Calibration verification can be validated either by weight or by flow. The weight method uses computer software and a calibrated scale, while flow is verified using an infusion pump analyzer.

Infusion pump analyzer

The infusion pump analyzer is designed to verify the operation of most medical infusion pumps and controllers. This includes volumetric, peristaltic, motorized syringe, or drop-counting types of infusion devices. The device will be configured to measure flow, volume, and occlusion. The analyzer can be used on a maintenance workbench or can be installed on an IV pole for use in the patient area.

Basic description of front panel

The following items may be found on the front panel of an infusion pump tester. First, you have the light-emitting diode (LED) display. This is the indicator that shows your measurements for mL per hour, mmHg, and psi. There are also soft touch buttons for configuring the device for flow, volume, and pressure testing. Depending on the type of analyzer that you use, you will either find a single channel fluid inlet port or multichannel connections for simultaneous channel testing as shown in figure 3–43.

Figure 3–43. Infusion analyzer. (Reproduced by permission courtesy of Fluke Biomedical.)

Tests

The infusion pump analyzer can perform the following tests:

- Instantaneous flow rate accuracy – This measurement is derived from a group of volumetric measurements taken. It can be done in the steady flow test mode or high accuracy test mode. The acceptable range of flow measurement is 0.5 – 1,000 mL per hour. The unit may require 15 minutes of warm-up time for low flow rates.
- Average flow rate accuracy – This measurement is derived from all of the previous measurements mentioned and is updated for each new reading taken. This reading changes rapidly at the onset of a test, but will gradually stabilize.
- Delivered volume accuracy – This measurement is achieved by taking the average flow rate value and multiplying it with the total test time.
- Occlusion – This test is used to detect the maximum pressure generated by the unit. The analyzer's fluid inlet is blocked and pressure will rise until the unit tested stalls, alarms, or reaches a pressure of 1,800 mmHg.

Setup

Deionized H_2O is used to test the analyzer. Any other fluids may cause damage to the analyzer. The configuration for testing an infusion device is fairly simple. The device being tested is connected to the analyzer through the fluid IN port. A drainage tube is connected to the fluid OUT port of the analyzer, and the other end is connected to a collection device. The analyzer has a serial port for connection to a computer and a parallel port for connection to a printer. Testing results can be printed or exported to a computer at designated intervals to ensure proper documentation of unit calibration.

Operation

To perform an accurate test of devices, the unit must first be primed. At least 20 mL of air is pushed through the analyzer to clear excess H_2O out of the unit. Then, the unit is switched on and at least 3 mL of H_2O is slowly injected into the unit. The analyzer is then connected to the infusion device for testing. If the analyzer is set to auto start, the unit will begin taking measurements once it senses the initial flow from the pump. Follow the infusion pump manufacturers guidance for flow, volume, and occlusion testing requirements and tolerances. The unit must be primed again before a new unit is tested.

Cleaning analyzer

The outside of the analyzer is cleaned using mild detergent. The inside is cleaned by injecting 20 mL of detergent into the unit, waiting 30 minutes, then flushing it out with deionized H_2O.

228. Hypo/hyperthermia machines

A hypo/hyperthermia machine can be used in surgery for whole body therapy, or to deliver heat or cold to specific parts of a patient's body. First, we bring you the role of the hypo/hyperthermia unit in surgery; then, we cover heat and cold applications.

Clinical applications

A hypo/hyperthermia machine is used primarily to maintain normal temperature in patients during and after surgery; decrease and stabilize the body temperature of febrile patients; and elevate the body temperature of victims of accidental hypothermia. Hypo/hyperthermia machines circulate warm or cold H_2O through tubing or flow channels in blankets below, or above and below, the recumbent patient.

Maintain body temperature

The core temperature of a healthy person is about 98.6° F or 37° C. This temperature range is maintained by the thermotaxic nerve mechanism, which maintains a balance between the thermogenetic (heat-producing) and thermolytic (heat-dispelling) processes. The normal temperature may be increased or decreased by disease, environmental conditions, or artificial means. Abnormal temperatures are often caused by infection, abnormal metabolic states, idiosyncratic reactions to anesthetic agents and drugs, or environmental influences. In many patients, cooling is required to reduce their temperature to normal. The application of lowering body temperature well below normal to helps to reduce metabolic requirements for blood flow, O_2, and elimination of wastes to provide greater ability to tolerate surgical procedures and tissue damage.

Metabolic rates of febrile patients may be many times the normal rate, and body temperatures may exceed 41° C (106° F). At this point, the body's thermoregulatory system becomes nonfunctional. Permanent brain damage may result from a prolonged body temperature of more than 41° C; heat stroke and death are common at body temperatures over 43° C.

Reduce heat loss

If you count out heat loss to the environment, metabolic heat would cause a body temperature increase of about 1° C per hour. Body heat loss occurs in several ways:

- Conductive loss is heat loss to cooler objects in contact with the skin. This loss is usually negligible, even when the patient is recumbent, because the contacted surfaces are rapidly warmed to near body temperature and most surfaces on which patients lie are poor thermal conductors.
- Convective loss is heat loss to air passing over the skin's surface. This loss increases rapidly with wind velocity; however, this accounts for less than 20 percent of the total heat loss in most hospital settings.

- Evaporative loss occurs mainly from the skin, respiratory surfaces, and open surgical wounds. It accounts for about 20 percent of the total heat loss at room temperature. This loss increases in very warm environments where it is the only method of heat loss.
- Radiative loss is heat loss from the transmission of infrared radiation to cooler objects in the environment. It accounts for about 60 percent of the total heat loss at room temperature for an unclothed patient. Such heat loss can be significantly reduced by covering exposed portions of the body.

Maintain core temperature during surgery

Ideally, the suggested minimum core temperature during surgery is 35° C. However, this may be too great a drop for the very old, very young, or cardiac patients. Temperature drops of 3° to 4° C, caused by the following, are common during surgical procedures:

- Convection heat loss occurs because large amounts of the body's surface are exposed in the OR where the humidity is low and the temperature is typically 18° to 19° C. Hypothermia is especially common during pediatric surgery because of the infant's large body surface area, which increases heat loss to the atmosphere, and the relatively small body mass for conserving heat.
- Increased evaporative heat loss occurs when the patient breathes in the dry anesthetic gases, volatile cleaning solutions are applied to the skin, and moist surgical wounds are exposed to the air.
- Infusing cold or room temperature fluids (blood) contributes to heat loss.
- Anesthetic agents can affect the patient's thermoregulatory system adversely.

Large temperature drops during surgery can pose significant dangers. The risk of ventricular fibrillation increases and is especially great for patients with cardiac disease. Patients who are already hypothermic are more susceptible to fibrillation caused by infusing cool fluids. Heat lost in the OR must be regained with increased circulatory and ventilatory effort in the post-operative period. Even a small temperature drop will cause increases in a patient's O_2 uptake during the recovery period. Shivering during this period may increase O_2 uptake and CO_2 production fivefold.

Induce temperature changes

Invasive methods of raising body temperature, such as peritoneal dialysis and partial cardiopulmonary bypass, are the most rapid and are usually used only for severe hypothermia, when the patient is fibrillating, or when the invasive procedure is being performed for other reasons. Other methods of raising body temperature, such using regular or hypothermic blankets, may be slow. Even when rewarming therapy has begun, the patient's core temperature may continue to drop. This "after drop" results from peripheral vasodilation and inhibition of metabolism and shivering, factors that also reduce the long-term effectiveness of external rewarming techniques in raising core temperature.

Clinicians can deliberately lower the temperatures of surgical, as well as febrile, patients by infusing cold H_2O or using ice baths, and using hypothermia machines. Reducing body temperature slows metabolism by reducing the speed of biochemical reactions.

As we said, hypo/hyperthermia units can aid in whole body therapy, or to administer heat and cold to specific body parts. Let's examine some therapeutic applications of this approach.

Heat applications

Some therapeutic benefits of applying heat are to relieve pain, relax muscles, promote healing, and reduce tissue swelling. When heat is applied to the skin, the heat causes the blood vessels in that area to dilate. Figure 3–44 shows the difference between the normal blood vessel (A), and the dilated or enlarged, wider blood vessel (B). This allows more blood flow through the vessel, increasing the amount of O_2 and nutrients available to the tissues for healing. The increased circulation also speeds

up the removal of toxic substances, waste products, and excess fluid from the area. The skin feels warm and appears reddened because of the increased blood flow in the area of the heat application.

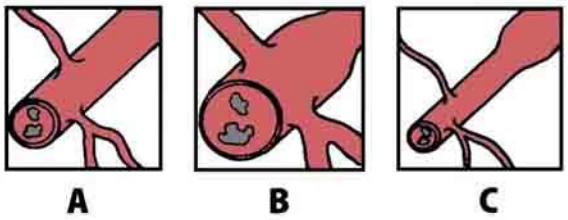

Figure 3–44. Thermal effects on blood vessels.

Although the application of heat has advantages for the patient, it also has some disadvantages. High temperatures, when applied and not monitored, can result in burns. When applying heat for a prolonged period, blood vessels have a tendency to constrict or narrow (fig. 3–44, C). Blood flow decreases when vessels are constricted, reducing the amount of blood available to the tissues. A decreased blood supply causes tissue damage and gives the skin a pale appearance.

Cold applications

Some therapeutic benefits of applying cold are to reduce pain, reduce swelling, decrease circulation, and cool the body when fever is present. When cold is applied to the skin, blood vessels constrict, resulting in decreased blood flow. When blood flow decreases, less O_2 and nutrients can reach the tissues. Tissue metabolism decreases, resulting in the removal of fewer toxic substances and waste products. Cold applications are useful immediately following an injury because the decreased circulation reduces the amount of bleeding and fluid accumulation in tissues. The numbing effect of cold on the skin helps to reduce or relieve pain in the area. The skin appears pale and feels cool because of the decreased blood flow in the area of the cold application.

Some disadvantages of local cold applications include pain, burns, blisters, and cyanosis. Burning and blistering have a tendency to occur from intense cold; they can also occur when dry, cold applications are in direct contact with the skin. When applying cold for a prolonged period, blood vessels have a tendency to dilate. Thus, blood flow increases with vasodilation, resulting in the same effects as local heat applications.

As you can see, the hypo/hyperthermia unit is a very important part of the total service provided by Air Force health care facilities. Let's acquaint you with some of the more equipment-specific areas of concern during operational inspections.

Operational characteristics

To supply warm or cool H_2O to a hypo/hyperthermic blanket, a hypothermia machine uses a cartridge heater or refrigeration system. A pump circulates the H_2O through the unit to the attached blanket. The blanket can be a reusable type with changeable covers or a disposable type. The blanket usually attaches with the use of male and female quick disconnects. A patient probe monitors patient temperature. Hypo/hyperthermia machines can operate in a manual, automatic, or patient temperature monitoring mode.

Manual mode

The operator selects the temperature of the H_2O delivered to the blanket for heating or cooling the patient. The temperature controller then maintains the H_2O temperature at the selected set point. The unit displays the selected and actual H_2O temperatures. The patient's temperature can also be monitored if the unit has the appropriate features.

Automatic mode

The operator selects the desired patient temperature. The machine senses the actual patient temperature through a rectal or esophageal temperature probe, and delivers heated or cooled H_2O to heat or cool the patient. The machine displays actual and selected patient and H_2O temperatures.

Patient temperature monitoring

The machine displays the patient temperature. No heating or cooling of the patient occurs.

Common features

Hypo/hyperthermia machines come with other features. Here are some common to all units:

- High/low temperature alarms – activate when the H_2O outlet temperature exceeds the limit of a temperature sensor at the end of the fluid path.
- Low flow indicator – warns the operator when there is an obstruction in fluid flow. Interruption or obstruction of the flow can be caused by an incorrectly attached hose, debris clogging the path, or a low reservoir level. If the condition goes unnoticed, the effectiveness of the therapy will be reduced.
- Probe alarm – is used to sense a patient's temperature within a range of temperatures specified by the manufacturer to operate in the automatic mode. Otherwise, the units discontinue therapy and sound an alarm. The minimum temperature should be higher than the ambient air temperature so the unit deactivates heating or cooling if the probe dislodges from the patient. This alarm could indicate a disconnected probe, a probe not properly positioned in the patient, or a defective probe. Also, while in automatic mode, the patient probe must be fully inserted into the unit or therapy will be discontinued.
- Set temperature range – controls therapy delivery. In automatic mode, the unit will not deliver therapy if the controls are set to allow a patient's temperature to diverge from a range around normal body temperature. Limiting the temperature range prevents the patient's temperature from lowering or raising to a dangerous level because the controls were set incorrectly.

229. Defibrillator

The defibrillator can be found throughout your facility. It is considered an emergency piece of medical equipment. Therefore, it should be maintained to its exacting standards. Let's learn a little about defibrillators.

Clinical applications

Defibrillation is necessary when the heart stops or when arrhythmias prevent adequate blood circulation. The classification of arrhythmias may be applied to a variety of irregular beating patterns of the heart. The most fatal cardiac arrhythmia is ventricular fibrillation, which causes immediate death. In ventricular fibrillation (sometimes abbreviated as "V-fib"), the cardiac ventricles exhibit uncoordinated, random contractions, emanating simultaneously from multiple areas of the muscle tissue. In this condition, the ventricles appear to be "quivering," rather than demonstrating the normal coordinated contractions, which pressurize the chambers and pump blood.

The most popular explanation of ventricular fibrillation involves the "circus motion theory." In normal ventricular beating, the depolarization wave front spreads from the apex upward, causing a coordinated contraction. Because of the refractory period during which a cardiac muscle cell cannot be activated, each contraction signal passes only once through the muscle. If the heart is damaged, local areas of depolarization can develop, initiating contraction signals independent of the SA node's synchronized signals. When these local signals are transmitted around the heart rather than from the apex to the base, they can return to their point of origin. If the local depolarization has recovered sufficiently to be reactivated when its own signal has passed around the heart and returned, then the

signal is renewed and once more sent along its path in a “circus motion.” Multiple sources of such signals cause ventricular flutter. As speed and geometry of individual “circus motion” wave fronts change, they break up into fibrillation. The key point, however, is without the coordinated contraction of the ventricles, blood pressure drops to zero. Organs and tissue require an uninterrupted supply of blood or they rapidly deteriorate. The brain is the first organ to be damaged, occurring only 3 to 5 minutes without blood circulation, followed shortly by death if circulation is not restored.

When ventricular fibrillation occurs or when the heart stops, cardiopulmonary resuscitation (CPR) must be administered immediately. The purpose of CPR is to prevent irreversible brain damage until a normal heart function can be restored.

Atrial fibrillation occurs in the same fashion as ventricular fibrillation, but without the serious consequences. The atria are the “superchargers” of the heart. They help the ventricles to fill and perform their function. If the atria fibrillate and fail to act as “superchargers,” cardiac output is reduced, but generally remains adequate. People can survive and live relatively normal lives while experiencing atrial fibrillation.

The goal of defibrillation is to restore normal cardiac rhythm. Defibrillators provide an electrical shock to the heart sufficient to resynchronize the cardiac muscle cells. The first defibrillators in clinical use delivered a 60 cycle AC output. AC defibrillators, as we refer to them today, had several serious disadvantages. First, several successive defibrillations were usually required to successfully correct ventricular fibrillation. Second, atrial fibrillation cannot successfully be treated by AC defibrillation. Because of the body’s natural sensitivity to AC, especially at 60 Hz, AC defibrillation of the atria can easily result in ventricular fibrillation, which is much more serious. For these reasons, it is no longer used. Today, defibrillators are designed to deliver a single, carefully controlled pulse of DC without the uncertainty and harmful side effects of AC. Electrodes (paddles) deliver the energy from a large storage capacitor, and a meter monitors the amount of energy available. The paddles are either standard reusable paddles with handles and delivery controls or disposal one-time use pads.

Operation

Defibrillators work by producing a uniform electrical state within the electrically excitable cardiac muscle tissue. That is, the multiple waves of contraction in all directions that cause the muscle to “quiver” during fibrillation are all overridden by the defibrillator’s output pulse. The overpowering force of this pulse produces a uniform refractory state. In the refractory state, the excitable cardiac muscle cell cannot respond to another stimulus. The ventricles are thereby uniformly forced into simultaneous polarization. In this state, they are again ready to accept a normal contraction-initiating pulse from the SA node transmitted through the AV node, His bundle, and Purkinje network, as in normal beating.

The defibrillation shock needed to place an individual cardiac muscle cell into the refractory state is very small. Only a few milliamperes (mA) of current applied directly to the cell accomplishes the task. When applying the defibrillating shock externally across the chest, however, 20 or 30 amperes may be necessary. Current of this magnitude is needed because of the reduced current density of the external defibrillation. As the defibrillating current passes across the chest, it spreads out and diffuses across the heart and its surrounding tissue (fig. 3–45). The current density at a particular cardiac muscle cell is significantly lower because of this spreading out effect. Internal pacemaker electrodes produce a high current density and are able to function well in the milliampere range, which we discuss later.

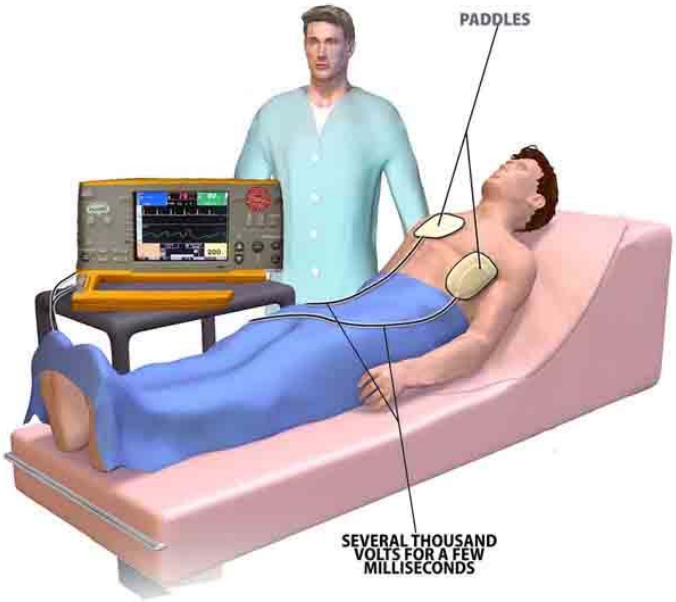

Figure 3–45. Defibrillator in action.

We cannot determine the exact amount of current actually delivered during defibrillation. Chest resistance (load resistance) varies from patient to patient, as does the value of the electrode/skin contact resistance. The defibrillator's stored energy (voltage), however, can be precisely determined. For this reason, the medical staff depends on the known energy of the defibrillator to estimate its clinical benefit to each individual patient. Actual delivered energy, reported in Joules (watt-seconds), best indicates for the staff what effect the defibrillator storage capacitor can be expected to produce. Many older units reported their capability based on misleading stored energy information, rather than on what was being delivered to the paddles. Energy losses due to internal inductor coil resistance, wiring, and relay contacts can easily reduce stored energy by 30 percent or more. Output meters of more recent defibrillators are calibrated in delivered energy to avoid confusion and to ensure the medical staff knows what output to expect. A major driving force behind the widespread efforts to verify and document defibrillator output energy during the early 1970s resulted directly from confusion regarding stored versus delivered energy.

A typical DC defibrillator is nothing more than an inductor used to shape the wave and eliminate the sharp current spike present at the start of the capacitor discharge. The output waveform of this type of unit produces the characteristic Lown waveform shown in figure 3–46. The classical Lown waveform shown is underdamped and dips slightly below the baseline on its trailing edge. Some manufacturers choose the specific values of the internal electronics carefully to ensure a critically damped waveform, in which case the trailing edge simply returns to the baseline without overshooting. The relative merit of one over the other is debatable.

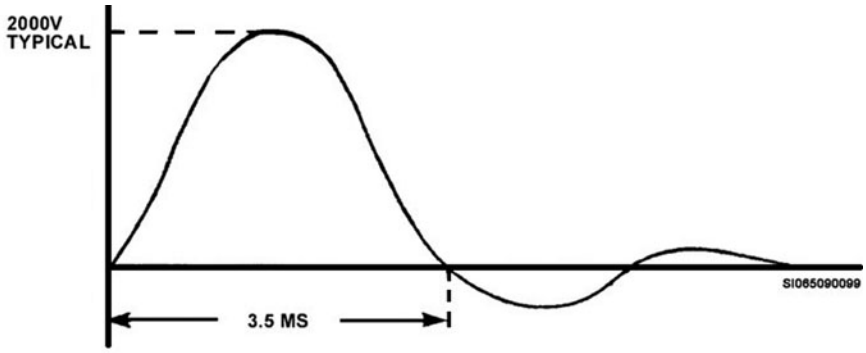

Figure 3–46. Lown waveform.

In addition to the emergency technique of ventricular defibrillation already discussed, defibrillators have other important uses. In cardiac surgery, such as bypass or valve replacement, for example, surgeons may choose to immobilize the heart temporarily by inducing fibrillation. When this happens, the patient is placed on a heart-lung machine that maintains vascular pressure and performs gas exchange. When the operation is complete, small spoon-like paddles are applied directly to the ventricles, which are defibrillated with a low energy pulse.

Defibrillators can also correct arrhythmias, which are less life threatening than ventricular fibrillation. We refer to such procedures as cardioversion. Cardioversion can effectively correct atrial fibrillation, atrial flutter, and tachycardia. In cardioversion, the defibrillator is discharged in sync with the patient's natural EKG. That is, the defibrillator synchronizes to discharge during the down stroke of the R-wave of the QRS complex. Synchronization circuits within the defibrillator ensure discharge takes place before the vulnerable period associated with the T-wave. Discharge during the T-wave could possibly induce ventricular fibrillation. Most defibrillators provide for synchronization with the patient's EKG, either through their monitoring circuitry or by receiving signals from a separate monitor. Most units with cardioversion capability provide screen displays and strip chart recordings of the EKG signal. When the defibrillator is in the synchronize mode and the discharge buttons on the paddles are pressed, the next available R-wave is sensed, causing the defibrillator to discharge.

Defibrillators are available as portable, battery-operated units or stationary units. Not only are they located in critical areas such as ambulances, emergency rooms, CCUs, ICUs, and surgery, but they are also found in immunization clinics, X-ray, catheterization labs, ward areas, dental offices, and wherever else patients are treated.

Regardless of location or usage rate, defibrillators are critical life-support items. As such, we should ensure they are always in the best possible condition. They must be ready to operate at peak proficiency on a moment's notice. The portable, battery-powered defibrillator plugs into an electrical outlet to ensure its batteries are fully charged. It usually mounts on an emergency crash cart. Besides helping carry the defibrillator to where it is needed, the crash cart also contains all of the drugs and equipment necessary to treat patients in emergency situations.

230. Defibrillator analyzer

A defibrillator analyzer is designed to verify the operation of an automatic external defibrillator. The analyzer is capable of measuring and displaying delivered energy, cardioversion, biphasic energy, peak voltage, peak current, and charge time. This list is not all inclusive. The analyzer can deliver 12-lead EKG simulation, and be battery or AC operated.

Basic components

The analyzer comes with a battery charger; operating and service manual; defibrillator contact plates; internal paddle adapter sets; and vinyl case. As accessories, the defibrillator may come with electrode adapters and adapter modules. Adapter modules contain the loads used for specific defibrillators.

