Making and Replacing Obsolete Gun Parts (#) Lesson: 2184

OBJECTIVES 3

INTRODUCTION 3

HEAT-TREATMENT OF STEEL 4
- Tempering 4
- Annealing 4
- Forging 4
- Normalizing 5
- Carburizing 5
- Hardness Testing 5
- Heat For Heat-Treating 7
- Thermocouple Pyrometers 8
- Hardening And Tempering 8
- Self- Test Questions 9

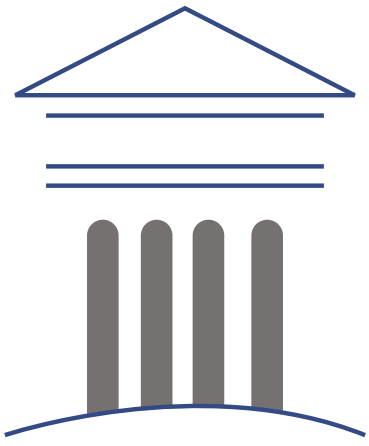
OBTAINING GUN PARTS 10

MILLING AND GRINDING 11
- Speed And Feed 12
- Depth Of Cut 12
- Measuring Cutting Speed 13
- Holding The Work 13
- Adjusting The Cutter 13
- Examining The Machine 14
- Choosing The Cutter 14
- Choice Of Machine 17
- Indexing 18
- Self-Test Questions 18

MAKING SPRINGS 19
- Spring Stock 19
- Initial Preparation 20
- Making The V Spring 21
- Making Complex Springs 23
- Forming Hooks 24
- Making Gun Parts 25
- Self-Test Questions 25

ANSWERS TO SELF-TEST QUESTIONS 26

LESSON QUESTIONS 27





Objectives

After completing this lesson, you should

1. Be familiar with the colors that steel will turn at certain temperatures.
2. Know to what temperature steel is heated in order to harden it.
3. Understand the use of a thermocouple pyrometer.
4. Know the temperature that steel is heated to in order to temper it.

Introduction

There are millions of obsolete firearms needing repairs and replacement parts. Some parts are available from manufacturers; others are available from dealers who specialize in obsolete gun parts; others simply are not available at all. In fact, in the near future, much of a gunsmith's work probably will consist of manufacturing parts to restore obsolete firearms, and those gunsmiths who are prepared for this work can, and will, reap dividends.

Using a metal file, you can shape almost any gun part by hand from a piece of metal stock, but this takes time and patience. This practice is too time-consuming to be worthwhile. Most gunsmiths use power tools (lathes and milling machines) to turn out replacement parts for obsolete firearms. Even with power tools, turning out a single gun part can be costly. Therefore, whenever available, a replacement part should be purchased.

Most metal components that combine to make a complete firearm, including screws like the ones shown in Figure 1, must be made to accurate dimensions for the gun to function properly. However, regardless of how accurately and nicely finished they are, most gun parts will be of little value if they are not heat-treated properly before their installation. Such treatment can include hardening, tempering, annealing, forging, normalizing, and carburizing. In general, heat-treatment is applied most to carbon and alloy steels.

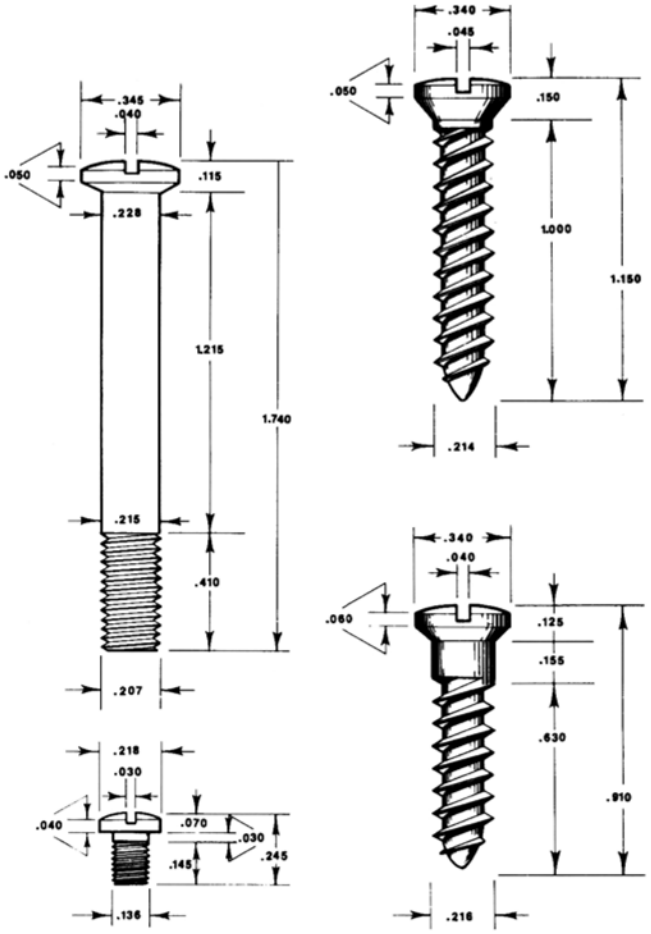


***Figure 1**: Gun screws, even those turned to exact dimensions, would quickly become worn if they were not heat treated before being placed in a firearm.*