Tests performed

There are many tests these analyzers can perform. Let's review some of the most common tests.

Energy measurement

The main purpose of the defibrillator is to deliver energy. This test will ensure that the energy delivered is within acceptable tolerances. Energy is measured in watts seconds/joules with a standard test load of 50 ohms, simulating human resistance. The most common measurements in the low range are 2–50 joules; in the high range, 100–360 joules. The analyzer will also measure the maximum energy delivered — the defibrillators maximum output in the low or high range. Refer to the manufacturer's literature for specific tolerances if the defibrillator under test.

Follow these general steps when performing the energy measurement test.

1. First, connect the defibrillator to the Analyzer using either the defibrillator paddles or test connection plugs (fig. 3–47).
2. Set the defibrillator to Defib mode and select the desired output.
3. Set the analyzer to output measurement mode, and select the desired range if applicable (high or low output).
4. Charge the defibrillator.
5. Discharge the defibrillator. Results appear in the test results pane immediately.

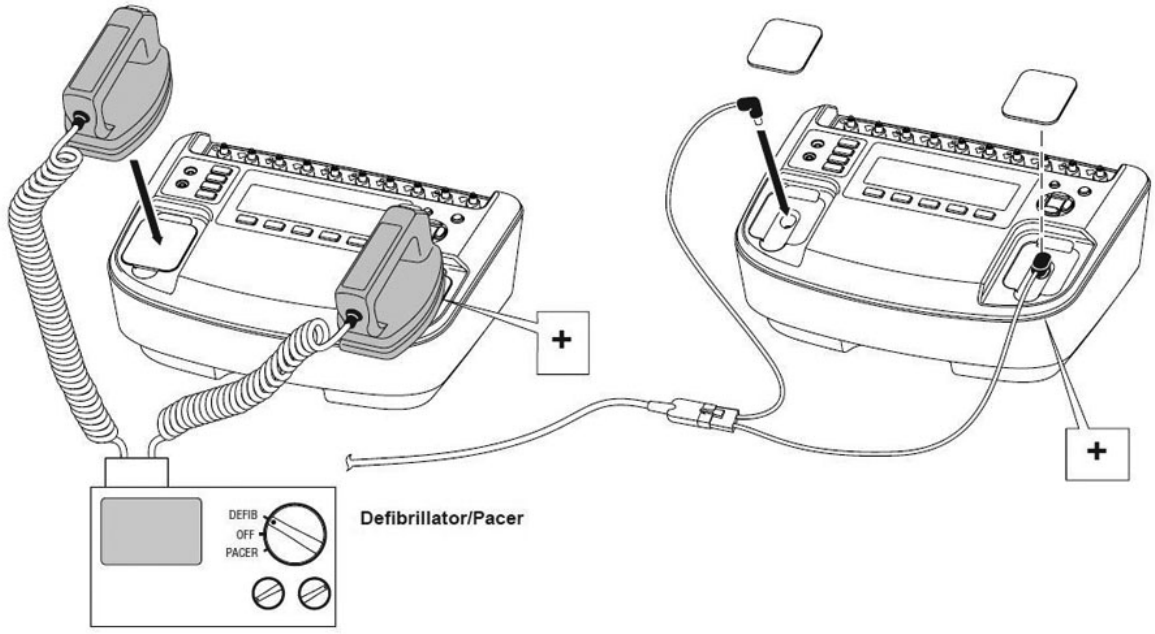

Figure 3–47. Defibrillator energy measurement setup.
(Reproduced by permission courtesy of Fluke Biomedical.)

Defibrillator charge time

This test measures the amount of time it takes the defibrillator to go from a full discharge to charge at the desired charge level (typically maximum setting) and then discharge into the analyzer's test load.

Cardioversion test

This test measures the defibrillator's capability of synchronizing a discharge of its output pulse with a predetermined EKG waveform. Set the defibrillator in sync mode and perform the energy measurement as outlined above. The output pulse of the defibrillator should be delivered within 30ms of the peak of the R-wave.

EKG performance

The analyzer is capable of delivering a 12-lead EKG simulation. The EKG waveform is available through the EKG lead-binding post, paddles, or high-level EKG output on the back of the analyzer. You can select a normal sinus rhythm from 30 – 300 beats per minute (bpm).

Pacemaker test

Most defibrillator analyzers have pacemaker analyzing capabilities as well. They can measure a variable load from 50 to 1500 ohms with a current range of 4 to 250 mA. The Analyzer measures and displays pacemaker pulse amplitude, rate, and width. It also performs demand sensitivity tests, measures and displays refractory periods, and tests the pacemaker's susceptibility to 50/60 Hz interference.

Autosequence test

Some analyzers come with stored autosequences that run a wide range of defibrillator tests for specific manufacturer models. These tests include defibrillator energy levels, maximum energy, cardioversion, EKG performance, and pacemaker tests.

Additional features

The defibrillator analyzer may come with external connection ports, such as an RS–232, serial, or USB connectors, to allow a connection to a computer or printer. It may also have a mannequin port to provide compatibility with training mannequins.

231. Medical laser systems

Although the word laser has become a common word in the English language, it is actually an acronym. LASER stands for light amplification by stimulated emission of radiation. These devices control the way that energized atoms release photons. For the purpose of this lesson, we will continue to refer to the term as laser. Let's take a look into how they work, the associated hazards, and their variety of medical applications.

Laser properties

Laser light has three properties: monochromatic, coherent and directional. Monochromatic light is light of one specific wavelength, or color. In contrast to that, ordinary white light is a combination of many different wavelengths, or colors.

Light is coherent when the photons launch in unison. These photons have a definite phase relation to each other. This means the wavelengths of the laser light are in phase in space and time.

Lasers can also emit light that is highly directional, meaning a very tight, strong and concentrated beam – unlike a flashlight, which releases weak light in many directions. In a flashlight, atoms release their photons randomly. In stimulated emission however, photons are organized. Laser light is emitted as a relatively narrow beam in a specific direction. Ordinary light, such as coming from the sun, a light bulb, or a candle, will emit in many directions away from the source.

Laser types

Lasers are designated by the type of lasing material, or medium, that they employ. Lasers produce a concentrated beam of pure light, usually of one color or wavelength. Depending on its wavelength, this light may be entirely invisible to the human eye. The wavelength produced by a laser depends on the material being stimulated to emit the laser light. There are currently more than 12 types of lasers, some of the more common ones are:

Type	Description
Gas	Helium and helium-neon (HeNe) are the most common; primary output of visible red light. CO_2 lasers emit energy in the far-infrared range of 10.6 micrometers (μm).
Excimer	The name derives from the terms excited and dimers, and it uses reactive gases such as chlorine/fluorine mixed with inert gases such as argon/krypton/xenon. When electrically stimulated, a pseudo molecule called dimer is produced, creating light in the ultraviolet range.
Dye	Use complex organic dyes such as rhodamine 6G in liquid solution/suspension as a lasing media; These vary across a broad range of wavelengths.
Semiconductor	Also called diode lasers, these are smaller and use low ranged power. They are generally built into larger arrays, such as the writing source in some laser printers or compact disc (CD) players.

Type	Description
Solid-state	Have lasing material distributed in a solid matrix, such as the ruby or yttrium-aluminum garnet (YAG) laser. The original laser invented in 1960 was a solid-state laser - it used a synthetic ruby rod with mirrors on both ends pumped with a helical xenon flash lamp surrounding rod. These first successful ruby crystal lasers produced a red beam. We now use high-energy rare earth crystals, such as YAG, doped with neodymium (Nd). This type of laser emits near infrared light at a single wavelength of 1,064 nanometers, which is in the invisible portion of the spectrum.

Components and function of a laser

The basic medical laser device consists of several components that are consistent across most laser systems. The components are the optical chamber, laser pump, cooling system, and aiming laser. The optical chamber is a cavity containing the lasing medium, excitation system (laser pump), and optical resonators. For example, a solid-state Nd:YAG laser optical chamber will contain a yttrium-aluminum garnet rod doped with neodymium (lazing medium), optical resonators at either end of the rod, and a krypton flash lamp (laser pump) to stimulate the Nd:YAG rod. The medium itself requires an external application of energy to start the process of coherent emissions of light. The laser pump supplies this external energy to the lasing medium, stimulating electrons in the medium to a higher energy level. After the stimulation of the lasing medium, optical resonators control and build the energy within the optical chamber to a usable level. The cooling system is a vital portion of any laser system. The largest byproduct of laser creation is heat. The cooling system removes the heat from the optical chamber allowing continuous use of the system. An aiming laser is a visible, low energy laser used to identify the treatment area of the higher energy laser produced in the optical chamber.

To produce laser light the medium must be excited, reflected, built to high levels of energy, and given direction to become usable. The process begins within the optical chamber. The laser pump maintains a constant low level of energy to ensure an immediate and instant excitation of the lasing medium can occur. When the circuit activates to produce laser energy, the laser pump excites the electrons within the laser medium causing a change in the energy levels. Because this high energy level is unstable, each electron emits a photon of light (spontaneous emission) and returns to its original energy state. Each emitted photon, in turn, can strike another electron, stimulating the spontaneous emission of a second and identical photon. At the end of both sides of the lasing medium there optical resonators, mirrors used to reflect the energy back and forth within the lasing medium. As these packets of pure energy or photons reflect back and forth within the laser tube itself, they produce many photons identical in wavelength, amplitude, phase, and direction. These photons eventually pass through the partially reflective mirror (optical resonator) as a concentrated laser beam.

Figure 3–48 shows the laser emission process. Using a mirror at each end of the lasing medium, the wavelength/phase specific photons reflect off the mirrors, travel back and forth through the lasing medium which stimulates other electrons. A cascade effect occurs. The mirror at one end of the laser is “half-silvered,” meaning it reflects some light and lets some light through. The light that escapes is laser light.

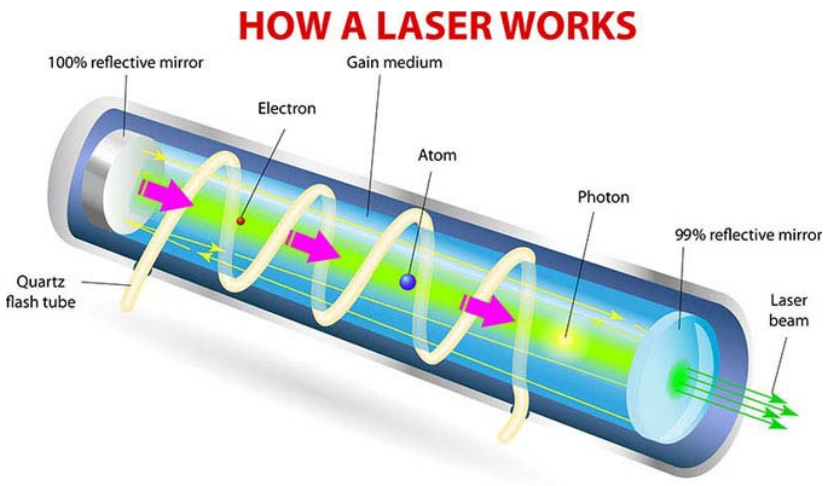

Figure 3–48. Laser emission process. (Reproduced by permission courtesy of T & L Publications, Inc.)

A second low-energy beam laser (HeNe), which produces a visible beam of light, will aim the primary laser beam. The aiming laser aligns with the primary laser to assure and allow the operator a means of verifying the treatment area before beam activation.

Laser classifications

Most laser products are required by law to have a label listing the class. It will be listed either in Arabic numerals (1, 2, 3R, 3B, 4) or in Roman numerals (I, II, IIIa, IIIb, IV). For visible-beam consumer lasers, there are four main classes: Class 2, Class 3R, Class 3B and Class 4. We describe each in more detail below. The first two classes are relatively safe for eye exposure; the last two are hazardous. Figure 3–49 shows how the eye injury hazard increases as the laser's power increases.

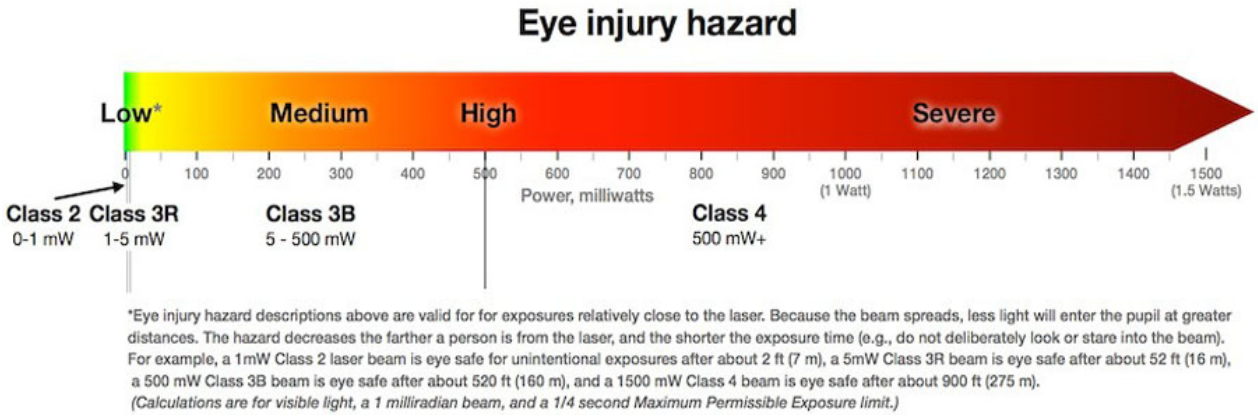

Figure 3–49. Laser class severity scale.
(Reproduced by permission courtesy of Laser Safety Facts.)

Class 2 (II)

This class will emit less than 1 milliwatt (mW) of power and is safe for normal operation. All Class 2 lasers emit visible light only. In Australia, the U.K., and many other countries, only Class 2 lasers can be sold as "pointers" or for pointing purposes. (In the U.S., pointers can also be Class 3R).

Class 3R (IIIa)

Class 3R lasers are safe when carefully handled, and emit power ranging between 1 and 4.99 mW. There is only a small hazard potential for accidental exposure. These are low-powered visible-light lasers. Class 3R lasers normally would not harm the eyes during a momentary exposure of less than ¼ second. This is within the aversion response, where a person turns away and/or blinks to avoid bright light.

Class 3B (IIIb)

Class 3B visible-beam lasers are medium-powered, from 5 to 499 mW. Class 3B lasers are hazardous for eye exposure. They can heat skin and materials, but are not considered a burn hazard. The more powerful the laser, the greater the chance of injury.

Class 4 (IV)

Medical procedure lasers are generally class 4 lasers. Class 4 lasers are the most hazardous of the classifications, ranging from 500 mW and above without an upper limit. These high-powered instruments are dangerous for the eyes, and can cause a significant injury if the beam, whether direct or reflected, enters the eye. They can also burn skin and materials, especially dark and/or lightweight materials at close range. By design, these inherent dangers of class 4 have been harnessed for the purpose of precision cutting, such as used in medical procedures. You should use them with extreme care.

Laser hazards

As you have already learned the dangers associated with different laser classifications, now we will discuss some of the additional hazards associated with the use of lasers. Most lasers use fiber optic probes for both non-contact and tip contact. If too many of the delicate fiber optic probes are broken, secondary burns to the patient can occur. Some CO_2 lasers have an “open beam” which is transmitted via mirrors. Keeping the mirrors aligned becomes a problem with unit movement; the laser beam will not be in the same location of the target beam. The target beam is a non-laser light that indicates where the laser beam will contact the skin. The re-alignment process can take several hours to correct.

Because lasers convert electrical energy to laser energy inefficiently, heat is a major byproduct. To prevent overheating, a cooling system carries away the excessive heat created inside the laser tube. Cooling systems include heat exchangers, radiators, or outside connections sourced to water. The internal radiator and fan assembly circulate the H_2O, helping to maintain a safe temperature. The cooling system requires service at least annually, including cleaning/flushing the system, checking for leaks, and refilling. Cooling system problems can cause premature failure of the laser tube.

Laser smoke (laser plume) is another issue that poses a danger to the patient, operator, and the equipment. The smoke is able to carry bacteria and viruses. In addition, smoke from treatment can leave a film on exposed optics of the laser system. This film will generate heat when exposed to laser light and will cause pitting and reduction of power output, damaging the laser. You should always use a smoke evacuator, with a filter change of at least annually. The used filter is considered hazardous waste and must be disposed of properly.

Because most lasers can cause serious injury if improperly used, many safety features are required. Depending on the type or laser classification these can include the following:

- Integral power meters that indicate laser power output at the laser head and tissue site.
- Safety interlocks that turn off the laser or block the laser beam with a shutter when the laser delivery system is engaged incompletely.
- A remote interlock feature that locks the laser room during lazing or turns off the laser if the door opens.
- A removable key to prevent unauthorized operation.
- A visual or audible alarm signaling laser beam emission.

Other safety and alarm features that signal laser gas and H_2O system functions, such as low-H_2O pressure and high temperature, are also included. You must always use eye protection when dealing with lasers. Unintentional reflection of the laser beam can cause a focusing of the beam directly onto the retina, which can result in severe injury to the eye. The manufacturer usually furnishes special glasses to wear during operation. Always be sure to check the safety range of your glasses, as they are

rated for specific wavelengths. Never assume the glasses you might grab out of your shop's laser safety glasses drawer is compatible with the unit you are working on.

Clinical application

There are many uses of the laser; we only attempt to give you some of the practical applications available. Lasers have been used successfully to repair holes and tears in the retina, to include retinal tumor treatment. The dental profession uses lasers to drill holes and create craters in teeth, and treat all sorts of gum disorders. Neurological disorders (i.e., brain tumors) are also treated with lasers.

Dermatology has benefited with the use of medical lasers. Various skin disorders (i.e., warts or skin cancers) are prime candidates for laser use. Malignant tumors of all types can be effectively treated and removed with greater precision and less surrounding tissue damage than with traditional methods.

When using lasers in place of conventional surgical methods, the following advantages exist:

- There is little or no touch or pressure contact on the tissues involved. This is important in certain kinds of operations (i.e., some types of brain surgery) when harm can result from applying pressure or movement against areas adjacent to the surgery location.
- Laser surgery's employment of heat and the minimal contact with tissue make for sterile conditions that are highly desirable for reducing the risks of infection.
- Laser surgery is carried out in highly localized sites in the body, and the precision of lasers makes them valuable for microsurgery. When surgery is done under a magnifying lens, it's easier to see and thus work on tiny intricate or delicate parts of various systems in the body. There are laser setups or rigs for freehand, as well as micro- and electro-mechanically assisted surgery.
- With certain lasers, a surgeon can work in the nose, ears, mouth, throat, vagina, and other close areas. In conventional surgery, extra cutting may be required to open up such areas enough to use a scalpel or other conventional surgical instruments.
- Because lasers operate by vaporization and destruction of tissues, healing is usually prompt and there is a minimum of scarring and swelling.

As you can see by the examples and advantages just discussed, lasers are continually breaking new ground in the medical profession. As technology advances, we will continue to find new ways to employ this technology in clinical applications.

232. Additional surgical and inpatient equipment

Let's turn our attention to some other equipment used in surgery and inpatient care. This section will cover various units such as dialysis equipment, pneumatic tourniquets, and sequential compression devices. These devices provide critical therapeutic functions for both surgical operations and bedside patient treatment.

Dialysis

The kidney is the only human organ with a function that we can artificially replace on a reliable and chronic basis. Although dialysis cannot claim to duplicate the intricate transport and endocrine processes inherent to normal renal function, dialytic technology has advanced to a point at which a tolerable homeostatic level of existence can be routinely achieved for patients with renal failure.

The artificial kidney provides a controllable transfer of solutes and H_2O across a semipermeable membrane separating flowing blood and dialysate streams. The transfer processes are diffusion (dialysis) and convection (ultrafiltration); the device is a dialyzer; and the three basic structural elements of all dialyzers are the blood compartment, membrane, and dialysate compartment.

Basic dialyzer designs

Three basic dialyzer designs have evolved in attempts to achieve fundamental and structural goals. A dialyzer can have a coil, parallel plate, or hollow fiber configuration.

Coil

The coil dialyzer was an early design in which the blood compartment consisted of one or two long membrane tubes placed between support screens, and then tightly wound with the screens around a plastic core. This resulted in a coiled tubular membrane, laminated between support screens, which was then enclosed in a rigid cylindrical case to minimize the increase in contained volume with an increase in coil pressure. Dialysate flowed vertically through the multiple support screen layers sandwiched between the coils of membrane. This was a cross-flow dialyzer because the dialysate path was across and at right angles to blood flow through the tubular membrane. This design had serious performance limitations, which gradually restricted its use as better designs evolved.

Parallel plate

In the parallel plate dialyzer, sheets of membrane are mounted on plastic support screens, and then stacked in multiple layers ranging from 2 to 20, or more (fig. 3–50). This design allows multiple parallel blood and dialysate flow channels with much lower hydraulic resistance to flow. At the inlet and outlet of the dialyzer, blood and dialysate manifolds distribute these streams to their respective compartments.

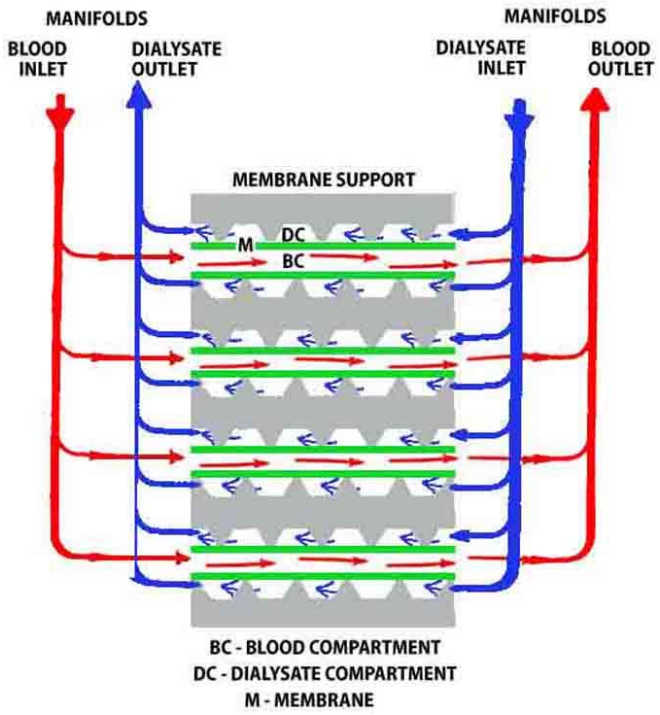

Figure 3–50. Structure of a typical parallel plate dialyzer.

The physical size of the parallel plate dialyzers has been greatly reduced since their introduction, and their efficiency has improved. These improvements have resulted from better membranes supports that provide thinner blood and dialysate channels with uniform dimensions; minimal masking or blocking of membranes on the support; and minimal stretching or deformation of membranes across the supports.

Modern plate dialyzers contain molded membrane supports produced with very tight dimensional tolerances. The membrane is typically supported on tiny pyramidal excrescences molded onto the plastic support surfaces. There is much less membrane deformation and masking, since the membrane

stress is bi-directional. The resulting thin and uniform channel heights afford better distribution of blood and dialysate flow, and high ratios of surface area to contained volume. A small increase in contained blood volume may accompany pressure changes in the dialyzer. The secondary flow paths around support points break up laminar flow profiles and promote mixing in the blood and dialysate streams; this also improves efficiency.

Hollow fiber

The hollow fiber dialyzer is the most effective design for providing low-volume, high-efficiency devices with modest hydraulic resistance to flow. Figure 3–51 schematically shows the essential structural elements. The membrane is composed of tiny cellulosic or synthetic hollow fibers approximately the size of a human hair, with an internal diameter of 200 μm, wall thickness of 8 to 40 μm, and length of 20 to 30 cm. The total membrane area ranges from 0.6 to more than 2 square meters; the surface area is generally determined by the number of fibers in the device. The aggregate fibers are termed the fiber bundle, which is enclosed in the cylindrical jacket. The fibers are potted in polyurethane at each end of the fiber bundle in the tube sheet, which serves as the membrane support. The blood inlet and outlet manifolds—shallow cylindrical caps covering the tube sheets—are termed headers, and the inlet and outlet of the dialysate manifolds are simply expanded sections of the dialysate jacket adjacent to the tube sheets.

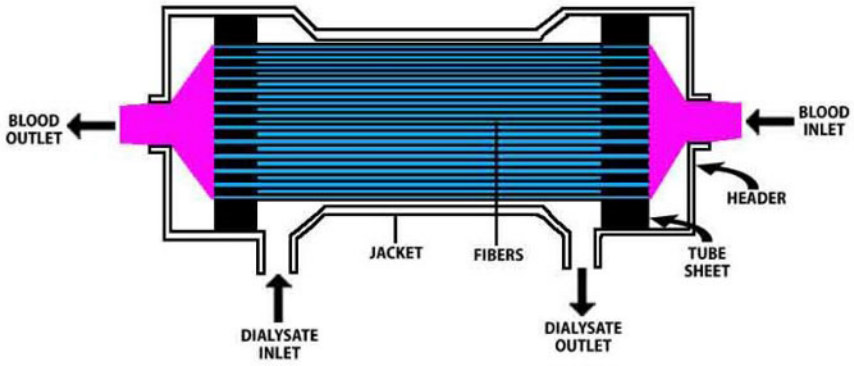

Figure 3–51. Hollow fiber dialyzer.

Uniform distribution of blood flow through the fiber bundle is achieved by maintaining the inner diameter constant during fiber spinning. This is a remarkable technical feat considering the total fiber length is between 1 and 2 miles in each device. Uniform dialysate flow distribution over the outside fiber surface is achieved by controlling fiber packing density, and using baffles in the inlet and outlet dialysate ports. The blood and dialysate flows may be in the same direction (concurrent) or in opposite directions (countercurrent) in plate and hollow fiber dialyzers. The most common flow geometry for clinical applications of dialyzers is countercurrent.

Ultrafiltration

Virtually all interdialytic intake must be removed from the bloodstream flowing through the dialyzer during dialysis. It is essential to prescribe and control the fluid removal rate so the total fluid removed during treatment will equal the total fluid gain since the previous treatment.

The process of H_2O removal from the bloodstream is called ultrafiltration, and the amount of fluid removed is the ultrafiltrate. The primary driving force for ultrafiltration is the hydraulic pressure difference across the membrane, that is transmembrane pressure (TMP), expressed in mmHg. The TMP is determined by the average blood pressure in the blood compartment minus the mean dialysate compartment pressure.

Ultrafiltration represents the bulk flow of H_2O across the membrane in ultrascopic streams and is analogous to H_2O flow in pipes, where flow rate is dependent on the pressure and cross sectional area

for flow. The ultrafiltrate stream is termed convective flow and the mechanism of H_2O transfer across the membrane is convective transport.

Dialyzers rate according to their ultrafiltration capabilities with an ultrafiltration coefficient. This coefficient takes into consideration the hydraulic permeability of the membranes, membrane area, and dialysate flow. The high coefficient rated dialyzers are used with volumetric ultrafiltration control systems, and during high-flux or high-efficiency dialysis.

High-flux and high-efficiency dialysis

Dialysis treatment times have steadily decreased over the years. The objective has been to minimize treatment time, while providing adequate or equivalent therapy. Development of efficient and more permeable membranes and volumetric ultrafiltration control delivery systems has provided the hardware to reduce treatment times to 2 to 3 hours. These systems can also provide comparable solute clearances.

Several approaches help to achieve short treatment times. They include high-flux dialysis, high-efficiency dialysis, and high-flux hemodiafiltration.

High-flux

This treatment employs a membrane system that is permeable to solutes across a broad spectrum of molecular weights up to and including β_2- microglobulin. These usually are synthetic membranes (i.e., polysulfone, polymethylmethacrylate, and polyacrylonitrile). Cellulose triacetate is a more recent addition to the high-flux membrane classification.

This procedure requires the use of precise volumetric ultrafiltration control systems with back filtration of dialysate across the membrane. Short treatment times with these membranes may require blood flow rates of 300 to 500 mL per minute, but individualization of treatment times is the key.

High-efficiency

This refers to the clinical use of membranes that generally are more permeable than conventional membranes to solutes in the low and middle molecular-weight range up to and including a molecular weight of 5,000. These are often called second generation cellulosic membranes, such as cellulose acetate. Volumetric ultrafiltration control systems are preferable with these membranes.

High-flux hemodiafiltration

This process involves the use of high-flux membranes in series to increase convective flux of particularly large molecules to augment the diffusive clearance of these species. In the first dialyzer, dialysate flow enters at 1,000 mL per minute and a high ultrafiltrate is used. In the second dialyzer, there is back filtration of dialysate quantity to achieve the desired net ultrafiltration. Very precise ultrafiltration control systems must be used along with a dialysate flow regulator between the dialyzers to maintain precise dialysate flow.

There are a number of considerations associated with the clinical application of any of these short treatment time therapies. H_2O purification and handling, and the H_2O/dialysate distribution system should be configured to deliver high-quality H_2O for dialysate preparation, cleaning, sterilizing agents, and reuse procedures. Impurities or bacterial degradation products with high endotoxin levels in equipment or solutions may produce pyrogen reactions with any of these membranes. Presterilization exposure of blood-contacting surfaces to contaminated H_2O may result in adsorption of endotoxin fragments to the membrane surface and stimulate reactions, even though the device is subsequently sterilized.

The blood circuit

Figure 3–52 depicts the blood circuit. The flow path from the patient to the dialyzer inlet is termed the arterial blood line, and the flow path from the dialyzer outlet back to the patient is termed the venous blood line. A blood pump is required with present-day arteriovenous fistulas and grafts to achieve

adequate and consistent blood flow through the dialyzer. Roller-type blood pumps are now universally used. Most of the newer roller pumps are self-occluding and can compensate for any small variability in the blood pump tubing segment. Roller pumps that are not self-occluding require periodic calibration to ensure accurate blood flows.

Drip chambers (not shown in this diagram) partially filled with air are incorporated into the blood circuit at each site of pressure measurement. They serve two functions: they provide a site for collection and evacuation of any air inadvertently introduced into the blood path flow, and permit measurement of blood flow path pressures in air rather than liquid, which simplifies the design requirements of the pressure-sensing blood interface. There are newer monitoring techniques that incorporate a sensing diaphragm. These avoid the need for pressure transducer protector filters and the possibility of retrograde blood contamination into the monitoring line.

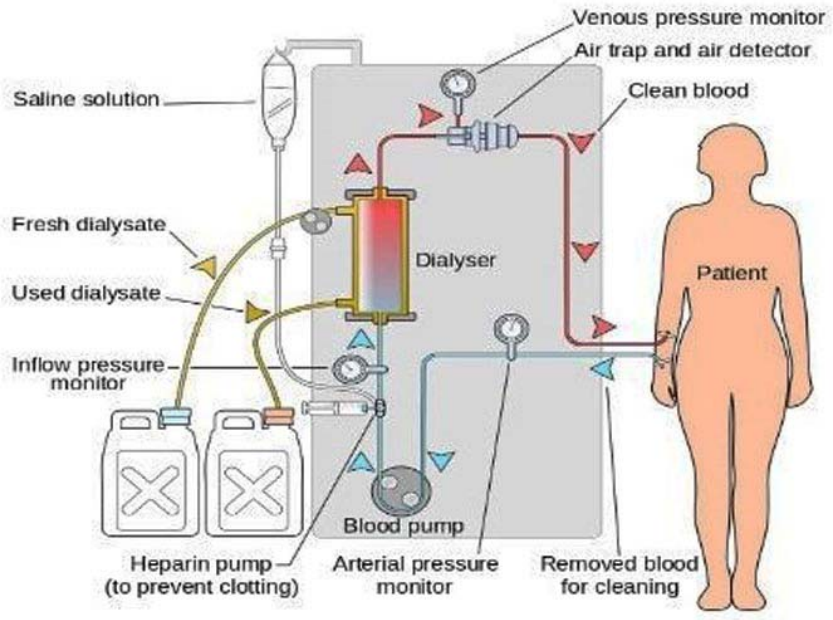

Figure 3–52. Blood circuit of a hemodialysis delivery system.

An air bubble detector is always incorporated into the venous blood line to guard against the potentially disastrous consequence of an air embolism. Although the drip chambers are effective in trapping small amounts of air introduced into the circuit, if massive amounts of air or many microbubbles are introduced, the drip chamber will be inadequate for collection. The air bubble detector provides a final safeguard by shutting down the blood pump and clamping the venous blood line if air is detected.

Filters are also frequently incorporated into the venous blood line to trap any thrombus formed upstream in the circuit. The value of these filters is suspect since many inspections of the filters after dialysis confirm they are actually producers of a thrombus. This is characterized by a thrombus located on the downstream side of a filter with none on the upstream side.

The delivery system

The delivery system functions are to provide on-line proportioning of H_2O with dialysate concentrates; monitor dialysate temperature, composition, and blood leaks; control dialysate pressure or ultrafiltration rate; and regulate dialysate flow rate through the dialyzer. The bloodstream monitors for pressure and air are also incorporated in the delivery system, whereas, in some systems, the blood pump and heparin pump may be separate from the delivery system. If the blood pump is separate, it must be electrically tied into the delivery system to interface safely and effectively with the blood circuit monitors.

The composition of the dialysate solution is designed to approximate the normal electrolyte concentration found in plasma and extracellular H_2O. In earlier days, a large batch of dialysate would be mixed up, and then delivered through piping to several dialysis stations. Since then, it has been discovered that patients have different electrolyte concentrations in their bodies, so now smaller delivery systems are used to tailor the electrolyte to each patient's needs. If you are working in an area where a large delivery system still exists, it is important not to let the piping become tangled, kinked, or restricted in any way that would prevent it from being flushed and sterilized.

Pneumatic tourniquets

Pneumatic tourniquets can be found in emergency rooms, cardiac care units (CCU), intensive care units, orthopedic clinics, and surgery units. We'll look at the operating principles and applications common to these devices during our discussion.

Principles of operation

There are several methods used to inflate pneumatic tourniquets: use of an air compressor, attached compressed air, nitrogen or Freon canisters, a central compressed air supply, or a simple hand pump. First, let's take a look at the type of pneumatic tourniquet that uses an air compressor.

A rotating tourniquet employs an air compressor to inflate each of its four blood pressure cuffs. Figure 3–53 illustrates the typical design of an automatic rotating tourniquet. Four blood pressure cuffs will encircle the upper arms and legs. These cuffs are identical to the ones used to measure blood pressure. The bladder of each cuff receives air from rubber tubing long enough to allow placement of the unit on a bedside table, out of reach of the patient. Notice each blood pressure cuff supply line connects to separate output ports from a timer motor-driven rotary air distributor. This air distributor assembly rotates by an in-line electrical timer motor that allows each cuff to inflate and deflate in a predetermined sequence. This sequencing releases one cuff while the other three remain inflated.

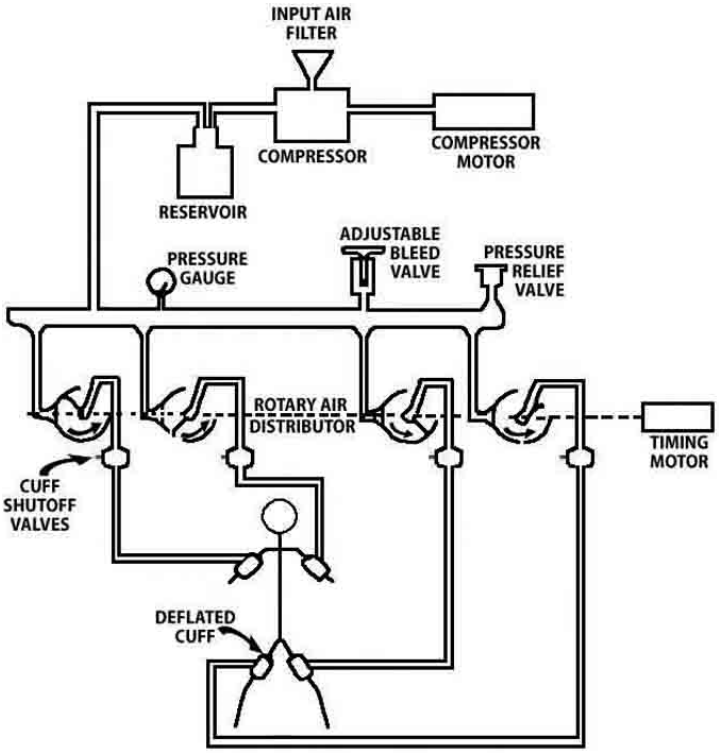

Figure 3–53. Automatic rotating cuff.

Air flows through the input air filter where the motor-driven compressor pressurize it. A reservoir or some form of pressure regulator smooths out the compressor pressure pulsations. The air bleed valve or the air pressure regulator allows adjustment of the pressure applied to the cuffs. Most units provide a safety pressure relief valve to prevent cuff pressure from exceeding acceptable ranges.

There is another type of tourniquet, which is smaller and has a single cuff. This unit may employ a small, nontoxic and nonflammable gas canister to provide pressure to the system. A typical unit will inflate the cuff from 0 to 1,000 millimeters of mercury (mmHg) (0 to 20 psi, and have approximately 20 to 40 inflations available per canister. The unit will inflate to the desired limit and remain there until changed by the operator. These units may also have a visual indicator of some sort to alert you to any gas remaining in the canister. It may also be worth mentioning the cuffs used with most of the various types of pneumatic tourniquets can be autoclaved for use in sterile environments.

The third type of pneumatic tourniquet employs the central hospital compressed air supply or uses a compressed gas cylinder arrangement. These units may be automatic, but are considered low-pressure tourniquets ranging from 0 to 600 mmHg. These units are quite simple to use, having an on/off switch, indicator gauge called a manometer, simple timer, and means to adjust cuff pressure.

Clinical application

Surgical procedures tend to employ tourniquets on the extremities. Pneumatic tourniquets are used to prevent venous oozing, but do not totally obstruct the arterial blood supply. This leaves the operative field as clear of blood as possible. Orthopedic surgeons also use these tourniquets to give a clear field on which to work. Emergency rooms may use pneumatic tourniquets to stabilize accident victims.

Pneumatic tourniquets have a therapeutic application when used in ICU or CCU. Acute pulmonary edema, characterized by the presence of excess fluid in the lung, may be drastically improved with the use of a rotating tourniquet. The application of the rotating tourniquet on the extremities decreases venous return and right ventricular output, and thus helps in decongesting the lungs. The immediate effect may actually be equivalent to removing about 1,000 mL of circulating blood. Pneumatic tourniquets also serve functions on patients with congestive heart failure to reduce some of the strain on the heart.

When tourniquets are used on a patient, they are generally positioned over a small towel as high as possible on the extremity being used. The pressure on the tourniquet is released every 12 to 15 minutes. This prevents excessive nerve damage to the area beneath the cuff, and also prevents gangrene and other complications. To reduce the nerve damage caused by tourniquets, some units have two bladders incorporated into one cuff, which enables the operator to rotate the pressure on the tissue of a specific extremity.

Sequential compression devices

Sequential compression devices (SCD) are circulatory assisting units used for the treatment and prevention of circulatory conditions such as deep vein thrombosis (DVT) and pulmonary embolisms (PE). DVT occurs when a blood clot, or thrombus, develops in one of the deep veins in the body. Blood clots occur when blood thickens and clumps together. Patients who are on bed rest or immobile because of an illness, injury, or surgery are at risk for developing DVT. In the days and weeks after surgery, you have a higher chance of developing DVT. This condition is most common in the leg, but a DVT may develop in an arm or another deep vein in the body. Without treatment a DVT can cause a potentially life threatening condition called Pulmonary Embolism. PE occurs when a piece of a blood clot, called an embolus, breaks off from a vein and travels though the bloodstream to the lungs. PE is a very serious condition, as this can cut off the flow of blood to the lungs. It can damage the lungs and other organs in the body and cause death.

Early ambulation is the best preventive strategy. However, when this is not an option, elastic stockings and sequential compression devices can help. A sequential compression device is a safe non-invasive therapy for the treatment of DVT. SCDs are shaped like sleeves that wrap around the

legs and inflate with air one at a time. An internal pump delivers air to the sleeves causing them to inflate and compress the treatment area. They provide intermittent compression to the lower extremities to promote venous return and to help prevent DVT. They can be applied to one or both lower extremities, depending on the patient's specific needs. The SCD mimics the contraction of the calf during walking. These units keep the blood moving and help to prevent it from clotting.

SCD machines are comprised of a main pumping unit, compression cuffs or sleeves and tubing to deliver air to the sleeve (fig. 3–54). These units require periodic maintenance including pressure verification, safety functions and timing controls.

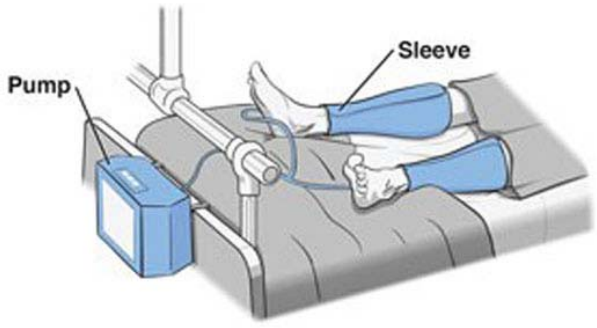

Figure 3–54. Sequential compression device.

Blood fluid warming systems

A blood fluid warming system warms blood, irrigation fluids, and IV fluids. These systems are used for infusions and transfusions, as infusing cold fluids into the human body can cause hypothermia. These cold fluids can drastically reduce the patients mean body temperature. In contrast, fluid warming can minimize heat loss when needing large amounts of fluid or blood. The temperature on these units can be set anywhere from 28° C to 42° C. The set point on a fluid warmer is usually set to 38° C. Liquids are delivered at flow rates from keep vein open (KVO) to 500 mL per minute. Blood fluid warmers use highly conductive aluminum heating plates, which disperse heat immediately and can handle sudden changes in flow rates. They also use a dry heat system that monitors plate temperature multiple times per second, and adjusts to maintain the operating set point. These units warm fluids through extension tubing or disposable cassettes. These disposable sets are available in pediatric, standard flow, and high flow applications. Blood fluid warming systems generally mount to IV poles.

Blood fluid warming systems will have an alphanumeric display that indicates the heater temperature during normal operation. These units also contain alert indicators that activate in either over or under temperature situations. When an over temperature condition exists (43° C or above) or and under temperature condition exists (33° and below), the unit will alarm and display high and low temperature alarms respectively. An audible alarm will also sound if any alert condition exists.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

224. Electrosurgical unit

1. What frequency ranges does the typical electrosurge operate?

2. Name the two electrodes used in electrosurgery and describe their function.

3. Why is the active electrode insulated?

4. What will happen to the patient if the dispersive electrode is misapplied or damaged?

5. How is the lack of the patient being grounded in the circuit compensated for in a monoterminal procedure?

6. What is the primary purpose of electrosurgery?

7. What type of waveforms are used in a monopolar cut mode of operation?

225. Maintenance and testing of electrosurgical units

1. What is the purpose of an electrosurgical analyzer?

2. What are the two main modes of operation?

3. What will the analyzer measure within each mode of operation?

4. What are the four measurements available for generator output?

5. Which test continuously monitors the current between the active and dispersive electrodes to ensure it is not excessive?

226. Infusion devices

1. Name the advantages of gravity-feed systems.

2. State the disadvantages of gravity-feed systems.

3. What are the advantages of infusion pumps?

4. What is a proven disadvantage of infusion pumps?

5. What are the two primary uses of controller devices?

6. Why are accuracy and safety requirements more stringent for parenteral hyperalimentation than for enteral feeding?

227. Maintenance and testing of infusion devices

1. The operation of which types of infusion devices can be measured by the infusion analyzer?

2. What are the measurements displayed on the front panel?

3. What tests does the analyzer perform?

4. What test is used to detect maximum pressure generated by a unit?

5. What test fluid is used with the analyzer?

6. How is the inside of the analyzer cleaned?

228. Hypo/hyperthermia machines

1. What are hypo/hyperthermia unit's primary use?

2. How is the core temperature of a normal, healthy person maintained?

3. At what temperature does the body's thermoregulatory system shut down?

4. How does our body lose heat?

5. What is the suggested minimum core temperature of a patient during surgery?

6. Name some therapeutic benefits of heat.

7. What can happen if heat is applied for a prolonged period of time?

8. Name some therapeutic benefits of cold applications.

9. What are the disadvantages to cold applications?

10 What are the three modes of machine operation?

229. Defibrillator

1. When is defibrillation necessary?

2. Name and describe the most fatal cardiac arrhythmia.

3. What is the goal of defibrillation?

4. Why are AC defibrillators not used today?

5. How much current is required when externally and internally defibrillating a patient?

6. What reading of a defibrillator best indicates to the medical staff the effect the defibrillator storage capacitor can be expected to produce?

7. When does the defibrillator discharge during a cardioversion?

230. Defibrillator analyzer

1. What measurements are used for a defibrillator energy load?

2. What are the most common measurements in the low and high ranges?

3 What are available load and current ranges in a pacemaker test?

4. What are the tests included in an auto sequence?

231. Medical laser systems

1. List and describe the three properties of a laser light?

2. How are laser types designated?

3. What are the consistent components across most lasers?

4. What is the major by-product of a laser and how is it controlled?

5. What is a visible low-energy beam used to identify?

6. What is the power range of a class 3B (IIIb) laser?

7. What are the hazards associated with laser plume?

8. Name the safety features and considerations when operating a laser.

232. Additional surgical and inpatient equipment

1. What is an artificial kidney designed to provide?

2. Name the three basic structural elements of all dialyzers.

3. What are the three basic dialyzer designs?

4. Which design is the most effective for providing low-volume, high-efficiency devices?

5. What is ultrafiltration?

6. What does the ultrafiltration coefficient take into consideration?

7. Name the three processes that have decreased the time patients spend in dialysis.

8. Which lines are considered the arterial and venous blood line in a dialysis machine?

9. Why is a blood pump used?

10. What is the function of the drip chambers that are partially filled with air and located within the blood circuit?

11. What provides a final safeguard by shutting down the blood pump and clamping the venous line if air is detected?

12. What is used to trap a thrombus? Is it effective?

13. What is the function of the delivery system?

14. What are the various ways in which a pneumatic tourniquet can be inflated?

15. What safety device is used in most cuffs to prevent over-inflation?

16. Why are tourniquets used during operative procedures on the extremities?

17. How often is the pressure released on a tourniquet and why?

18. Why are sequential compression devices used?

19. What can happen if a condition such as DVT is not treated?

20. What do sequential compression devices provide and why?

21. What is a blood fluid warming system?

22. What are the flow rates ranges for a blood fluid warming system?

3–5. Labor and Delivery

The labor and delivery department is where a woman goes when she is in labor and ready to deliver her baby. It provides quiet rooms for the mother to progress through the various stages of childbirth and may provide in-room delivery in break-down beds. Unfortunately, things can go wrong, so the department has fully equipped surgical suites should the delivery require it.