Heat-Treatment of Steel

Hardening steel is the process of imparting certain physical properties to the steel so it will resist wear, have tensile strength so it will not stretch or strain, and have sufficient impact strength to withstand blows. The degree of heat and the length of time the heat is applied in each case depend on the material the piece is made of, the shape and size of the piece, and how the piece will be used.

Hardening steel consists mainly of heating the part to a predetermined temperature for a predetermined length of time. The temperature at which steel will harden most efficiently is called the *critical temperature*, or *point of recalescence*. In some cases, the part may be heated somewhat beyond this temperature, then quickly immersed in water, which is known as the quench. Many steels used for making firearm parts are quenched in oil or a combination of oil and water, while others are allowed to cool in still air. This latter method is often used when making springs.

TEMPERING

All steel parts that are heated to a high temperature and immediately quenched are subjected to internal strains. When exposed to sudden changes in temperature, the steel is likely to crack unless these strains are relieved by the heat-treating procedure known as *tempering*, sometimes called *drawing*. The procedure involves reheating the steel to a lower temperature than it was subjected to during the hardening process, usually between 300˚ and 600˚ F, depending on the degree of hardness desired. Once the tempering temperature has been reached and maintained for the predetermined time, the part should not be quenched; rather, it should be allowed to cool in still air.

ANNEALING

Hardened steel is normally not in a machinable state and must therefore be annealed during the work stage and then rehardened once the machining operation has been completed. *Annealing* is done by applying heat at a temperature of about 15˚-100˚" F below the critical point. The annealing process, when performed correctly, demands a slow, increasing heat until the desired temperature is reached. Then the part is allowed to cool slowly; it is never quenched.

FORGING

In most cases, steel must be heated to *forging* temperatures before it can be shaped. Parts to be forged should be heated slowly to the required temperature, which is usually 200˚- 350˚ F above the critical point. After the steel is removed from the furnace, or forge, it is allowed to cool in still air, away from drafts and dampness.

NORMALIZING

The *normalizing* process is similar to tempering, but the term is usually applied to work that has been forged. Most modern steels do not require this process unless excessive forging strains have been applied. Normalizing requires a temperature 50˚- 75˚ F above the critical point. Gun barrels that have been forged, bored, and rifled often are normalized to relieve stresses so that they will remain straight when tapered, chambered, and threaded to fit on a receiver.

CARBURIZING

Carburizing is a heat-treating process that uses special gases to introduce an extra amount of carbon to low-grade steels so they can be used as substitutes for more expensive steels. This process is also known as case hardening because it is a surface-*hardening* process. The resulting carbon content and depth of hardening, or "case," will depend on the packing mixture, type of equipment, and heating time.

Parts to be case hardened must be machined to dimensions, yet allowances for ground finishes can be made by estimating and controlling the depth of case, which may be $^{3}/_{16}$" and over. If you do the work properly, the result is a uniformly hard exterior section with no effect on the core or internal structure of the steel. A quench bath is normally used after each part or batch of parts has been heated for the required period of time.

Carburizing is not the only form of surface hardening. *Nitriding* is a similar process that uses ammonia gas as a treating agent. There are also many other methods in current use. A cyanide bath is frequently used when a shallow case is desired, but cyanide is an extremely dangerous chemical to use, and only experienced persons should use it.

Flame-coloring is another method used to obtain a simulated case-hardened effect, especially where there is little surface wear. Induction hardening is another method, which is done by placing the work inside a magnetic field set up by an inductor coil which carries high-frequency currents. The heating and quenching cycle takes only a few seconds for each part.

A cold-treating furnace is often used to stabilize the steel used in precision instruments like calipers, micrometers, etc. The furnace is actually a carbon dioxide refrigerator in which the temperature can be reduced to 120˚ Fahrenheit. This treatment stabilizes the steel and offsets the effects of subsequent temperature changes.