Immediately after the birth of the baby, an assessment is done, along with cleaning, wrapping, and warming the baby. Once again, normal delivery can lead to complications, such as premature babies. The labor and delivery department must be able to react immediately to the mother and child's needs. Because of this requirement, we are going to discuss a couple pieces of equipment you will probably encounter in the labor and delivery department. These are the infant care center and infant incubator.

233. Infant care center

Although you may consider infant care centers to be relatively simple, they are used to prevent infant deaths and so must be maintained with great care. In this lesson, we give you the clinical application of infant care centers and some generic information on the principles of operation as they apply to most models you may encounter.

Clinical application

The human body can compensate for many of the abnormal conditions it may encounter. However, to a premature or newborn infant even slight changes in temperature, humidity, and O_2 can mean the difference between life and death. These drastic changes occur when the baby is born. As the internal monitoring system of the mother is gone, some means of controlling these factors is essential for the baby immediately upon birth. The infant care center helps to serve this purpose, and is used in the hospital nursery and at delivery. It can supply constant, automatically controlled heat, and can deliver O_2 at high or low concentrations. It also provides a means to monitor the child's temperature at this critical point. Figure 3–55 is an illustration of a typical infant care center.

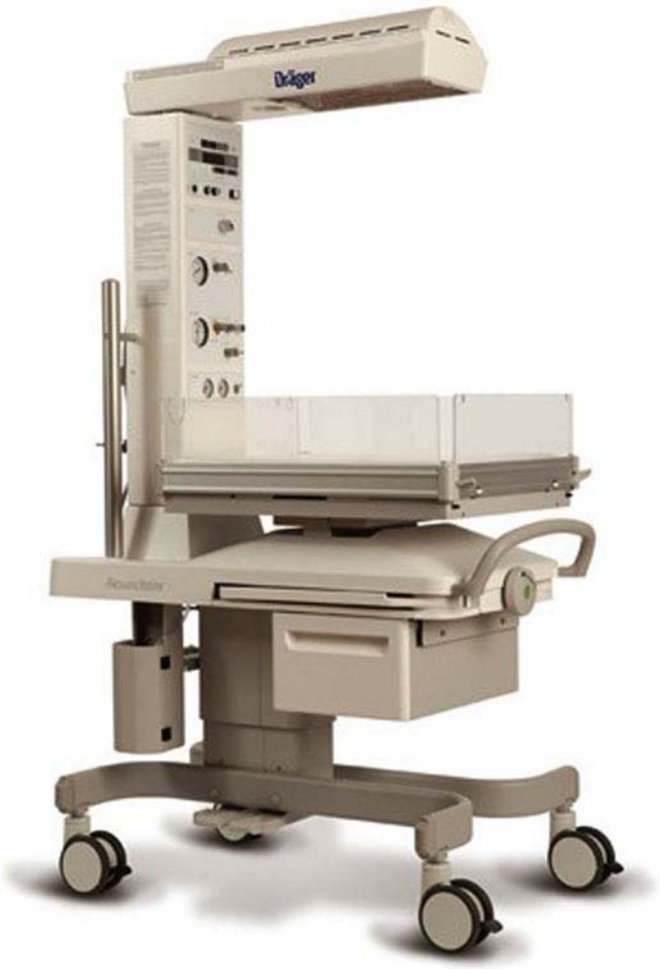

Figure 3–55. Infant care center.
(Reproduced by permission courtesy of Draeger Inc.)

Support structure

The support structure provides excellent stability for the radiant heater and optional accessories. The support structure consists of a weighted base assembly and uprights with an integral rail system. The rails provide a means for mounting accessories and ancillary equipment.

Heater assembly

The heater assembly, located above the center of the support structure, consists of a radiant heater, parabolic reflector, and an examination light. The parabolic reflector focuses the radiant energy from the heater toward the bed surface. This effect minimizes energy loss due to scattering and provides an even field of radiant heat over the bed surface. The examination light provides intense light for procedures. The entire heater assembly rotates 90 degrees to the side for X-ray purposes.

Control unit

The control unit contains all of the electronic circuits and controls used to operate the radiant heater and examination light. The electronic circuit uses integrated circuits for high reliability. The control unit also performs self-checks during its operation and has failure diagnostic capability.

The operator may select manual or servo mode of operation. In the manual mode, the operator selects the level of radiant heat output as indicated by the power percent display on the control panel. The control circuit then maintains the selected level of radiant heat. The manual mode has a preheat setting to allow the warmer to be preheated. In the servo mode of operation, the operator selects the baby's control temperature. A skin temperature probe is used to monitor the baby's skin temperature. The control system modulates the radiant heat to maintain the selected control temperature. The baby's skin temperature is continuously displayed.

Alarms activate to alert the operator of low or high skin temperature, skin temperature probe failure, power failure, or equipment failure.

Finally, the Apgar tones and indicator are activated when the timer is turned on. Apgar is nothing more than an assessment of the baby's condition after birth. The timer provides a tone at one minute, and then at five minute intervals after the elapsed timer has been started. This gives the nurse an auditory reminder that an assessment of the baby needs to be made.

Additional features

Some units have additional features and abilities as options above the standard setup. A built in scale is a common feature. This makes the infant care center a more inclusive unit, eliminating the need to move the infant from their controlled environment to another piece of equipment to weigh them. A built in under mount slot for x-ray film or digital detectors is also an option. This makes it easier to use spot film without having to lift the infant to place a detector under their body. More advanced units even integrate a resuscitation option into their setup, complete with a respiratory monitoring system, air and O_2 blender, bag and mask resuscitation accessories, as well as SpO_2 monitoring.

Operational inspection

It is important you use the manufacturer's literature for preventive maintenance and calibration requirements. The following list of checks is generic in nature:

1. Inspect the mechanical integrity of the housing, chassis, strain relief, line cord, AC plug, connectors, and fittings.
2. Check the circuit breaker for freedom of movement or verify the fuse is the correct size.
3. Inspect the mechanical integrity and operation of all switches and controls to ensure they are positioned properly for operation of the unit.
4. Inspect indicators, alarms, displays, interlocks, audible signals, meters, gauges, and lights for proper operation.
5. Inspect mechanical components for wear.
6. Verify warning labels and index tags are present and legible.
7. Clean the interior and exterior of the unit.
8. Verify the skin temperature alarm functions properly.
9. Verify the safety thermostat and high temperature alarm functions properly.
10. Check the accuracy of the temperature monitor; verify the temperature accuracy to ±0.3°C at 34° and 36°C.
11. Verify alarm accuracy, high and low, at ±0.5°C.
12. Check any pneumatic flow controls and blenders as applicable.
13. Perform an electrical safety inspection as required.

This piece of equipment is used when a healthy or noncritical baby is born. What happens when a premature baby is born and cannot survive our cold environment? We use an incubator to regulate environmental conditions.

234. Infant incubator

An infant incubator is a piece of equipment common to birthing centers and neonatal intensive care units. While the unit may serve several specific functions, it is generally used to provide a safe and stable environment for newborn infants, often those who were born prematurely or with an illness or disability that makes them especially vulnerable for the first several months of life.

Principles of operation

Incubators provide a fully temperature controlled environment, shielding infants from harmful cold, while providing insulation from outside noise. Incubator environments can be kept sterile, protecting infants from germs and minimizing the risk of infection. The enclosure also keeps out all airborne irritants like dust and other allergens.

The incubator controls temperature, humidity and oxygenation of the air. These units are equipped with heaters and temperature control systems. Neonatal patients have limited thermoregulatory ability and rely on external heat sources to maintain their core body temperature. Maintaining fluid and heat balance is of vital importance to a newborn infant. At birth the infant is exposed to a cold and dry environment, putting preterm neonates at risk of dehydration and hypothermia. Most units allow the user to vary humidity from either a built in reservoir or an outside source (e.g. a humidifier that attaches to one of the ports). An O_2 cylinder or external supply line also provide the required O_2 necessary for treatment of the infant.

Transport incubator

A transportable incubator is used by the professional staff as an intensive care isolation incubator, designed for intra-hospital or inter-hospital transportation via a mobile stand, ambulance, or aircraft for a critically ill newborn. The infant transport incubator provides total environmental control during these hospital transfers. Figure 3–56 shows a typical transport infant incubator.

Figure 3–56. Transport incubator.
(Reproduced by permission courtesy of Draeger Inc.)

We mentioned transport incubators are quite versatile and for a very important reason. The newborn critically ill infant may be born anywhere, anytime. Having a means of safe, rapid transport of the

infant to a larger well-equipped hospital is of vital importance. Since the method of transport varies from base to base, the transport incubator must be equipped to handle multiple power adaptations.

The transport incubator operates on 12 or 24 volts DC, or 115 volts AC at 50 or 60 Hz. Thus, the incubator may be operated off convenient DC sources in the transport vehicle or the accessory portable power-pak, as well as from any standard hospital or home AC power outlet. Some units are also designed for 220 volts, 50 Hz AC operation overseas.

Most transport incubators are equipped with access doors to allow access to the infant without opening the Plexiglas hood, which would expose the infant to ambient temperatures. A support board and mattress are used to give the infant rigid support. An IV stand is provided, which can be stored in the DOWN position and locked out of the way when not in use.

The heater assembly is removable for cleaning and servicing. The control panel contains all the necessary voltage selection buttons or dials, and some sort of variable temperature control. All units come equipped with power, heat, and high temperature illuminated indicator lights.

As with infant incubators, all transport incubators have some sort of safety thermostat that limits the incubator air temperature between 99° to 100°F.

The transport incubator also has a humidity chamber for increasing the desired humidity. This is achieved in some cases by a disposable sponge. Humidity can be increased in a range between 40 to 60 percent, which is considered a comfort range for 3 to 4 hours.

Various size O_2 cylinders are attached to the incubator body to provide a portable source of O_2. Most transport incubators you encounter can provide O_2 concentrations from 40 to 60 percent.

Ambient air is pulled into the transport incubator through micron filters, usually 0.5 micron. These filters are disposable, and you can replace them very easily.

The transport incubator is equipped with a self-sustaining power battery pak, which is usually charged during periods of non-use by an onboard 115 volt battery charger circuit.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

233. Infant care center

1. What is an infant care center designed to do?

2. What comprises the heater assembly?

3. Describe the two selectable modes of operation.

4. What reference source do you use for preventive maintenance and calibration procedures?

5. What is the temperature accuracy tolerance?

234. Infant incubator

1. What does the incubator control?

2. How is a transport incubator used?

3. List the various operating power capabilities of transport incubators.

4. Why is the heater assembly removable?

5. What is the limit range of air temperature in a transport incubator?

6. What is considered the humidity comfort range for newborns?

7. How is ambient air pulled into the transport incubator?

Answers to Self-Test Questions

214

1. Provide comfort to the patient and position the mouth so the dentist can comfortably see inside the mouth.
2. Adjustment capability for back tilt, seat lift, and rotation.
3. By pressing any of the other switches or the safety stop plate.
4. It takes the chair from the laid out position to the original entry position.
5. The base up function.
6. The articulating headrest allows the patient's head to be moved in a 60 degree arc; the horseshoe headrest maintains the head in a set position.
7. No.
8. Provides the basic utilities required for dental treatment including H_2O, compressed air, electricity, and vacuum.
9. Floor utility box.
10. The 3-way syringe, cuspidor, cup filler, and hand piece H_2O spray.
11. A large central air compressor.
12. Sediment in the air-lines, algae that can ruin precision hand pieces, and debris that can be ejected into the patient's mouth.
13. 80 – 100 psi.
14. The solids separator.

15. Disconnect one end of the hose and find the obstruction by massaging the hose. Massage the obstruction toward the open end of the hose.
16. HVE is used to remove the H_2O spray from the hand pieces and the three-way syringe from the patient's mouth. The saliva ejector is good for the removal of small amounts of liquid, such as saliva.
17. (1) Hand piece.
    (2) Foot controls.
18. Water coolant on/off toggle.
19. Shuts off air and H_2O to the hand piece when it is in the holder.
20. Arm brake toggle.
21. Through the use of a foot controller.
22. To remove debris from the treatment site by sending a blast of air through the hand piece when it is not running.
23. Control tubing and main valve.
24. (1) Ceiling track.
    (2) Wall.
    (3) Dental chair.
25. (1) Transformer and rigid arm.
    (2) Flex arm.
    (3) Light head.
26. Spring tension.
27. Gently clean it with cotton soaked in ethyl alcohol.
28. Soft lint free cloth and isopropyl alcohol.
29. Scratch marks, discoloration, peeling reflector material, or cracks within the reflector surface.

215

1. High frequency sound waves fracture deposits from the teeth and cavitate the H_2O to flush the area.
2. 30,000 cycles per second vs. 16,000 – 18,000; elliptical.
3. Control box, foot control, H_2O connector, and hand piece and cable assembly.
4. Clears stagnant H_2O and associated contaminants.
5. To prevent overheating of the hand piece.
6. The H_2O will burst forth from the tip in a halo of fine mist.
7. Cavitation activity, heat, and acoustic streaming.
8. On patients with amalgam restorations, pacemakers, tuberculosis, or hepatitis.
9. Filter out a large percentage of airborne contaminants.

216

1. Designed solely for firing or fusing the porcelain in crowns and fixed partial denture work.
2. Drive out all the moisture.
3. 28 – 30 pounds.
4. For wax elimination, preheating, and heat treatment of the dental cast used for the creation of dental appliances.
5. Potential fire hazard.
6. Burnout of removable partial denture framework molds.
7. It will activate the oven, maintain a predetermined maximum burnout temperature for a specified time period, and deactivate the oven after the programmed burnout time has elapsed.
8. To cast molten metals.
9. Centrifugal force.
10. Weaken or break the spring.

11. Shell blaster is used to remove gypsum products from resin prosthesis during the deflasking operation; the sand blaster is used in cast removable partial denture work, or to remove casting investment and surface oxides from the metal framework.
12. Acrylic or porcelain.
13. Rubber gloves.
14. 90 – 100 psi.
15. To operate the straight hand piece assembly, which, in turn, is used to trim the acrylic and teeth.
16. Series-wound electric motor.
17. Reversing current flow in the field windings or armature.
18. Grinding, finishing, and polishing procedures.
19. Draw smoothing and polishing agents away from the operator.
20. Low-speed polishing of cast removable partial frameworks, polishing gold, fixed partial dentures, and for all types of acrylic resin restorations.
21. Extremely hard chrome alloy metals.
22. Gold.

217

1. Conversion.
2. Sound.
3. Ultrasound.
4. Differences in frequency.
5. 0.8 – 1 MHz.
6. (1) Power supply.
   (2) Oscillating.
   (3) Transducer.
7. Transducer.
8. ½ – 1″ away from the skin.
9. Irregular surfaces and bony prominences.
10. (1) Temperature obtained in the tissues.
    (2) Duration of the temperature elevation.
    (3) Rate of temperature rise within tissues.
11. (1) Joint capsules.
    (2) Ligaments.
    (3) Tendons.
12. Any three of the following: increased tissue temperature; increased tissue metabolism; increased blood flow; increased clearing of metabolites and heat; increased supply of O_2, nutrients, antibodies, and leukocytes; analgesia; and phagocytosis. One of the following: sedation, increased cardiac output, and increased pulmonary ventilation.
13. Eyes, ischemic areas, malignancies, pregnant uterus, or a patient with predisposition to hemorrhagic disease.
14. Wrap a piece of 1″ adhesive or masking tape around the front edge of the transducer to form a cup; with the transducer head in the inverted and vertical position, pour approximately ¼″ of H_2O into the cup formed by the tape; operate the machine in the normal manner, slowly increasing the intensity control from zero to maximum output; and, as the intensity is advanced, the H_2O forms a small cone (at full output, it forms a sharp peak and shows violent agitation).
15. The test can also be performed in a tank of H_2O of sufficient depth to accommodate the transducer, with the transducer free in a horizontal position, about ¼″ below the surface.
16. (1) Remove the transducer and cable assembly, and X-ray it.
    (2) Swap out the transducer and cable assembly; then, verify operation.

17. Up to 30 Watts.
18. Degassed water.
19. More than 5–10 parts per million (PPM) of air.
20. 24.0 ±3.0°C (75.2 ±5.4 °F).

218

1. Transmits an electrical impulse, which mimics the action of the central nervous system.
2. The level of muscular function and response to treatment.
3. The amount of time it takes the unit in each cycle to reach maximum intensity.
4. The difference is in their functions. TENS therapy uses electric current to stimulate nerves, while the NMES stimulates the muscles. The output waveforms are also different.
5. As a form of both muscle training and electrotherapy, NMES are a treatment modality for disuse muscle atrophy due to a condition such as limb casting or hip replacement surgery, where the nerve supply to the muscle is intact.
6. Prescription and over-the-counter.
7. They are used as "pain blockers." The buzzing sensation is thought to block the pain signal from the nerve to where it is perceived in the brain as pain. TENS units are also thought to aid in the release of endorphins, which are the body's natural pain fighting mechanism. These devices serve as a form of pain management as well as for prevention of muscle atrophy, and help strengthen muscles, maintain or gain range of motion, and temporarily reduce spasticity.

219

1. The development of tachycardia, vasoconstriction, an increase in systemic vascular resistance, or peripheral shunting of blood away from the kidneys and lower extremities.
2. Proximally or distally.
3. (1) Weighted bellows.
   (2) Spring loaded bellows.
   (3) Non-linear driven piston.
   (4) Linear driven piston.
   (5) Pressure-reducing valves (PRV).
   (6) Blowers.
   (7) Injectors.
4. To increase the overall flow rate capability of the ventilator.
5. When the natural breathing frequency must be exceeded with small tidal volumes.
6. (1) HFOV.
   (2) HFJV.

220

1. (1) Initiation of inspiratory phase.
   (2) Inspiratory phase.
   (3) Changeover from inspiration to expiratory phase.
   (4) Expiratory phase.
2. (1) Patient cycling.
   (2) Time cycling.
   (3) Manual cycling.
3. Move the gas into the lungs.
4. (1) A pressure generator is a ventilator that generates a fixed pattern of pressure at the mouth regardless of lung conditions, while the flow waveform is free to vary.
   (2) A flow generator is a ventilator that generates a fixed pattern of flow regardless of the lung conditions, while the mouth pressure waveform is free to vary.

5. (1) Pressure cycling.
   (2) Flow cycling.
   (3) Volume cycling.
   (4) Time cycling.
6. Entirely on the level of pressure generated by the drive mechanism and the patient's lung characteristics.
7. Allow the lungs to empty.
8. (1) PEEP maintains positive pressure in the lungs throughout the respiratory cycle during controlled ventilation.
   (2) CPAP maintains positive pressure in the lungs during spontaneous ventilation, and lung pressure never reaches atmospheric pressure.
   (3) EPAP therapy allows positive pressure to be maintained in the lungs during exhalation only.
   (4) With IMV and PEEP, positive pressure is maintained in the lungs and the patient receives controlled breaths intermittently between spontaneous breaths.
9. (1) Sustain life when a surgical procedure or patient condition depresses or paralyzes the respiratory system.
   (2) Help sustain respiration when a condition hinders a patient's ability to breathe fully on their own.
10. Static flows or ventilator waveforms.
11. 8 to 18 pounds per square inch absolute (PSIA).
12. Determine the various phases of a ventilator breath and calculate the parameter.
13. The analyzer is passive while the tester is active.

221

1. Local and general.
2. By novocaine or procaine injections into the area you want to anesthetize. Ethyl chloride or the application of cracked ice is also a form of local anesthesia.
3. (1) The first stage is the period that extends from the beginning to the point of loss of consciousness; it is also called analgesia.
   (2) The second stage is the dream stage of anesthesia; it is also referred to as the state of delirium.
   (3) The third stage is characterized by regular automatic breathing; it is referred to as the surgical stage.
   (4) The fourth stage represents the period beginning with central respiratory paralysis, and ending with cardiac failure and death.
4. Prolonged depression in this stage may cause circulatory collapse.

222

1. A color coding system was designed so medical gases could be identified immediately by the external color of the cylinder. The PISS was designed to prevent accidental interchange of medical gas cylinders. The system is built around the matching of pins and holes.
2. O_2.
3. It regulates the high pressure inlet gas coming from the cylinders to a safe operational pressure of 50 psi.
4. To prevent the flow of all gases to the patient if the unit loses O_2 supply.
5. To control the rate of evaporation of a given liquid anesthetic and introduce a precise volume percentage of that anesthetic vapor into the carrier gas stream.
6. An exclusion or lock-out system.
7. Usually located on the inspiratory valve.
8. In manual, the expired gas fills the breathing bag. When the patient needs to inspire again, the breathing bag is squeezed. Automatic, adds the bellows assembly to the circuit, while eliminating the breathing bag and APL valve. The bellows expands and contracts for patient-assisted breathing.

9. (1) Exhaust hose from the pop-off or APL valve or ventilator.
   (2) Interface.
   (3) Gas disposal tube or hose.
   (4) Exit mechanism for the gas from the operating room.
10. For safety reasons. If a leak develops within the anesthesia system, you could be rendered unconscious before anyone finds you. A buddy is there for assistance.
11. The O_2 flush valve is used to provide pure O_2 to the patient during a procedure. It is not a normally operated valve and must be selected by the anesthesiologist.

223

1. When the monitoring of respiratory gases is critical.
2. In the "y."
3. Tubing, filters, and O-rings.
4. (1) Sevoflurane.
   (2) Isoflurane.
   (3) Desflurane.
   (4) Halothane.
5. To provide a distributed solution that permits comprehensive data management for the anesthetist. These systems capture and manage anesthesia vital signs information in the operating room (OR) environment.
6. Update the domain service accounts, local service accounts, application accounts, third party application accounts, and verify that the system is fully functional.

224

1. 500 kHz to 4 MHz.
2. (1) The active electrode is small and used for cutting and coagulating.
   (2) The dispersive electrode uses the patient as part of the circuit, and provides the ground or return of the active electrode.
3. To prevent accidental burning of the patient's surrounding tissues.
4. Burns may appear on the body.
5. An increase of voltage is necessary.
6. To arrest bleeding by closing off blood vessels.
7. Continuous unmodulated sine wave to lightly modulated sine wave.

225

1. To verify the performance of an electrosurgical unit.
2. (1) Manual.
   (2) Auto.
3. Generator output and RF leakage.
4. (1) Peak-to-peak voltage.
   (2) Crest factor.
   (3) Current.
   (4) Power.
5. Return fault test.

226

1. Are simple, familiar, and readily available, and require no power and electrical safety checks, and few, if any, in-service training sessions.
2. Need frequent adjustments to maintain steady flow rate; are restricted in the ranges of flow rates attainable; and medication administration over a period of time is difficult to achieve.

3. Able to infuse large volumes of fluid with alarms for problems; can be used with any type IV solution container; reduce complications; and can deliver precise amounts of prescribed fluids.
4. High cost (initial and continuing).
5. (1) Hyperalimentation.
   (2) Drug therapy.
6. Because the fluid is infused directly into the blood stream.

227

1. Volumetric, peristaltic, motorized syringe, or drop-counting.
2. mL per hour, mmHg, and psi.
3. (1) Instantaneous flow rate accuracy.
   (2) Average flow rate accuracy.
   (3) Delivered volume accuracy.
   (4) Occlusion.
4. Occlusion.
5. Deionized H_2O.
6. By injecting 20 mL of detergent into the unit, and then flushing it out with deionized H_2O after 30 minutes.

228

1. Maintain normal temperature in patients during and after surgery; decrease and stabilize body temperature of febrile patients; and elevate the body temperature of victims of accidental hypothermia.
2. By the thermotaxic nerve mechanism that maintains a balance between the thermogenetic and thermolytic processes.
3. 41° C.
4. Conductive loss, convective loss, evaporative loss, and radiative loss.
5. 35° C.
6. Relieve pain, relax muscles, promote healing, and reduce tissue swelling.
7. Blood vessels have a tendency to constrict or narrow. Blood flow decreases when vessels are constricted, thus reducing the amount of blood available to the tissues.
8. Reduce pain, reduce swelling, decrease circulation, and cool the body when fever is present.
9. Pain, burns, blisters, and cyanosis.
10. Manual, automatic, or patient temperature monitoring.

229

1. When the heart stops or when arrhythmias prevent adequate blood circulation.
2. Ventricular fibrillation; the cardiac ventricles exhibit uncoordinated, random contractions, emanating simultaneously from multiple areas of the muscle tissue.
3. Restoration of normal cardiac rhythm.
4. They required several successive attempts of defibrillation before correcting ventricular fibrillation, and atrial fibrillation cannot be successfully treated by AC defibrillation.
5. Internally, in the milliampere range; externally, approximately 20 to 30 amperes.
6. Actual delivered energy.
7. In sync with the patient’s natural EKG during the down stroke of the R-wave of the QRS complex.

230

1. Watts seconds/joules.
2. Low range, 2–50 joules; high range, 100–360 joules.
3. 50 to 1500 ohms with a current range of 4 to 250 mA.
4. Defibrillator energy levels, maximum energy, cardioversion, EKG performance, and pacemaker.

231

1. (1) Monochromatic light; one specific wavelength, or color.
   (2) Coherent light; photons launch in unison and have a definite phase relation to each other. This means the wavelengths of the laser light are in phase in space and time.
   (3) Directional; a very tight, strong and concentrated beam
2. By the type of lasing material, or medium, that they employ.
3. Optical chamber, laser pump, cooling system, and aiming laser.
4. Heat; the cooling system removes the heat from the optical chamber allowing continuous use of the system.
5. The aiming laser is used to identify the treatment area of the higher energy laser produced in the optical chamber.
6. 5 to 499 mW.
7. The smoke is able to carry bacteria and viruses. In addition, smoke from treatment can leave a film on exposed optics of the laser system. This film will generate heat when exposed to laser light and will cause pitting and reduction of power output, damaging the laser.
8. Integral power meters that indicate power output at the laser head and tissue site; safety interlocks that turn off the laser or block the laser beam with a shutter when the laser system is engaged incompletely; a remote interlock feature that locks the laser room during lazing or turns off the laser if the door is opened; a removable key to prevent unauthorized operation; and a visual and audible alarm signaling laser beam emission.

232

1. Controllable transfer of solutes and H_2O across a semipermeable membrane separating flowing blood and dialysate streams.
2. (1) Blood compartment.
   (2) Membrane.
   (3) Dialysate compartment.
3. (1) Coil.
   (2) Parallel plate.
   (3) Hollow fiber.
4. Hollow fiber.
5. The process of H_2O removal from the bloodstream.
6. The hydraulic permeability of the membranes, membrane area, and dialysate flow.
7. (1) High-flux dialysis.
   (2) High-efficiency dialysis.
   (3) High-flux hemodiafiltration.
8. The flow path from the patient to the dialyzer inlet is the arterial line; the flow path from the dialyzer back to the patient is the venous blood line.
9. To achieve adequate and consistent blood flow through the dialyzer.
10. They provide a site for collection and evacuation of any air introduced into the blood path flow, and permit measurement of blood flow path pressures in air rather than liquid.
11. The air bubble detector.
12. Filters; the value of the filters is suspect because many people believe they create a thrombus.
13. To provide on-line proportioning of H_2O with dialysate concentrates; monitor dialysate temperature, composition, and blood leaks; control dialysate pressure or ultrafiltration rate; and regulate dialysate flow through the dialyzer.
14. Use of an air compressor; attached compressed air; nitrogen or Freon canisters; a central compressed air supply; or a simple hand pump.
15. A safety pressure relief valve.

16. To prevent venous oozing without obstructing the arterial blood supply; provide a clear field on which to work; stabilize accident victims; improve acute pulmonary edema; help decongest the lungs; and reduce dome of the strain on the heart.
17. The pressure is released every 12 to 15 minutes; to prevent excessive nerve damage to the area beneath the cuff, and prevent gangrene and other complications.
18. For the treatment and prevention of circulatory conditions such as DVT and PE.
19 It can cause a potentially life threatening condition called Pulmonary Embolism.
20. Intermittent compression to the lower extremities to promote venous return and to help prevent DVT. It mimics the contraction of the calf during walking to keep the blood moving and help to prevent it from clotting.
21. A system designed to warm blood, irrigation fluids, and IV fluids.
22. From keep vein open (KVO) to 500 mL per minute.

233

1. Supply constant, automatically controlled heat; deliver O_2 at high or low concentrations; and provide a means to monitor the child's temperature.
2. A radiant heater, parabolic reflector, and an examination light.
3. (1) In manual, the operator selects the level of radiant heat output and the control circuitry maintains it at that level.
   (2) In servo, the operator selects the baby's control temperature and the unit modulates the heat to maintain the desired temperature.
4. The manufacturer's literature.
5. ±0.3° C at 34° and 36° C.

234

1. Temperature, humidity and oxygenation of the air.
2. As an intensive care isolation incubator for intra-hospital or inter-hospital transportation via a mobile stand, ambulance, or aircraft for a critically ill newborn.
3. 12 or 24 volts DC; 115 volts AC at 50 or 60 Hz; and 220 volts AC at 50 Hz.
4. For cleaning and servicing.
5. 99° to 100° F.
6. 40 to 60 percent for 3 or 4 hours.
7. Through micron filters, usually 0.5 micron.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to AFCDA.

37. (214) What controls continue to function on the dental chair once the safety stop plate is activated?
    a. Back up.
    b. Base up.
    c. Seat up.
    d. None.

38. (214) Water enters the dental unit via
    a. a floor utility center.
    b. a hose from the sink.
    c. floor mounted plumbing.
    d. cabinet mounted water lines.

39. (214) *Most* hand pieces on the dental unit operate on air pressure within the range of
    a. 40 – 100 pounds per square inch (psi).
    b. 20 – 100 psi.
    c. 40 – 80 psi.
    d. 20 – 80 psi.

40. (214) To adjust pressure on the dental unit, first adjust the
    a. air pressure, turning the pre-regulator knob clockwise to decrease, or counter clockwise to increase pressure.
    b. air pressure, turning the pre-regulator knob clockwise to increase, or counter clockwise to decrease pressure.
    c. water pressure, turning the pre-regulator knob clockwise to decrease, or counter clockwise to increase pressure.
    d. water pressure, turning the pre-regulator knob clockwise to increase, or counterclockwise to decrease pressure.

41. (214) Which item turns on the air and water to the control system of the dental unit?
    a. Master On/Off switch.
    b. Hand piece control.
    c. On/Off indicator.
    d. Foot control.

42. (214) To adjust the air and water flow from the three-way syringe on the dental unit, you use the
    a. drive air pressure and syringe flow controls.
    b. drive air pressure and water flow controls.
    c. water and coolant flow controls.
    d. syringe flow controls.

43. (214) Which item on the dental unit is used as a safety precaution to control drive air and coolant whenever burs are being replaced or removed?
    a. Automatic hand piece holder.
    b. Water coolant On/Off toggle.
    c. Hand piece lock-out toggle.
    d. Master On/Off toggle.

44. (214) What is *not* a proper procedure to clean the inside reflector surface of the dental light?
    a. Use a soft lint-free cloth dampened with isopropyl alcohol.
    b. Do not rub heavily or clean the reflector when it is hot.
    c. Use water or any water-based cleaning solution.
    d. Wipe the surface in one direction only.

45. (215) The tip on an ultrasonic scaler vibrates at how many cycles per second?
    a. 16,000.
    b. 18,000.
    c. 22,000.
    d. 30,000.

46. (216) The method used to force molten metal into a mold while using a dental casting machine is
    a. induction.
    b. conduction.
    c. centrifugal force.
    d. gravitational force.

47. (216) A dental shell blaster is used to remove
    a. wax from prosthesis.
    b. gold from prosthesis.
    c. gypsum from prosthesis.
    d. porcelain from prosthesis.

48. (216) The dental bench engine has what type of motor?
    a. Shunt.
    b. Induction.
    c. Compound.
    d. Series-wound.

49. (216) The high-speed lathe should *not* be used to polish
    a. gold.
    b. ticonium.
    c. chrome alloy.
    d. hard metal alloys.

50. (217) How long is ultrasound *typically* applied to the patient during therapeutic treatment?
    a. 3 – 10 minutes.
    b. 5 – 15 minutes.
    c. 8 – 20 minutes.
    d. No specific duration.

51. (217) The radiant power of an ultrasound wattmeter is directly proportional to
    a. voltage applied to the target.
    b. frequency range of the transducer used.
    c. the amount of time therapy is administered.
    d. the total downward force (weight) on the target.

52. (218) Which is *not* a function of a neuromuscular electrical stimulation (NMES) unit?
    a. Re-educating muscles and regaining muscle memory.
    b. Increasing or maintaining range of motion.
    c. Blocking pain signals from the nerves.
    d. Preventing venous thrombosis.

53. (219) What drive mechanism is *most* popular and is used extensively in microprocessor-controlled ventilators?
    a. Venturis.
    b. Weighted bellows.
    c. Linear-driven pistons.
    d. Pressure-reducing valves.

54. (220) During what breathing phase does the ventilator allow gas to move *into* the lungs?
    a. Expiratory.
    b. Inspiratory.
    c. Initiation of the inspiratory.
    d. Changeover from the inspiratory to the expiratory phase.

55. (220) Which is *not* a type of constant positive pressure generator used in modern ventilators?
    a. Continuous positive airway pressure (CPAP).
    b. Expiratory positive airway pressure (EPAP).
    c. Intermittent mandatory ventilation (IMV).
    d. Zero end-expiratory pressure (ZEEP).

56. (221) What type of anesthesia affects the body's *entire* sensory system?
    a. Local.
    b. Topical.
    c. General.
    d. Surgical.

57. (222) Oxygen, helium, carbon dioxide, and nitrous oxide are considered to be
    a. support gases.
    b. unusable gases.
    c. anesthetic gases.
    d. flammable gases.

58. (222) What is the *main* function of a vaporizer on an anesthesia unit?
    a. Control the humidity of the air.
    b. Shut down the system when oxygen is not present.
    c. Control the rate of evaporation of liquid anesthetic.
    d. Regulate the amount of support gas delivered to the patient.

59. (222) What is the *most* complex part of the scavenging system on an anesthesia machine?
    a. Exhaust hose from the pop-off or automatic pressure limiter valve.
    b. Exit mechanism for the gas from the operating room.
    c. Gas disposal tube or hose.
    d. Interface.

60. (223) What is the function of a multigas monitor?
    a. Eliminate the need for an oxygen monitor.
    b. Monitor carbon dioxide and oxygen.
    c. Monitor nitrous oxide and oxygen.
    d. Monitor respiratory gases.

61. (223) The multigas monitor's sensor is usually mounted in the
    a. "Y" of the patient breathing circuit.
    b. inspiratory valve.
    c. expiratory valve.
    d. vaporizer.

62. (223) Which is *not* a gas measured by an anesthetic gas analyzer?
    a. Oxygen.
    b. Isoflurane.
    c. Sevoflurane.
    d. Carbon dioxide.

63. (224) What is the frequency range of a *typical* electrosurgical unit that cuts and coagulates?
    a. 500 kilohertz (kHz) to 4 megahertz (MHz).
    b. 400 kHz to 5 MHz.
    c. 5 kHz to 400 MHz.
    d. 4 kHz to 500 MHz.

64. (224) During electrosurgery, what is used to *decrease* the likelihood of burns to the patient?
    a. Larger patient plate.
    b. Ultrasonic gel or paste.
    c. Electroconductive gel or paste.
    d. Smaller cross section of an active electrode.

65. (225) What are the two *main* modes of operation on an electrosurgical analyzer?
    a. Auto and utility.
    b. Manual and auto.
    c. Auto and auxiliary.
    d. Manual and auxiliary.

66. (225) Current flowing from the active electrode to ground when activating the electrosurgical unit (ESU) output is known as
    a. Radio-frequency leakage.
    b. crest factor (CF).
    c. lead to lead current.
    d. patient return current.

67. (226) Besides gravity feed, what are the other categories of infusion devices?
    a. Pump and controller.
    b. Pump and drip sensor.
    c. Injector and controller.
    d. Injector and drip sensor.

68. (226) Besides drug therapy, controllers and infusion pumps are used *primarily* for
    a. hyperacidaminuria.
    b. hyperalimentation.
    c. hyperalonemia.
    d. hyperalgesia.

69. (227) Which infusion pump analyzer measurement is achieved by taking the average flow rate value and multiplying it with the total test time?
    a. Instantaneous flow rate accuracy.
    b. Average flow rate accuracy.
    c. Delivered volume accuracy.
    d. Average volume accuracy.

70. (227) What fluid is used in the infusion pump analyzer to test infusion devices?
    a. Oil.
    b. Water.
    c. Detergent.
    d. Deionized water.

71. (227) What is the *minimum* amount of air and water pushed through the analyzer to prime it before testing?
    a. 5 milliliters (mL) of air, 5 mL of water.
    b. 10 mL of air, 5 mL of water.
    c. 20 mL of air, 3 mL of water.
    d. 30 mL of air, 10 mL of water.

72. (228) What is the core temperature of a healthy person?
    a. 33° C.
    b. 35° C.
    c. 37° C.
    d. 39° C.

73. (228) What is the *minimum* body temperature at which heat stroke and death are common?
    a. 39° C.
    b. 41° C.
    c. 43° C.
    d. 45° C.

74. (228) Invasive methods of raising a patient's body temperature are used *only* for
    a. severe hyperthermia.
    b. severe hypothermia.
    c. hyperthermia.
    d. hypothermia.

75. (229) What type of output is delivered by modern defibrillators?
    a. Alternating current (AC), single pulse.
    b. Direct current (DC), single pulse.
    c. AC, 60 Hz.
    d. DC, 60 Hz.

76. (230) What item contains the loads used for specific defibrillators?
    a. Contact plates.
    b. Internal paddles.
    c. Adapter modules.
    d. Electrocardiogram leads.

77. (230) Which test is designed to measure the defibrillator's capability of synchronizing a discharge of its output pulse?
    a. Energy.
    b. Cardioversion.
    c. Maximum energy.
    d. Electrocardiogram.

78. (231) Which is not a property of laser light?
    a. Monochromatic.
    b. Bichromatic.
    c. Directional.
    d. Coherent.

79. (231) Which component of a laser contains the optical resonators?
    a. Aiming laser.
    b. Optical chamber.
    c. Excitation system.
    d. Yttrium-aluminum garnet (YAG) rod.

80. (231) What is a *major* byproduct of laser energy conversion?
    a. Heat.
    b. Smoke.
    c. Foul smell.
    d. Negative ions.

81. (232) What is *not* taken into consideration for the ultrafiltration coefficient?
    a. Hydraulic permeability of the membranes.
    b. Membrane area.
    c. Dialysate flow.
    d. Blood volume.

82. (232) The dialyzer component that shuts down the blood pump if air is detected in the line is the air
    a. bubble chamber.
    b. bubble detector.
    c. drip chamber.
    d. drip detector.

83. (232) What is *not* used to inflate pneumatic tourniquets?
    a. Air supply.
    b. Hand pump.
    c. Compressed oxygen.
    d. Compressed nitrogen.

84. (232) The pressure should be released on a tourniquet every
    a. 8 – 10 minutes.
    b. 10 – 12 minutes.
    c. 12 – 15 minutes.
    d. 15 – 18 minutes.

85. (232) What temperature is the control point *usually* set on a blood fluid warmer?
    a. 45° C.
    b. 42° C.
    c. 38° C.
    d. 35° C.

86. (233) You *must* verify the temperature accuracy of the temperature monitor on the infant care center to
    a. ±0.3° at 34° and 36° C.
    b. ±0.1° at 34° and 36° C.
    c. ±3° C.
    d. ±1° C.

87. (234) What piece of equipment provides total environmental control for a premature newborn during hospital transfers?
    a. Infant incubator.
    b. Infant care center.
    c. Infant transport incubator.
    d. Infant transport care center.

Please read the unit menu for unit 4 and continue ➔

Unit 4. Therapeutic Support Equipment

THERE ARE SEVERAL AREAS within the medical treatment facility that provide much needed support to the clinics. They contribute to a professional health care environment, and work behind the scenes of direct patient care. This unit discusses therapeutic equipment support functions such as central sterile supply (CSS) and other miscellaneous support equipment.

CSS is the silent, but essential support area. It cleans, disinfects, sterilizes and assembles kits for surgery and inpatient care. Each gown, instrument, and surface a patient comes in contact with has had some type of sterilization process. This is the first area we will cover.

The second area we will cover is the miscellaneous therapeutic support equipment including water purification equipment, suction units, and refrigeration systems.

4–1. Central Sterile Supply

CSS is usually located in the bowels of a medical treatment facility. Most patients aren't even aware it exists, but without it, the patient may be exposed to harmful infections. CSS is also known by other names such as sterile processing department (SPD) and a few others, but its purpose is the same—using its expertise and knowledge of sterilization and disinfection to ensure high standards of cleanliness.

These high standards are applied particularly to surgical instruments—their cleaning and disinfection. This section discusses some of those processes and the equipment utilized.

235. Ultrasonic cleaner

Dirty instruments are collected from the wards and surgery by a CSS technician. These contaminated and dirty utensils come to CSS, and a technician immediately logs them in and prepares them for cleaning. These instruments are either cleaned manually or mechanically. Manual cleaning is the simple concept of a person cleaning by hand, so we will focus this lesson on the mechanical aspect. There are three acceptable ways instruments are mechanically cleaned—washing machine, washer/disinfector (discussed in the next lesson), and ultrasonic cleaner.

This ultrasonicator is a sophisticated, expensive, extremely efficient piece of equipment. It uses high-power output to dislodge all organic matter. This piece of equipment generates many of your calls in the CSS. Let's talk about how it works.

Principles of operation

You may recall ultrasonic energy consists of sound waves at frequencies above those detectable by the human ear. For most standard ultrasonic cleaning applications, the frequency range is 20 – 40 kHz. The cleaning action consists of high-powered acoustical energy applied to solid objects immersed in a light-viscosity liquid. Fine bubbles develop in the liquid and drive into the solid objects where they implode, loosening foreign matter or dirt. The formation of these fine bubbles in a liquid is known as cavitation. Electrical energy, produced by an electronic oscillator, is coupled to a transducer. The transducer, which is physically attached to the tank, converts that energy to a periodic

mechanical vibration. Since the bubbles produced are extremely fine (microscopic), they find their way into tiny crevices in glassware and instruments not accessible by conventional cleaning methods.

At the onset of cavitation, the gas nuclei vary in size, depending upon the surface tension of the liquid, temperature, wetting action of the detergent, and frequency of the applied ultrasonic energy. The implosion (bursting inward) we talked about generates minute vacuum areas that are responsible for the cleaning process. The forces of cavitation initiate at the instant of implosion, and the binder or matrix that causes adherence of the soil to the instrument surface is dislodged, dispersed, or dissolved. Soluble binders go into solution in the bath water and the heavier insolubles settle to the bottom of the cleaning tank.

The optimum bath temperature for cleaning surgical instruments soiled with blood and tissue debris is 80° – 110º F (27° – 44º C). If the temperature rises above 140º F (60º C), protein coagulates and is more difficult to remove. Coagulated protein absorbs sound waves, thereby reducing its effective action. Controlling the bath temperature to forestall coagulation is the most effective removal of proteinaceous soil.

If excess gas is present in the cleaning water, it decreases cleaning efficiency because the cavitation bubbles fill with gas and the energy released during implosion reduces due to the “cushioning” effect. Water is readily degassed by applying ultrasonic energy to the cleaning bath. However, there is no definitive time for degassing other than to state that tap water requires degassing for not less than 5 minutes each time it is changed. In addition, conditions arise where degassing is not required, such as water held in a dormant state overnight.

Clinical application

Ultrasonic cleaners decontaminate and remove foreign matter from glassware and surgical instruments. It removes protein soil and destroys pathogenic micro-organisms that might otherwise be shielded by protein soil. This process, in turn, reduces post-operative infection and cross-contamination between patients.

236. Washer/disinfector

The washer/disinfector is another method of mechanical cleaning prior to sterilization. Let’s go over its intended uses and functions.

Clinical application

Historically, instrument washers were developed from commercial dishwasher technology and adapted to today’s science-based requirement designed to increase throughput and consistency. Washer/disinfectors, also called washer/decontaminators, clean instruments and utensils by removing blood, bone, fat, and other organic debris that can adhere to surfaces and crevices, which provide a substrate for growth of microorganisms. These substances are sometimes difficult to remove, especially when dry or in hard-to-reach areas. Washer/disinfectors are often used as an adjunct to manual cleaning of surgical instruments, which typically involves use of a soft-bristle brush to remove deposits remaining after a presoak period to reduce the biohazard risk to central supply or other healthcare workers. Use of washer/disinfectors may reduce staff exposure to risky manual cleaning of soiled instruments and ensure that cleaning is done in a consistent manner. After decontamination, the technician arranges the instruments in packs for final sterilization. Washer/disinfectors differ from washer/sterilizers in that they do not have a steam sterilization cycle.

Cart washers, large-scale washers, clean and disinfect case carts and large items such as plastic crates, containers and lids, toilet seats, and wheelchairs. Carts are noncritical devices; however, they transport a wide variety of medical devices and may accumulate organic debris on the surface as a result. Most washer/disinfectors are not designed to accommodate carts so a dedicated cart washer is often included in a facility’s SPD.

Principles of operation

A washer/disinfector consists of one or more corrosion-resistant chambers that are freestanding, recessed in a wall, or installed between walls (pass-through or tunnel washers that load on one side of a wall and unload on the other). The pass-through configuration keeps contaminated material away from clean areas where instruments are packed before final sterilization. The doors are typically counterbalanced front opening, either hinged at the bottom of the door or a vertical sliding method. Cart washers are structurally similar to washer disinfectors and offer many of the same configuration options; additionally, some cart washers can mount in a pit.

In shelved washer/disinfectors, decontamination begins when wire mesh stainless steel baskets containing soiled materials load manually or automatically onto racks in the wash chamber. Most surgical case carts can easily roll into the facility's cart washer, which lacks racks or shelves to accommodate carts of varying sizes. The washing action typically consists of high-pressure jet-spraying water or a water/detergent mixture through several manifold inlets above, below, and at the sides of the racks or from inlets in rotary spray arms. Most units feature a number of selected wash, rinse, and drying cycles. The rinse cycle can use either distilled or deionized water (distilled water is vaporized and then condensed in a separate container; deionized water is passed through an ion-exchange resin) and is followed by heated forced-air drying. Some units also have ultrasonic cleaning and lubricating rinse cycles. Ultrasonic cleaning can help to remove soil and residues from hard-to-reach areas.

The devices to be cleaned are commonly rinsed in cool or tepid water to prevent proteinaceous material from baking on before the water temperature is increased to wash temperature. Most manufacturers can provide units designed for either steam or electric water heating with selectable water temperature and automatic detergent dispensing. Single-chamber washers typically wash, rinse, and dry the instruments or carts in the same chamber; in most, the user can elect to reuse or drain the rinse water between cycles. In multi-chamber units, the devices automatically pass into the next chamber for subsequent processing. Some models also have detectors that calculate and allot the minimum amount of water, detergent, and cycle time needed to process the load.

Some units have an automatic loading feature to minimize the need for operator attention and help reduce staff injuries associated with moving heavy loads. Several units also have automatic unloading, further reducing handling times. In addition, most vendors offer a conveyor system to further automate the process.

Power tilt is a feature present on larger cart washers that tilts the floor of the washer to encourage better water drainage prior to the drying cycle. If a washer does not have power tilt, the operator may position the cart on a tilt to simulate the effect.

Washer/disinfectors and cart washers have either electromechanical or microprocessor controls and can usually provide the user with a record that consists of a chart or printed copy of wash/rinse cycle parameters such as temperature, time, alarms, and detergent concentration.

Safety features

Safety features often include audible alarms, visual indicators of alarm conditions such as "door ajar" or "low water temperature," emergency stop buttons or cables, and a safety interlock switch to stop all machine action if the door opens during operation. The units have a safety lockout feature so the cycle cannot start unless the door is fully closed. A door interlock feature (power double doors only) helps to prevent cross-contamination in a double door unit. This feature allows only one door to open at a time whenever power is on.

Cycles

The washer/disinfector runs through a series of cycles during its cleaning process including pre-wash, wash, rinse, thermal rinse, and drying. Let's look at some of the cycles you might see.

Pre-wash

Water (cold or hot) enters the sump from the building supply. Once the sump fills, pre-wash water recirculates and sprays over the load for the selected time interval, between 15 seconds and 15 minutes. On completion of the phase, water transfers to the drain.

Wash

Hot tap water enters the sump from the building supply, where the unit adds a selected amount of detergent automatically. Detergent solution is heated and maintained at a temperature ranging between 140 and 180° F (60 and 82° C). Once set temperature is reached, solution recirculates and sprays over the load for the selected time interval (2 to 15 minutes). On completion of the phase, solution transfers to the drain.

Rinse

Hot tap water enters the sump from the building supply. Rinse water may be heated and maintained at a temperature ranging between 110 and 180° F (43 and 82° C). Once sump fills, rinse water recirculates and sprays over the load for the selected time interval (15 seconds to 15 minutes). On completion of the phase, water transfers to the drain.

Thermal rinse

Water (hot or optional purified) enters the sump from the building supply. Rinse water is heated and maintained at a temperature ranging between 180 and 203° F (82 and 95° C). Once reaching set temperature, rinse water recirculates and sprays over the load for the selected time interval (1 to 10 minutes). On completion of the phase, water transfers to the drain.

Drying

Electric heaters maintain chamber air at temperatures ranging between 150 and 240° F (66 and 116° C). If the unit is equipped with ventilation, then additional ducting will vent the air outside, otherwise the unit may exhaust chamber vapors through a condenser to the room.

Operational maintenance

Just like with sterilizers, proper and timely maintenance is essential with units that operate using water and moving parts. Failure to replace components at the minimum prescribed intervals or adjust your maintenance based on location and water characteristics can have an impact on the overall units operation. While these units vary in size and scope, let’s take a look at some generic maintenance principles.

Preventative maintenance (PM)

When performing a PM, check the following functions and components as applicable:

- Check the door seals to ensure they are clean, free of cracks and remain secured to the unit (replace as needed).
- Inspect the door safety features including the interlock when the unit is running, closing sensor to detect objects in the way, and single door at a time operation if the unit is a pass through system (as applicable).
- Check the accessories of the machine visually with regard to their intended use and function, (e.g. blocked ducts or worn and missing parts that might affect the performance of the machine).
- Check all supply pipes and hoses for damage or leaks.
- Ensure the unit dispenses detergent during the required cycles and detergent pumps operate as intended.
- Inspect the spray arms for proper operation, freedom of movement, and build up or clogs that might restrict flow (clean as necessary).
- Inspect free flow of drains and operation of drain valves.

- Check to see if the couplers are connected and secure when the rack is in place.
- Check that temperatures reach specified limits throughout the cycles as intended. Validate using a temperature measurement device against unit displayed temperatures.
- Ensure the unit dryer is functional, check filters and dryer sensor (clean as necessary).
- Ensure the control panel functions properly including buttons, knobs, and read out displays.
- Inspect operation of the printer and proper cycle reporting.

As mentioned previously, these units can range from the size and style that you might find in your kitchen dishwasher, to medium scale pass-through and conveyor systems, and even large cart washing systems. Always follow the recommended preventative maintenance instructions from the manufacturer and inspect items and options as applicable.

Calibration

Some units have the ability to measure and calibrate functions such as detergent flow and volume. Depending on the unit under test you can either hook up a laptop via communication port or use the built-in control unit and display to access calibration functions. You can calibrate each flow sensor individually. Using the calibration software and a graduated cylinder, or other volume measuring device, select the desired volume and activate the detergent pump and sensor. Entering the measured results in the calibration software will allow the unit to compensate for the values, ensuring the unit is supplying the correct amount of solution for proper disinfection.

237. Sterilization

After the cleaning process, the instruments must be packaged and sterilized. There are many ways to provide a bacteria free environment when dealing with medical instruments and medical devices. Each method of sterilization has its advantages and disadvantages. Most hospitals and clinics employ several ways to sterilize their belongings. Let's begin by discussing the various methods available for sterilization, then the equipment most commonly used for sterilization, and, finally, quality control.

Methods of sterilization

A bacterium can be killed by reducing the water in it to a point where all of its vital processes are stopped, or by coagulating or solidifying its protoplasmic mass. Various forms of heat help to accomplish these results, but we also use chemicals or antiseptics in some instances. Basically, methods of sterilization fall into the three categories: chemical agents, heat, and gas.

Chemical agents

The effectiveness of these agents depends upon the antiseptic used. The most common are phenol and mercuric chloride used in a liquid form. In many cases, they do not ensure a complete sterilization, but merely produce a partial or temporary arrest of the activity of the invading microbes. Concentrations strong enough to ensure true sterilization are not normally used since they prove to be a source of irritation and damage to tissue. For these reasons, they are used strictly for surface sterilization or for items that cannot be sterilized in any other manner.

Heat

The most widely applicable and efficient agent for sterilization is heat. Humans have used heat as a sterilizing agent for hundreds of years. It was an ancient custom to pass knives and other metal objects through a flame to cleanse and purify them. Dry heat in the form of hot air was the agent employed by primitive humans in preserving food. The process was not even thought of as a process of sterilization, but, in reality, they were the humble beginnings of our present-day sterilization techniques.

Sterilization by flame is the most effective method of sterilization. It is, however, impractical due to its destructive properties and is probably the least used method. Its use is limited to small objects used in handling bacteria in the laboratory, and the destruction of worthless and infectious material.

Sterilization by dry heat is used primarily for sterilizing laboratory glassware and certain metal instruments. A hot air chamber or oven can accomplish dry heat sterilization. A temperature of 160° – 180° C must be maintained in the sterilizing chamber for at least 1 hour to secure absolute sterilization. This method of sterilization is not recommended for dressings since hot air does not penetrate very well, and the high temperature scorches and damages the material. The medical laboratory and bioenvironmental engineering commonly use dry heat sterilizers.

Sterilization by moist heat is the method now used in modern hospitals for securing the necessary sterile supplies for surgical use. Moist heat is more penetrating than dry heat and effectively kills disease-producing bacteria in a short time. Additionally, it does not damage the material under sterilization. Its applications come in the form of boiling water, free-flowing steam, or steam under pressure. With boiling water or free-flowing steam, a maximum temperature of 212° F can be maintained for any desired period of time. Much higher temperatures are easily obtainable by the use of steam under pressure. The degree of heat is dependent upon the pressure employed.

We have already determined that heat destroys bacteria, coagulating or solidifying its protoplasmic mass. The temperature at which the protoplasmic mass coagulates depends upon the amount of moisture present. A scientist named Lewith (1888) experimented with proteins using egg albumen, which is very similar to bacterial protoplasm. He discovered that when there was an abundance of moisture present, the albumen or protoplasmic mass coagulated at a relatively low temperature. With very dry albumen, extreme heat up to 338° F failed to cause the protoplasmic mass to coagulate. Heat and moisture then, when applied for the proper period of time, are essential elements necessary to destroy bacteria. Naturally, boiling water and moist steam under pressure are the easiest and most convenient ways to apply these agents.

The thermal death points of many bacteria has been carefully studied. These studies and repeated experiments revealed that you can destroy non-spore-forming bacteria (e.g., those causing typhoid, tuberculosis, pneumonia, etc.) by exposing them to water heated to 125° – 160° F for 10 minutes.

All vegetative forms of non-spore-bearing bacteria can be destroyed by boiling them in water (212° F) for 10 to 20 minutes. The application of moist heat at much higher temperatures and for longer periods of time, however, is required to render the spore formers inactive or sterile.

Experts in the field were unable to agree on the optimum temperature and time required to destroy the most resistant pathogenic spore-forming bacteria. Their conclusions range from 230° – 248° F applied in the form of moist heat for 5 to 25 minutes. It is evident then that pathogenic spore-forming bacteria subjected to moist heat of 240° F for at least 25 minutes will be destroyed.

Under certain conditions, a moist heat from 250° – 259° F may be applied to dressings or other wrapped material for 30 minutes or longer without ensuring complete sterilization. The moist heat must thoroughly penetrate the material; otherwise, not all of the germ life that is present will be destroyed.

All air must be removed from the sterilizing chamber to allow steam to thoroughly penetration the material. Consider a fundamental property of matter—no two substances, whether solids, liquids, or gases, can occupy the same space at the same time. One must move before the other can occupy its place. When packages of material are prepared for sterilization, they are filled with air. This air must be removed before steam, even under pressure, can occupy its place and penetrate to the center of the package. To remove the air and overcome this problem, high-pressure sterilizers are equipped with an air and condensation ejector. The air in the chamber of an autoclave is relatively cool and more than twice as heavy as steam at the normal operating range. When steam is forced into the chamber, it rises to the top, compressing the air to the bottom. The condensate ejector (thermostatic steam trap) mounts to a line running from the bottom of the chamber and automatically ejects the air.

The presence of air in the sterilizer chamber also affects the maximum temperature obtained in the chamber. It prevents the temperature from reaching the degree of heat that corresponds to the steam

pressure indicated. Dalton's law in physics states that when air and steam occupy the same closed vessel, the total pressure in the vessel is equal to the sum of the partial pressures of both the steam and air present, and the temperature in the vessel will correspond to the partial pressure of the steam only.

When the air leaves the vessel, the steam rushes in to take its place, which thoroughly immerses the packs in moist heat. After subjecting the packs to the moist heat for the desired time, the unit evacuates the steam and replaces it with air. The sterilizer allows the packs to dry prior to the door opening.

Steam sterilizers

At the start, we should recognize that, of the several sterilizing agents available to the hospital, moist heat in the form of saturated steam is the most dependable for the destruction of all forms of micro-organisms. Also, in contrast to chemical and gaseous sterilizing agents, steam leaves no toxic residue. In addition, steam is readily available and comparatively inexpensive.

There are two types of steam sterilizers used in health care facilities: gravity-displacement and prevacuum.

Gravity-displacement

Steam enters at the top of the chamber and displaces the air within the chamber. Air is heavier than steam and, therefore, sinks below the steam. As the pressure in the chamber rises, the steam pushes the air out the drain. The pressure continues to rise until the temperature of the steam at the chamber drain reaches a preset temperature, as measured by a thermometer in the drain line. To speed up chamber heating, the jacket (an envelope around the chamber) fills with steam at the same pressure and temperature as the chamber is set to attain. The steam in the jacket heats the walls of the chamber, which helps maintain a constant chamber temperature throughout the cycle. The following table shows a typical cycle for a gravity displacement sterilizer:

Phase	Description
1 – Pressurize	A valve opens and saturated steam enters into the chamber from a port in the top rear portion of the chamber. The steam pushes the air out the drain as it fills the chamber. The pressure and temperature inside the chamber rise until reaching the preset temperature; then, the timer starts.
2 – Exposure	The sterilizer maintains the temperature by periodically removing cooled steam through the drain and replacing it with fresh steam at the top. This process continues until the sterilization time is completed.
3 – Depressurize	When the timer reaches the end of the sterilization cycle time, the steam valve is shut off, the drain opens, and the steam is exhausted from the chamber.
4 – Dry	When the chamber reaches atmospheric pressure, the drying time begins. The jacket remains hot and its dry heat slowly drives excess moisture out of the packs. After this drying phase, which helps prevent wet packs, a buzzer or other signal indicates the cycle is complete.

Because of the time required to eliminate air from the chamber, the sterilization cycle is longer in the gravity-displacement sterilizer than in the prevacuum sterilizer. The relative difficulty of air removal also means dense items may require extended cycle times in a gravity-displacement sterilizer.

Only gravity-displacement cycles may be used to sterilize liquid loads. Never sterilize liquids with other items; rather, sterilize liquids in a dedicated load. The sterilization of liquids requires exhaust and cooling cycle parameters that differ from those of a conventional gravity-displacement cycle. Steam does not penetrate the liquid; instead, the steam is used to heat liquid to 250º F (121º C). Several minutes are required for the liquid to attain this temperature, which must then be maintained for an additional time to achieve sterilization. The volume of liquid in each container dictates the total steam exposure time. Since the sterilization temperature is above the boiling point of water at atmospheric pressure, the chamber pressure must be released slowly to allow the liquid to cool to

below 200º F (93º C) before the sterilizer door is opened. If this is not done, the solution containers explodes when the door is opened, possibly causing serious injury to the operator. It is also very important that the operator properly use containers specifically designed for sterilization of liquids. The following table shows a typical cycle for a liquid load:

Phase	Description
1 – Pressurize	Steam enters into the chamber, pushing out air as it fills the chamber. The pressure and temperature inside the chamber rise until reaching the preset temperature. The timer then starts.
2 – Exposure	The sterilizer maintains the temperature until the exposure time is completed.
3 – Depressurize	Steam cuts off and the drain opens slightly, allowing the steam to escape very slowly. Also, the jacket pressure releases slowly so the temperature drops gradually. This process can take 30 or more minutes. When the steam is all out and the chamber temperature falls to below 200º F, the door can be opened. Take special care at this point in moving hot bottles because some bottles may boil over or even explode. After cooling, burp the flasks with non-disposable caps by tapping on the cap. The purpose of this procedure is to check for proper seal. Disposable caps appear concave if properly sealed.

Prevacuum sterilizers

A vacuum system pulls most of the air from the sterilizer chamber and the load contents out through the drain in the bottom front floor of the sterilizer. As in the gravity-displacement sterilizers, a jacket surrounding the chamber fills with steam at the same pressure and temperature as the chamber is set to attain, to maintain a uniform chamber temperature. The following table shows a typical sequence of events in a prevacuum sterilizer cycle:

Phase	Description
1 – Prevacuum	The vacuum system pumps approximately 90 percent of the air out of the chamber.
2 – Condition	Steam enters into the chamber for several seconds, thereby beginning to heat the contents of the load and help drive air out of the hard-to-reach areas.
3 – Prevacuum	The vacuum system comes back on and removes about 90 percent of the remaining air. Together, the two vacuum phases remove almost 99 percent of the original air.
4 – Exposure	A valve opens and saturated steam flows into the chamber. The preset temperature setting is reached and holds fairly constant for the exposure time. The temperature holds steady by automatic evacuation of cooler steam at the bottom of the chamber and replacement with fresh steam at the top.
5 – Depressurize	After the sterilization period, the drain opens and the chamber empties of steam.
6 – Dry	Once most of the steam pressure is out of the chamber, the vacuum system comes on and again draws a 90 percent vacuum. Then, with the vacuum system still running, a timer starts timing a drying period. This hold time allows the removal of excess moisture from the packs by means of dry heat from the jacket. When the drying phase is over, the vacuum releases by allowing filtered air into the chamber; then, the cycle is complete.

The vacuum system of prevacuum steam sterilizers provides very efficient air removal. Therefore, overall cycle time is shorter than for gravity-displacement sterilizers.

Another version of the prevacuum sterilizer is the prevacuum pulsing sterilizer. The main difference between the pulsing-type and conventional prevacuum sterilizers is instead of the two prevacuums discussed in the preceding table, a pulsing sterilizer draws up to five partial vacuums throughout its cycle, with only the final one being a 90-percent vacuum. Between each vacuum, steam enters into the chamber. This process serves to efficiently drive out any entrapped air and thoroughly precondition the load. In all other respects, the cycles of the two types of prevacuum sterilizers are the same.

Major components

Construction of the steam sterilizer incorporates a body, utilizing a jacket and chamber combination (fig. 4–1). This body is a cylindrical, seamless drawn shell, which holds a similar shell of a smaller size. The edge of the two body shells fasten with a gas-tight seal to a cast bronze door collar. The space between the inner and outer shell is the jacket. The interior of the inner shell is the chamber. Insulating material surrounds this assembly. A third stainless steel outer shell, sometimes referred to as the ornamental jacket, encases the entire unit.

The door is the safety-lock type. Rotating the handwheel clockwise engages locking bars in the door collar so it cannot open until the handwheel is rotated counterclockwise. During operation, or any time pressure is present inside the chamber, a diaphragm on the inside of the door engages a clutch preventing counterclockwise rotation of the handwheel to unlock the door. The hinge assembly is adjustable to permit proper positioning of the door.

The vacuum dryer mounts in the chamber drain line and aids the drying process by allowing air to enter the chamber to replace the steam. It is packed with tightly compressed monel wool, which removes foreign matter from the air before it enters the sterilizer chamber. A conventional ball-check valve prevents loss of steam during normal operation.

The thermostatic steam trap (mounted in the chamber drain line) consists of heat-sensitive bellows, which operate a needle valve. When the trap is cold, the valve is open, permitting steam to flow through the sterilizer and into the waste line. In passing through the trap, the steam heats the expansion bellows, which expand and close the valve, allowing pressure to build in the sterilizer. During the sterilization period, some steam condenses into water and drains, by gravity, into the steam trap. This condensate, being cooler than steam, causes the expansion bellows to contract, opening the valve. The condensate, mixed with steam, passes through the valve until the live steam again heats the bellows, closing the valve.

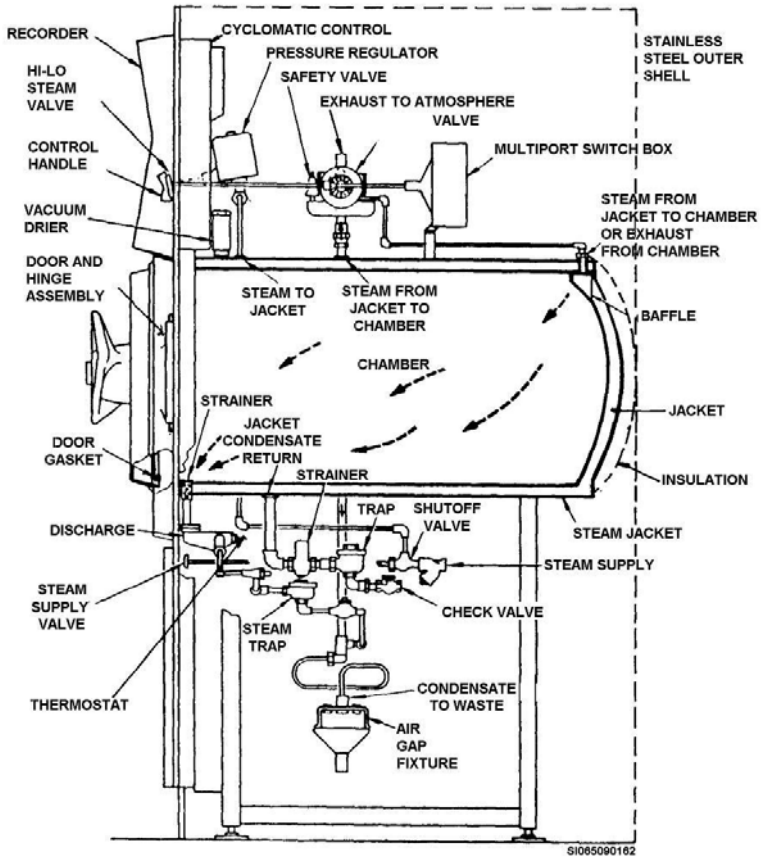

Figure 4–1. Basic sterilizer components.

The safety valve, installed in the exhaust-to-atmosphere line and connected directly to the jacket of the sterilizer, is a conventional spring-loaded valve that opens when the pressure in the jacket exceeds the spring tension.

A check valve rests in the steam water and waste lines to prevent reverse flow and to permit the sterilizing chamber to draw a vacuum.

The automatic control or pressure regulator valve is installed on the steam supply line and is the last valve the steam passes through before entering the chamber jacket. This valve may be set to maintain any predetermined pressure. With this valve, you can obtain a higher pressure for sterilizing dressings and a lower pressure for sterilizing rubber goods. Any desired pressure within approximately 20 pounds may be obtained. Due to wide variations in steam pressures at various facilities, the valve must be set after installation of the sterilizer.

A pressure sterilizer always has a thermometer calibrated to register temperatures from 100° to 300° F. It is located in the chamber evacuation (condensate) line, because this is the coolest point in the sterilizing chamber.

These are just some of the components necessary in sterilizer operation, which includes a self-generating steam system, conventional steam system, a plumbing system for water and waste, and an electrical system for timing circuits.

Operational inspection

The cornerstone to an effective maintenance program is a proper operational inspection. Always consult the manufacturer's literature before performing an inspection. The following list contains some general checks you should make during a sterilizer inspection.

- Check the door gasket. Ensure it seats properly, and there are no cracks or cuts. This is a safety issue because steam could escape through the cracks and out the sterilizer, causing burns to the operator or any other person in the vicinity. Also, ensure the mechanical integrity of the door locking mechanism is good. The pressure can be great enough that if the door were to be unsound, it could blast off the machine and go through a wall. It has happened!
- Verify the recording system is operational and accurate. This is the record of all the sterilization cycles and needs to operate properly. Service as required.
- Check the sequence and function of all the controls, along with verifying operation of all indicator lamps and gauges. Check the vacuum, steam, and water system for leaks. Replace filters according to the manufacturer's literature and more frequently if your water and steam has a high mineral content.
- Verify the temperature by placing an autoclavable holding thermometer in a cycle. This thermometer will read the highest temperature achieved during the cycle. Verify it matches the selected temperature for the cycle. At the same time, verify the operation of the timer. Exposure times should be as long as selected and indicated.
- Finally, verify the operation of the safety pop off valve. This valve lets steam out of the chamber if an overpressure condition occurs. Remove the safety wire and press the handle. Ensure your body and face are away from the opening of the valve. This is one facial you could do without! When testing is finished, replace the safety wire. If your sterilizer should happen to over pressurize, the safety wire will break and the valve will actuate to release steam. The broken safety wire is one indication the process occurred. It also signals it requires replacement.

Clinical application

Sterilizers, or autoclaves, eliminate all living microorganisms in goods such as dressings, bandages, sponges, instruments, utensils, water, and other solutions. Because the basis for the living process of microorganisms is protein in nature, conditions that adversely affect protein destroy these cells. The

sterilizer creates the conditions harmful to these microorganisms and, thus, provides the safest germ-free environment possible to the patient.

Gas sterilizers

Gas sterilizers are also a valuable tool in the fight against microorganisms in your hospital. They have a specialized application that steam sterilizers cannot provide—that of sterilizing goods at lower temperatures, thus allowing us to sterilize items that would normally melt in an autoclave.

Some control over sterilization is offered by sterilization indicators. There are three commonly used controls:

1. An indicator is a glass tube containing a small tablet that melts or fuses when subjected to sterilizing temperature in the autoclave. We know that in the process of manufacturing, certain changes may be introduced in the material, which alters the melting point.
2. A paper indicator in which color changes take place, denoting various exposure times.
3. A glass tube with a live bacterial culture is placed in a sterilizer pack. The live bacterial culture should be killed by the steam sterilization. After removing the pack from the sterilizer, the tube goes in an incubator for 24 hours to attempt to grow the bacteria. If something grows, the goods were not properly sterilized and must be redone. If nothing grows, the goods were properly sterilized and may be used.

Plasma sterilizers

Plasma sterilizers work by injecting hydrogen peroxide into the chamber. The hydrogen peroxide molecules are excited and transform into a plasma state. This state will safely sterilize most medical instruments without leaving any toxic residue. The plasma sterilizer will complete a sterile cycle in approximately 75 minutes and the system requires no special pipes or venting.

Operation

The sterilization process begins by placing the unsterilized item in the chamber. Once the chamber properly closes, it draws a vacuum. The unit then injects a solution of the hydrogen peroxide into the chamber. The solution vaporizes and then diffuses. After a period of time, the pressure in the chamber reduces. The combination of vapor and plasma safely sterilizes the items. Once the sterilization process is complete, the active components of the plasma deenergize, leaving behind a non-toxic by-product. The vacuum releases, the pressure vents, and the items are ready for use.

Sterilization cycle

The sterilizer automatically controls the sterilization process through use of a microprocessor. The microprocessor controls and monitors the following five stages of the sterilization process:

1. Vacuum stage – The unit removes the air from the chamber and reduces the pressure during this stage. This process can take 5 – 20 minutes, depending on the load.
2. Injection stage – Hydrogen peroxide is injected into the chamber and vaporized during this stage. This process takes 6 minutes.
3. Diffusion stage – The vaporized hydrogen peroxide diffuses over the materials requiring sterilization during this stage. This process takes 44 minutes.
4. Plasma stage – This stage introduces RF energy into the chamber, turning the vaporized hydrogen peroxide into plasma to sterilize the materials. This process takes approximately 15 minutes.
5. Vent stage – The RF energy turns off and the plasma is deenergizes. It now vents safely, releasing the pressure. This stage takes 4 – 9 minutes. The materials are ready for use.

Maintenance

Let’s take a quick look at the maintenance for the plasma sterilizer. Remember, the manufacturer’s literature may vary slightly to accommodate any peculiarities in the equipment.

Cleaning

The outside of a plasma sterilizer can be cleaned using a mild detergent. The inside chamber normally requires no cleaning. Never use an abrasive like steel wool or a wire brush to clean the sterilizer.

Replacement

The printer cartridges and paper are items routinely replaced on a plasma sterilizer. Refer to the operator's manual for specific instructions on replacing these items.

Auto test

Tests that manually run from the control panel are the user interface, sensor, injection, heater, door, analog, vacuum, cassette, and printer.

Steam generators

Hospitals generally have a central supply of steam piped throughout the facility, called house steam, to support many items including heating and utility functions, as well as sterilizers and other support equipment. When there is no central steam supply to a required area, or where the central facility steam cannot consistently and efficiency support the equipment, we require the use of steam generators. These can vary in size and are typically either an individual onboard steam generator for each sterilizer or a larger generator that can supply a particular section. The smaller onboard steam generator, also known as an integral boiler, mounts within the footprint of a sterilizer and can fit under the chamber. Integral boilers run at 45 kilowatts (kW) or below. Larger units, known as remote boilers, mount either next to the unit or in another room. These are generally greater than 45 kW. A dedicated steam generator, whether built-in or stand-alone is designed with an optimal operating pressure, quality piping and components to ensure that the process of sterilization by steam is not compromised. As the pressure of house steam can fluctuate depending on the current demand draw, steam generators ensure a constant and dedicated supply to the unit, reducing cycle failures.

Tissue culture work, sterile water preparation and other special processes require high quality steam. House steam is not sufficient to produce clean steam, so we use steam-to-steam boilers when house steam is available, but the equipment requires clean steam that is free of contaminants. Steam-to-steam units come in integral or remote mounted configurations. These units use high purity water from sources such as reverse osmosis systems to create the steam. They use the house steam as an indirect heat source, along with heat exchangers, to create a clean steam supply for equipment. These units are not very common in the Air Force, as most sterilizers run on house steam.

Steam generators generally require descaling and cleaning of the heating elements. Buildup of sediment inside the units can lead to overheating as well as mineral deposits making their way into the sterilizers.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

235. Ultrasonic cleaner

1. Name the three acceptable ways instruments can be mechanically cleaned.

2. How does the ultrasonicator clean equipment?

3. What is the term used for the formation of fine bubbles in a liquid?

4. What happens to the binders once they are dislodged from the instruments?

5. What is the optimum bath temperature for cleaning surgical instruments soiled with blood and tissue debris? Why isn't a higher temperature better?

6. Why is degassing the water important?

7. What is the clinical application of ultrasonic cleaners?

236. Washer disinfector

1. How do washer disinfectors clean instruments and utensils?

2. How do washer disinfectors differ from washer/sterilizers?

3. What is the purpose of the pass-through washer disinfector configuration?

4. What kind of water does a rinse cycle use?

5. What type of units automatically pass devices into the next chamber for subsequent processing?

6. Explain the function and purpose of the door interlock safety feature for double door units.

7. At what temperature range does the electric heater maintain the air in the chamber?

8. What are you checking for when inspecting the door seals during a PM inspection on a washer disinfector?

237. Sterilization

1. Name the three categories for methods of sterilization.

2. What is the main disadvantage to chemical sterilization?

3. What is the most effective, yet impractical, method of sterilization?

4. Which sterilization method is most commonly used for securing sterile supplies for surgical use?

5. Why is steam under pressure used instead of atmospheric steam for sterilization?

6. How does air affect the sterilization process?

7. Name the four phases of a gravity-displacement sterilization cycle.

8. When comparing the gravity-displacement and prevacuum sterilizers, which has the longer cycle?

9. Which sterilizer should be used for sterilization of liquids?

10. Name the six phases of the prevacuum sterilization cycle.

11. What is the difference between conventional and pulsing prevacuum sterilization?

12. What is the purpose of the vacuum dryer?

13. Briefly describe how a safety valve works.

14. What is the approximate temperature range of a sterilizer's calibrated temperature thermometer?

15. What could happen if a sterilizer is used with a cracked door gasket?

16. What should you consider replacing more often when you know water and steam has a high mineral content?

17. What piece of test equipment is used to verify cycle temperature?

18. What is the clinical application of a sterilizer?

19. Name the three commonly used methods for quality control of a gas-sterilized product.

20. What material is injected into the chamber of a plasma sterilizer?

21. What are the five stages of the plasma sterilization process?

22. What piece of equipment would you use to supply steam to a sterilizer if the central steam supply is not available?

4–2. Miscellaneous Support Equipment

Therapeutic support units are some of the behind the scenes heroes. They are foundational units that keep operations going in the hospital. Just as CSS is the backbone of a surgical department, other items such as water purification systems, suction units, and refrigerators can provide support functions for many clinics around the hospital. Let get right into it.

238. Water purification

Water purification systems are used in many areas of the MTF (e.g., surgery, CSS, pharmacy, dental clinic, medical maintenance, and clinical laboratory). "Distilled," "deionized," and "pure" water is used for such things as rinsing surgical instruments, mixing pharmaceuticals, water for table top autoclaves, battery maintenance, and clinical laboratory reagents. In this lesson, you will learn about

filtration, distillation, ion exchange, deionization, the reagent grades of water, and resistivity as it applies to use in clinical laboratories.

Filtration

Whatever the commercial source of the water, some form of prefiltration must be used. It can be as simple as a cotton filter that removes up to 98 percent of the particulate, or microfiber glass that removes 98 percent or more of the particulate. These prefilters help protect the whole system and are economical because the prefilters can be cleaned and reused. After the prefilter, there can be additional filtration.

These additional filters can be located in various points along the water line. They can be positioned immediately after the prefilter or as the last filtration at the point of water delivery. Like the prefilter, they remove particulate and other contaminants from the water, and protect the system. The three types of filters we will discuss are activated charcoal, ultraviolet (UV), and submicron.

The activated charcoal filter is generally located immediately after the prefilter, but before the deionizer or distillery. This type of filtration traps nearly all of the organic matter and chlorine as water flows through the filter. It is especially useful to increase the life expectancy of the ion exchange columns.

A UV filtration system is a chamber containing UV lamps which are controlled by a ballast. The pre-filtration water passes through the chamber where it receives a UV dose sufficient enough to kill bacteria and to inactivate viral particles in the incoming water. The UV irradiation system is located after the pre-filters.

The submicron filter removes all particles and microorganisms larger than the pore size of the filter. The pore size of the filter is usually about 0.2 micrometers in diameter. This type of filtration is generally used in the final stages of the water purification process.

Distillation

Distillation is the oldest form of water purification. The distillation apparatus, commonly called a still, removes most impurities found in regular tap water. The process heats the water until it reaches the boiling point. The steam with the impurities from the boiling water rises, and then cools in a condenser. The steam releases the impurities as it returns to the liquid state. This water is collected in a reservoir as distilled water. The impurities return to the boiler and drain off. While this water is fairly pure, it can contain some dissolved metals from the distiller itself. You should only make enough distilled water as you need and use the distilled water immediately. The man-hours required to maintain the distillation apparatus, coupled with the cost of electricity, makes distillation the most expensive method for obtaining reagent-grade water.

In most cases, distilled water is further processed, using ion exchange, before it is used for clinical laboratory tests. Let’s take a brief look at how the ion exchange process works.

Ion exchange

The water produced by the ion exchange method is commonly called “deionized” water. After the incoming water processes through the prefilter, filter, and, possibly, the distiller, it enters the cation exchange column. The cation exchange column contains an insoluble resin core that reacts with positive charged ions (i.e., Na+). This reaction releases a hydrogen (H+) ion. This water passes through to the second column, called the anion exchange column. Negative charged ions (e.g., chloride (Cl–) react with the column. This produces a reaction that releases a negative hydroxide (OH–) ion. The two released ions, H+ and OH–, join together to form H_2O. The deionized water then passes through charcoal filters to remove the organic compounds, followed by submicron filtration to remove particulates. Deionized water doesn’t store well because bacteria will form in it. So, only prepare the amount you need to accomplish the test.

Reagent grades of water

Over the years, the terms distilled water and deionized water have been used to describe the pure water required for preparing solutions and reagents in the laboratory. These terms are inaccurate since they refer to the methods used to obtain the water and do not reflect the actual purity of the water. The term reagent-grade water is a better representation of the actual purity of water, rather than the method used to achieve the water. First, we will look at the reagent grades of water, and then we'll take a quick look at the resistivity of reagent grade water.

Reagent grades

The Clinical and Laboratory Standards Institute (CLSI) classifies water used in clinical laboratory settings into three grades. While there is more than one laboratory standardization authority, the AF primarily aligns with standards set by the CLSI. The CLSI has moved away from the traditional "type class" system (i.e. types I, II, and III) and instead uses designations such as clinical lab reagent water (CLRW), special reagent water (SRW), and instrument feed water (IFW). To help you become familiar with each grade of water, we will look at them from the least pure to the most pure by using the following table:

Grade	Description
CLRW	Water of this grade is generally produced by ion-exchange, or with a very good distillation apparatus. CLRW replaces most previously deemed type I and type II applications and is appropriate for most general laboratory testing applications such as preparing culture media, and many microbiology and bacteriology procedures that don't require ultrapure waters in the range of SRW.
SRW	This is a very high grade of water produced from the ion-exchange apparatus. It is used in tests that require the least interference and utmost accuracy. SRW is used in critical applications such as trace analysis, high performance liquid chromatography (HPLC), liquid chromatography–mass spectrometry (LC-MS), molecular biology based assays, in vitro fertilization (IVF), and any other critical applications for which CLRW would not be appropriate. This water should be used immediately after processing and cannot be stored because its resistivity will decrease, and metals and/or organic compounds will be leached from the storage container, and bacterial contamination will occur.
IFW	This is the grade of water you would usually get from a distilling apparatus to wash glassware. It also has uses in general autoclaves, staining applications, incubator/humidity cabinets, or polisher feed for preparation of ultrapure water.

Resistivity

The resistivity or specific resistance of reagent-grade water is the electrical resistance of the water. The resistance is measured between opposite faces in a centimeter (cm) cube container and reported as one million ohms per centimeter (megaohm/cm). The better the grade of water, the higher the resistivity. According to the CLSI, the only classification that has specific resistivity requirements for the particular class is CLRW, which requires a resistivity of at least 10 megaohms/cm. SRW resistivity levels are application specific given their unique and critical testing requirements, although generally around 18 megaohms/cm or higher. While instrument feed water similarly does not have a resistivity requirement, you will generally see water used for these application around 0.05 megaohm/cm to 1 megaohm/cm.

239. Suction pressure unit

Suction-pressure units are medical devices used to remove fluids from various areas of a patient's body where they can cause harm to the patient or are obscuring the view of the personnel treating the patient. They also provide a source of pressure for uses requiring air under pressure. Usually the suction is from a main vacuum line in the hospital and hooked through the floor plate to the unit. If that suction system fails, the suction pressure unit is used to complete the procedure without patient rescheduling.

Principles of operation

Medical suction-pressure units generally operate using one of two principles: thermotic and vane action. Let's begin with the thermotic type.

Thermotic

The thermotic aspirator (fig. 4–2) is more commonly known as an intermittent suction unit. The thermotic aspirator works on the principle of heating an enclosed volume of air to a given temperature, causing it to expand and create the positive pressure at point A. The one-way valve at point A lets the expanded air out and becomes the source of positive pressure. Looking at figure 4–2 (B), we see the heating element is turned off, causing the air to cool and contract. This creates a vacuum in the container, closing valve A and creating a negative pressure at point B. This, then, becomes the source of suction. Valves A and B are one-way valves. These units are ideally suited where drainage needs to be gentle and recurrent.

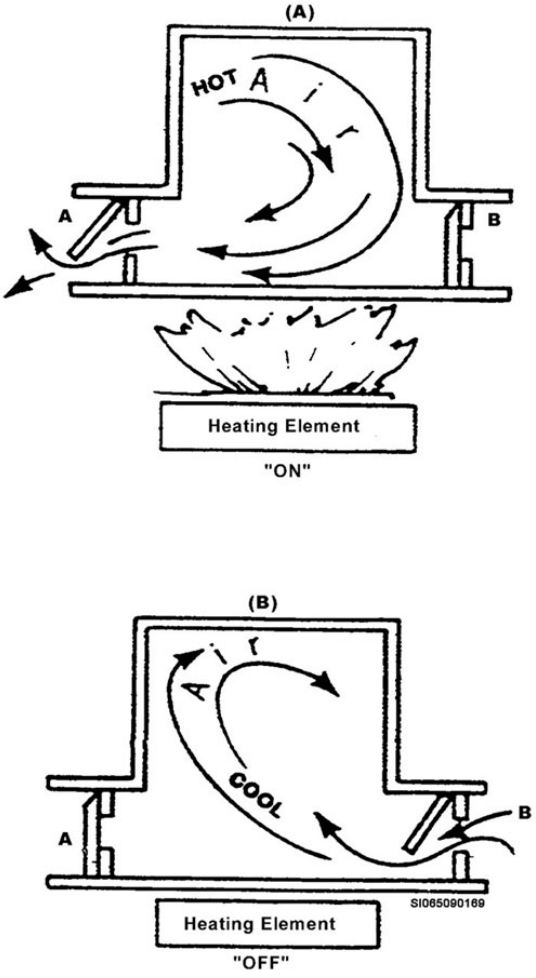

Figure 4–2. Thermotic aspirator principles.

Vane

The vane type of suction unit is a continuous duty device. This device provides continuous suction and pressure using one pump. Figure 4–3 shows how this is done by spinning vanes past two outlets in the pump housing. The action of each vane, in turn, pulls air in at the suction outlet "A" and pushes it out at the pressure outlet "B." Increasing the number of vanes produces more suction and pressure. Most pumps usually have three vanes, which produce a maximum suction of approximately 20 inches of water and maximum pressure of approximately 30 inches of water for clinical application.

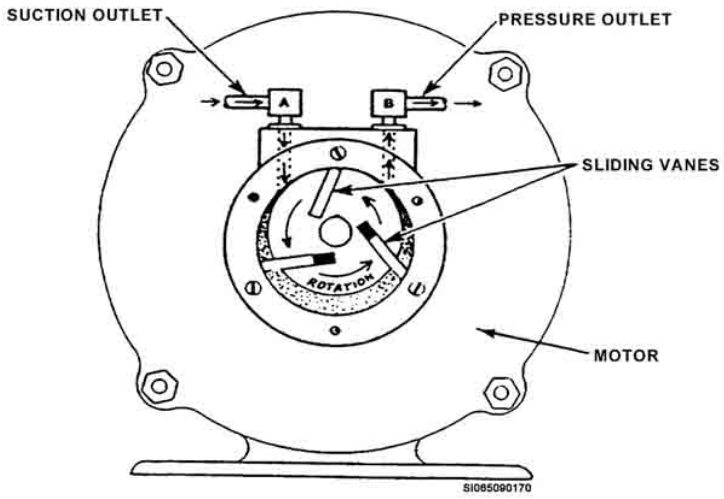

Figure 4–3. Standard vane suction/pressure unit.

Clinical application

Suction-pressure units function throughout your facility as primary and backup support units. Some examples of their use include aspirating saliva from the mouth of a dental patient, fluids from the throat of unconscious patients, drainage from body cavities of postoperative patients, and fluids from surgical cavities to maintain a clear and dry field for the surgical team to work. Those units that provide positive pressure are a source of air needed to administer medications by spray, administer anesthetics, or any use requiring air under pressure.

Although suction-pressure units are relatively simple, they play an important role in the recovery of patients. Operational inspections and calibrations of these units should not be taken lightly.

Operational inspection

Operational inspection of suction-pressure units is possible, in most cases, at the site or department using the unit. You need to know the normal operating parameters of your unit to detect discrepancies in pressures before a possible failure occurs. In-line filters are of special concern because they provide an added safeguard against cross-infections and contamination of units and, in turn, patients. Practice proper infection control procedures when changing these filters. You should adhere to current manufacturer's checklists, which include such items as line cords and lubrication, as well as suggested PM procedures. You can also check overflow protection verification by aspirating enough fluid into the collection bottle until the protection system activates. Do a safety inspection to ensure safe operating parameters for the patient and operator.

Finally, this piece of equipment has many things considered user-maintenance items, such as the filters previously mentioned. You should provide training to the users on items that fall under their responsibility. This training should be repeated annually or as you notice user maintenance is not being accomplished. Cleanliness and appropriate filter changes enhance the life of the suction pressure unit and eliminate frequent service calls.

240. Refrigeration systems

People are not the only ones needing environmental control. The medical community has many perishable medicines and supplies. Refrigeration systems (fig. 4-4) store medicines, blood, lab reagents and samples, and immunizations. As such, we use them in many sections around the hospital including Pharmacy, Lab, Immunizations Clinic, ICU and wards, Logistics, as well as many other clinical and support elements. This lesson will discuss the operation and components of refrigeration systems and some foundational maintenance.

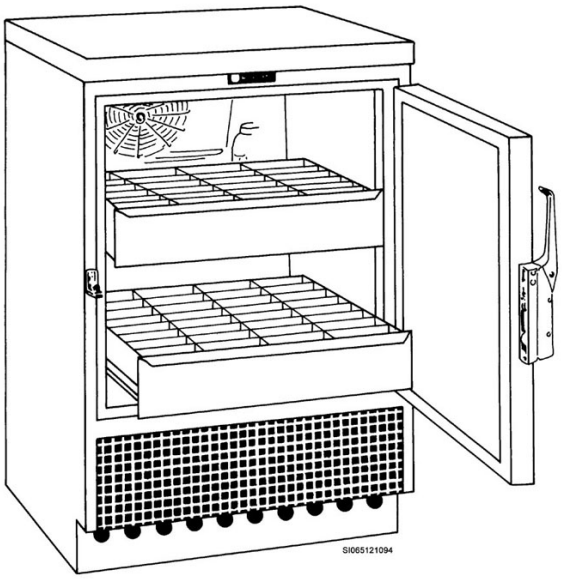

Figure 4–4. Blood bank refrigerator.

Operation of a refrigeration system

You can follow the theory of operation for basic refrigeration in figure 4-5. Mechanical refrigeration is achieved by continuously circulating, evaporating, and condensing a fixed supply of refrigerant in a closed system. Evaporation occurs at a low temperature and low pressure, while condensation occurs at a high temperature and high pressure. Thus, it is possible to transfer heat from an area of low temperature (inside the refrigerator) to an area of high temperature (the room it's housed in).

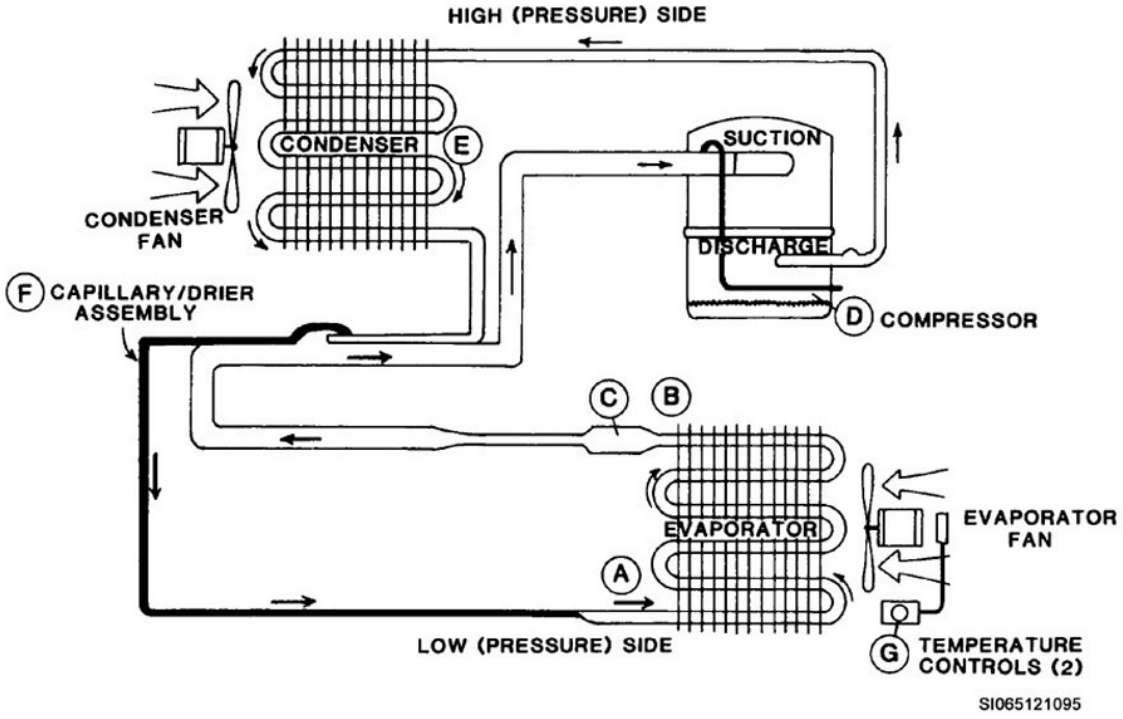

Figure 4–5. Basic refrigeration theory of operation.

The cycle begins at the evaporator inlet (A). The low-pressure liquid expands, absorbs heat, and evaporates, changing to a low-pressure gas at the evaporator outlet (B). The compressor (D) pumps this gas from the evaporator through the accumulator (C). This increases the gas pressure and

discharges the high-pressure gas into the condenser (E). The accumulator is designed to protect the compressor by preventing slugs of liquid refrigerant from passing directly into the compressor. An accumulator should be included on all systems subjected to varying load conditions or frequent compressor cycling.

In the condenser (E), heat is removed from the gas. The gas then condenses and becomes a high-pressure liquid. As the high-pressure liquid refrigerant enters the evaporator (A), it is reduced to a much lower pressure by the suction of the compressor and the pressure drop across the capillary/drier assembly (F). Thus, the refrigerant tends to expand and evaporate. In order to evaporate, the liquid must absorb heat from the air passing over the evaporator. The air that passes over the evaporator is then cooled; finally, this air circulates within the refrigerator cabinet. Eventually, the desired air temperature within the refrigerator is reached, and temperature control (G) breaks the electrical circuit to the compressor motor and stops the compressor. As the temperature of the air through the evaporator rises, the temperature control remakes the electrical circuit. The compressor starts and the cycle resumes.

Monitoring systems

Due to the perishable nature of blood, medications, and lab samples, refrigerators require an extensive temperature monitoring system. A major component of the monitoring system is an audible alarm. The sensor for the alarm is located on a high shelf in a liquid-filled container. The container volume should be no larger than the smallest volume stored, normally 200 to 250 mL. Refrigeration temperatures vary based on the products inside and the department's requirements. Regardless of what the control ranges are, you can set the refrigerator alarm limits to monitor high and low tolerance set points. If the refrigerator temperature varies outside these two parameters, an audible alarm sounds. This sometimes occurs if a technician spends too much time with the door open or the refrigerator power goes out. The electrical source for the alarm must be separate from that of the refrigerator because the alarm must be able to signal if the refrigerator power goes off and the temperature climbs. If the alarm is hooked up to the same power source, it turns off when the refrigerator loses power. Thus, the alarm can't operate as the internal temperature increases.

Alarms can be silenced for a short period of time. This is to allow you to make repairs without having an alarm screaming in your ear. It is not designed to allow a technician to keep hitting it and not call a qualified maintenance person to repair the problem. Most medical refrigerators, such as the large units used in Lab and Pharmacy, will have a digital display of both current and set temperatures. This way you can monitor the real-time temperature and trends before it falls outside of tolerances, and puts the product at risk. There is usually a battery backup for the unit's interface and display, but it lasts only for a limited time. This is so that if power to the unit fails, the warning system is still active to let you know there is an issue.

Central monitoring and remote monitoring systems are being readily employed within hospitals. Similar to the local audible alarms systems, these will monitor the parameters of the unit using a probe. In a central monitoring system, the parameters are relayed to a building automation system that is constantly monitored by facility personnel. A central monitoring system can also store logs, allowing you to go back and verify the equipment's status over a period of time. In a remote alarm system, or call out system, the alarm connects to a programmable monitor attached to a phone line. When the refrigerator strays outside of acceptable tolerances, it calls down the list of programmed numbers with an automated message of the system's status. This system should call the clinic's on-call number or leadership first! The BMET on-call number, if applicable, should be the last number called. If the unit is down, the first step should be for the section to relocate the items to another refrigerator, in order to save the product. A remote system can have multiple channels, or ports, to hook up various cooling systems to one monitor. Each channel can be programmed with a different tolerance range to accommodate both refrigerator and freezer systems. Both central and remote monitoring systems are beneficial for sections that do not run 24-hour operations. This allows fault notification when no one is around to hear an audible alarm.

The chart recorder (fig. 4-6) is a device used to keep a permanent and accurate temperature record. The temperature is recorded on chart paper that spans seven days. The chart paper lays under the pen, which can be felt-tipped or self-inking. Felt-tip pens are much easier to maintain because when they dry out, you just replace them. Self-inking pens have an ink reservoir and plastic tubing. Many things can cause self-inking pens to dry out and clog. This can create quite a mess for the repair person. Usually, you must remove the pen from the recorder and try to unclog the pen with tiny wires or by soaking it in alcohol. If that does not help, you may need to replace the whole pen assembly. Then, you must bleed the air out of the pen so the ink can flow freely.

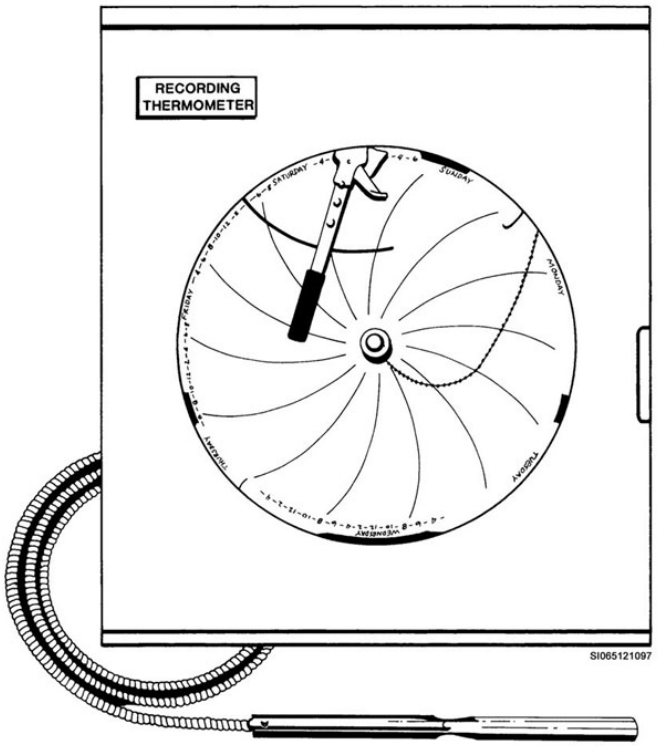

Figure 4–6. Seven-day chart recorder.

The refrigerator temperature is tracked on the chart and the chart is replaced every seven days. This chart then becomes a record required to answer all questions about the quality of the product inside. The sensor for the recording thermometer is steel encapsulated. It must also be run through the top of the refrigerator and immersed in fluid in the appropriate size container. This is what tells the chart recorder the refrigerator temperature.

Organizational maintenance

As refrigeration systems vary in size, temperature ranges and applications, always be sure to follow the manufacturers recommended maintenance. The following procedures are general guidelines for maintaining refrigerator systems:

1. Inspect door gasket for cracks and cleanliness.
2. Clean condenser coils using a vacuum and a soft brush. If the coils are clogged with dust, they can stress the compressor.
3. Clean unit fans. If the fans are dirty they can overheat and burn out.
4. Verify the temperature reading indicated on the unit against a calibrated temperature-measuring device. The indicated reading might be an integrated unit readout, an external monitoring system, or a mercury thermometer placed inside solution within the unit. Place your probe near the internal monitoring probe or thermometer for the most accurate

comparison. Close the door and let the unit stabilize for 10 minutes before recording results. Most modern refrigeration units can be adjusted in the unit calibration settings, if the readings are not consistent.

5. Check the battery on the internal alarm system and chart recorder (if applicable).
6. Perform an alarm/battery system test. There is usually a test button on the control panel. When activated, a visual alarm indicator light blinks and an audible tone sounds, indicating proper operation.

The unit may also have a door open alarm that sounds after being left open for more than a minute, but take the contents inside the refrigerator into account. If the contents are sensitive to temperature changes, the fluctuations in temperature from leaving the door open could harm the product.

Common problems

If the temperature is not reaching the desired set point there could be a few different issues. First, check the door seals to ensure it is free from cracks and the cool air is not leaking out. Next check to make sure the unit is relatively level. If the unit is not level, the door might not be able to hold a good seal. Then check to make sure the compressor and fans activate as necessary. The compressor should cycle on and off, so pay attention to ensure it is completing its cycles. If the compressor is not engaging, check the compressor relay. Also, check the cleanliness of the condenser coils and fans. Excess dirt and dust can wear on the unit. Lastly, check for leaks in the units plumbing as well as the refrigerant level. A refrigerant leak can prevent the unit from getting up to temp. As most BMETs do not have certifications to work with refrigerants, be sure to have a qualified refrigeration specialist make any leak repairs.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

238. Water purification

1. What are the two types of prefilters?

2. How much particulate does a microfiber glass filter remove?

3. What are the three types of filters placed after a prefilter?

4. Where is the activated charcoal filter generally located?

5. How does the submicron filter work?

6. What is the oldest form of water purification?

7. Describe how a distillery works.

8. What is the most expensive method for obtaining reagent grade water?

9. How does the cation exchange column work?

10. How does the anion exchange column work?

11. How much deionized water should you prepare at one time?

12. What does the term reagent grade water mean?

13. What is the resistivity of water and how is it measured?

239. Suction pressure unit

1. Which type of suction device is an intermittent duty device?

2. State the principle involved in thermotic suction-pressure units.

3. Which type of suction unit is a continuous duty device?

4. State how suction and pressure is accomplished in a vane-type unit.

5. Identify some clinical uses of suction-pressure units.

6. During an operational inspection of a typical suction-pressure unit, what would be your concern in checking the in-line filter?

7. What is the general method used to verify the overflow protection system is functioning?

240. Refrigeration systems

1. How is mechanical refrigeration accomplished?

2. What function does the compressor serve?

3. What is the accumulator designed to do?

4. What action is required for the refrigerant to evaporate?

5. What are the volume requirements for an alarm sensor container?

6. Why must the electrical source for the alarm be separate from that of the refrigerator?

7. When should the alarm silence button be used?

8 Describe the function of a central monitoring system.

9. Describe the function of a remote monitoring system.

10. What is the chart recorder used for on a refrigerator?

11. How many days does the chart recorder paper cover?

12. What type of pen is preferred for use on the chart recorder?

13. What should you use to clean the condenser coils?

14. Who should perform repairs when you have a refrigerant leak?

Answers to Self-Test Questions

235

1. (1) Washing machine.
   (2) Washer/disinfector.
   (3) Ultrasonic cleaner.
2. Consists of high-powered acoustic energy being applied to solid objects immersed in a light viscosity liquid.
3. Cavitation.
4. Soluble binders go into the solution in the bath water; the heavier insolubles settle to the bottom of the cleaning tank.
5. 80° and 110º F; protein will coagulate and be more difficult to remove.
6. If excess gas is present in the cleaning water, it will decrease cleaning efficiency.
7. Decontaminate and remove foreign matter from glassware and surgical instruments.

236

1. By removing blood, bone, fat, and other organic debris that can adhere to surfaces and crevices, which provide a substrate for growth of microorganisms.
2. They do not have a steam sterilization cycle.
3. It keeps contaminated material away from clean areas where instruments are packed before final sterilization.
4. Distilled or deionized.
5. Multi-chamber units.
6. It helps to prevent cross-contamination by only allowing one door to open at a time whenever power is on.
7. Between 150 and 240° F (66 and 116° C).
8. To ensure they are clean, free of cracks, and remain secured to the unit.

237

1. (1) Chemical agents.
   (2) Heat.
   (3) Gas.
2. Do not ensure a complete sterilization.
3. Flame.
4. Moist heat.
5. For the sole purpose of attaining higher temperatures.
6. It interferes with the penetration of steam into packages being sterilized, it must be removed for steam to thoroughly penetrate the materials.
7. (1) Pressurize.
   (2) Exposure.
   (3) Depressurize.
   (4) Dry.
8. Gravity-displacement.
9. Gravity-displacement.
10. (1) Prevacuum.
    (2) Condition.
    (3) Prevacuum.
    (4) Exposure.
    (5) Depressurize.
    (6) Dry.

11. The conventional prevacuum sterilizer has two prevacuum stages in its cycle; the pulsing prevacuum draws five partial vacuums throughout its cycle.
12. Aids the drying process by allowing air to enter the chamber to replace the steam.
13. Conventional spring-loaded valve that opens when the pressure in the jacket exceeds the spring tension.
14. 100° – 300º F.
15. Steam could escape through the crack, causing burns to the operator or bystander.
16. Filters.
17. Autoclavable holding thermometer.
18. Used to eliminate all living micro-organisms in goods such as dressings, bandages, sponges, instruments, utensils, water, and other solutions.
19. (1) A glass tube containing a small tablet that melts or fuses.
    (2) A paper indicator.
    (3) A glass tube containing a live culture.
20. Hydrogen peroxide.
21. (1) Vacuum.
    (2) Injection.
    (3) Diffusion.
    (4) Plasma.
    (5) Vent.
22. A steam generator.

238

1. (1) Cotton filter.
   (2) Microfiber.
2. 98 percent or more.
3. (1) Activated charcoal.
   (2) Ultraviolet.
   (3) Submicron.
4. Immediately after the prefilter, but before the deionizer or distillery.
5. By removing all particles and microorganisms larger than the pore size of the filter.
6. Distillation.
7. The process heats the water until it reaches the boiling point. The steam with the impurities from the boiling water rises, and then cools in a condenser. The steam releases the impurities as it returns to the liquid state. This water is collected in a reservoir as distilled water. The impurities return to the boiler and drain off.
8. Distillation.
9. The cation exchange column contains an insoluble resin core that reacts with positive charged ions; this reaction releases an H+ ion.
10. Negative charged ions react with the column, which produces a reaction that releases an OH– ion; the two released ions, H+ and OH–, join together to form H_2O.
11. Only prepare the amount you need to accomplish the test.
12. The actual purity of water.
13. The electrical resistance of the water; between opposite faces in a 1-cm cube container and reported in megaohm/cm.

239

1. Thermotic aspirator.
2. The heating and cooling of air opens and closes valves, creating a vacuum.
3. Vane.
4. Spinning vanes pull air in from the suction outlet and push it out of the pressure outlet.

5. Suction is used in aspirating saliva, bodily fluids, and surgical sites; pressure can be used to administer medications by spray, administer anesthetics, or any use requiring air under pressure.
6. They provide an added safeguard against cross-infection, so you should use infection control procedures when changing the filters.
7. Aspirate enough fluid into the collection bottle until the protection system activates.

240

1. By continuously circulating, evaporating, and condensing a fixed supply of refrigerant in a closed system.
2. It pumps gas from the evaporator through the accumulator.
3. Protect the compressor by preventing slugs of liquid refrigerant from passing directly into the compressor.
4. The liquid must absorb heat from the air passing over the evaporator.
5. Volume should be no larger than the smallest volume stored, normally 200 to 250 milliliters (mL).
6. Because the alarm must be able to signal if the refrigerator power goes off and the temperature climbs. If the alarm is hooked up to the same power source, it turns off when the refrigerator loses power.
7. To silence the alarm after the repair person has been called, or when you are working on the refrigerator and do not want the alarm screaming in your ears.
8. Equipment parameters are relayed to a building automation system that is constantly monitored by facility personnel. It can also store logs, allowing you to go back and verify the equipment's status over a period of time.
9. The alarm connects to a programmable monitor attached to a phone line. When the refrigerator strays outside of acceptable tolerances, it calls down the list of programmed numbers with an automated message of the system's status.
10. To keep a permanent and accurate temperature record.
11. Seven.
12. A felt-tip pen.
13. A vacuum and a soft brush.

14 A qualified refrigeration specialist.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to AFCDA.

88. (235) What are the three ways surgical instruments can be *mechanically* cleaned?
    a. Washing machine, washer/disinfector, and ultrasonic cleaner.
    b. Hand washed, washing machine, and washer/disinfector.
    c. Washer/disinfector, ultrasonic cleaner, and hand washed.
    d. Ultrasonic cleaner, washer/disinfector, and sterilizer.

89. (235) The frequency range for *most standard* ultrasonic cleaning applications is
    a. 20 – 40 kilohertz (kHz).
    b. 20 – 40 megahertz (MHz).
    c. 25 – 35 kHz.
    d. 25 – 35 MHz.

90. (236) What kind of water is used in a washer/disinfector rinse cycle?
    a. Deionized or degassed.
    b. Distilled or deionized.
    c. Degassed or distilled.
    d. Distilled or pure.

91. (236) Which is *not* a cycle found on a washer/disinfector?
    a. Drying.
    b. Pre-wash.
    c. Prevacuum.
    d. Thermal rinse.

92. (237) How can you determine if a sterilizer safety pop off valve activated?
    a. An indicator light eliminates.
    b. The safety wire is broken.
    c. The valve remains open.
    d. The safety wire is intact.

93. (237) The clinical application of a sterilizer is to
    a. eliminate living micro-organisms.
    b. create micro-organisms.
    c. eliminate tissue.
    d. clean tissue.

94. (237) Sterilization indicators for quality control include
    a. melting tablet, live culture, and thermometer.
    b. indicator paper, thermometer, and live culture.
    c. melting tablet, indicator paper, and live culture.
    d. live culture, indicator paper, and temperature pill.

95. (237) What solution is used in plasma sterilization?
    a. Hydrogen peroxide.
    b. Steam.
    c. Water.
    d. Gas.

96. (238) How many reagent grades of water are used in the clinical laboratory?
    a. 2.
    b. 3.
    c. 4.
    d. 5.

97. (239) The thermotic aspirator operates on the principle of
    a. vanes spinning over openings, drawing air in, and then forcefully pushing it out.
    b. heating an enclosed volume of air to a given temperature, causing it to expand.
    c. heating air as it is drawn in by vanes on a motor, and then forcefully expelled.
    d. creating suction through the use of a venturi.

98. (239) The *typical* suction pump has three vanes that produces how many inches of water suction and pressure?
    a. 10; 20.
    b. 10; 30.
    c. 20; 20.
    d. 20; 30.

99. (240) Where in the refrigeration process is heat *removed* from the gas?
    a. Condenser.
    b. Evaporator.
    c. Compressor.
    d. Accumulator.

100. (240) The chart paper is replaced in the refrigerator chart recorder *every*
    a. 2 days.
    b. 4 days.
    c. 5 days.
    d. 7 days.

Glossary of Abbreviations and Acronyms

µm	micrometer
AC	alternating current
AMA	actual mechanical advantage
APL	automatic pressure limiter
AV	atrioventricular
BMET	biomedical equipment technician
bpm	breaths per minute; beats per minute
CCU	critical care unit; cardiac care unit
CD	compact disc
CF	crest factor
CFR	Code of Federal Regulations
CGA	Compressed Gas Association
CHCS	Composite Health Care System
Cl	chloride
CLRW	clinical lab reagent water
CLSI	Clinical and Laboratory Standards Institute
cm	centimeter
cmH_2O	centimeter of water
CO_2	carbon dioxide
COAG	coagulation
CPAP	continuous positive airway pressure
CPR	cardiopulmonary resuscitation
C_SOH	cesium hydroxide
CSS	central sterile supply
DC	direct current
DOT	Department of Transportation
DPDT	double-pole, double-throw
DVT	deep vein thrombosis
EKG	electrocardiogram
EPA	Environmental Protection Agency
EPAP	expiratory positive airway pressure
ER	emergency room
ESU	electrosurgical unit
FDA	Food and Drug Administration

FRC	functional residual capacity
H	hydrogen
H_2O	water
He	helium
HeNe	helium-neon
HFJV	high-frequency jet ventilation
HFO	high-frequency oscillator
HFOV	high-frequency oscillatory ventilation
HIDS	host intrusion detection system
HNP	herniated nucleus pulposus
HPLC	high performance liquid chromatography
HVE	high volume evacuation
Hz	Hertz
I:E	inspiration-to-expiration
ICU	intensive care unit
IFW	instrument feed water
IMA	ideal mechanical advantage
IMV	intermittent mandatory ventilation
IT	information technology
IV	intravenous
IVF	in vitro fertilization
KCl	potassium chloride
kHz	kilohertz
KOH	potassium hydroxide
KVO	keep vein open
KVpp	peak-to-peak voltage
kW	kilowatt
L/min	liters per minute
LASER	light amplification by stimulated emission of radiation
LCD	liquid crystal display
LC-MS	liquid chromatography–mass spectrometry
LED	light-emitting diode
LVDT	linear variable differential transformer
mA	milliampere
MAP	mean airway pressure
megaohm/cm	one million ohms per centimeter

MHz	megahertz
mL	milliliter
mmHg	millimeter of mercury
ms	millisecond
MTF	medical treatment facility/military treatment facility
mW	milliwatt
N_2	nitrogen
N_2O	nitrous oxide
Nd	neodymium
NEEP	negative end-expiratory pressure
NFPA	National Fire Protection Association
NMES	neuromuscular electrical stimulation
NTC	negative temperature coefficient
O_2	oxygen
OH	hydroxide
ohm	international standard for resistance
OR	operating room
PE	pulmonary embolism
PEEP	positive end-expiratory pressure
PII	personally identifiable information
PISS	pin index safety system
PM	preventive maintenance
PMI	patient movement item
PN	positive-negative
PPM	parts per million
PRV	pressure-reducing valve
psi	pounds per square inch
psia	pounds per square inch absolute
psig	pounds per square inch gauge
RCS	remote calibration system
RF	radio-frequency
ROM	range of motion
S3	Surgical Scheduling System
SA	sinoatrial
SCD	sequential compression device
SPD	sterile processing department

SpO_2	saturation of peripheral oxygen
SRW	special reagent water
SSN	social security number
TENS	transcutaneous electrical nerve stimulation
TMP	transmembrane pressure
TPN	total parenteral nutrition
US	ultrasound
W	watt
W/cm^2	watts per centimeter squared
YAG	yttrium-aluminum-garnet
ZEEP	zero end-expiratory pressure

Student Notes

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