HARDNESS TESTING

Hardness testing involves making an impression on the surface of the steel; the deeper the impression, the softer the metal. One system of hardness testing that has been in use for many years is the *Brinell System*. With this system, a hardened steel ball is pressed into the smooth surface of the metal, making an indentation that can be measured under a microscope. The diameter of this indentation has a definite relationship to the hardness of the metal. Brinell Machine manufacturers supply tables showing how these figures relate. From these tables, the hardness number can be obtained.

The *Rockwell method* of testing has been the most popular hardness-testing method for the past several decades. With this method, a dead weight controlled by a series of levers presses a diamond cone into hard metals or a $^{1}/_{16}$" steel ball into softer metals. Fully hardened steels are tested on the C scale with a 120˚ diamond point, while softer metals such as annealed or partially hardened steel are tested on the B scale, using a steel ball. The depth of penetration is measured, and the hardness value is read directly on a dial scale. The harder the material, the higher the Rockwell number. Figure 2 shows a Rockwell Hardness Tester.

The Rockwell method of testing is especially efficient and reliable on fully hardened steels. However, the Brinell method is considered more accurate and reliable for softer materials. The Superficial Rockwell tester is used on very thin sheet or strip steels or to measure hardness at the immediate surface, since it measures only about 0.0003" deep, while the standard C scale measures about 0.005" deep.



***Figure 2**: A Rockwell hardness tester.*

Regardless of what material is being tested, the piece must have a clean, uniform surface in order for you to obtain accurate readings. The usual practice is to either grind both the place to be tested and the portion which rests upon the supporting pedestal or rollers, or to clean them by sand blasting, polishing with an emery cloth, or filing.

Instructions for using the Rockwell Hardness Tester are as follows:

- Select the proper penetrating point, clean it thoroughly, place it in the head plunger rod, and tighten it in place.
- Select the proper anvil, clean it thoroughly, and place it on the elevating screw.
- Place the work to be tested securely upon the anvil or table.
- Elevate the specimen into contact with the penetrator and turn the elevating screw until the small pointer is nearly vertical and slightly to the left of the dot. Then turn the screw slightly more until the large pointer is pointing upward.
- Turn the bezel of the dial gauge until the Set arrow on the scale is exactly behind the large pointer.
- Push the crank handle backward. This procedure has applied the load of 100 kilograms.
- Pull the crank handle to the starting position. This lifts the major load, but leaves the minor load on.
- Read the Rockwell C Hardness number, lower the elevating screw, and remove the work from the machine.

Dia. in mm., 3,000 kg. load 10 mm. Ball.	Hardness No.	C 150 kg. load 120° Diamond Core	B 100 kg. load 1/16 in Dia. Ball	Shore Scleroscope No.	Tensile Strength 1,000 psi.
2.05	898	—	—	—	440
2.10	857	—	—	—	420
2.15	817	—	—	—	401
2.20	780	70	—	106	384
2.25	745	68	—	100	368
2.30	712	66	—	95	352
2.35	682	64	—	91	337
2.40	653	62	—	87	324
2.45	627	60	—	85	311
2.50	601	58	—	81	298
2.55	578	57	—	78	287
2.60	555	55	120	75	276
2.65	534	53	119	72	266
2.70	514	52	119	70	256
2.75	495	50	117	67	247
2.80	477	49	117	65	238
2.85	461	47	116	63	229
2.90	444	46	115	61	220
2.95	429	45	115	59	212
3.00	415	44	114	57	204
3.05	401	42	113	55	196
3.10	388	41	112	54	189
3.15	375	40	112	52	182
3.20	363	38	110	51	176
3.25	352	37	110	49	170
3.30	341	36	109	48	165
3.35	331	35	109	46	160
3.40	321	34	108	44	150
3.45	311	33	108	44	150
3.50	302	32	107	43	146
3.55	293	31	106	42	142
3.60	285	30	105	40	138
3.70	269	28	104	38	131
3.75	262	26	103	37	128
3.80	255	25	102	37	125
3.90	241	23	100	35	119
3.95	235	22	99	34	116
4.00	229	21	98	33	113

Figure 3: *Hardness conversion table.*

The table in Figure 3 show the relation of the Rockwell and Brinell scales as well as approximate tensile strengths.

Another type of tester is the *Scleroscope Hardness Tester.* With this method of testing, a diamond-tipped hammer falls a fixed distance onto the polished tool surface. You observe the height of the rebound, reading the hardness value from a dial positioned on the instrument.

To operate the scleroscope, lower the instrument onto the work held in the anvil. Turn the knurled knob clockwise for about $^{5}/_{8}$ of a turn or until it reaches interval stop. At this point the rebound occurs, and the height of the rebound is indicated on the dial. Releasing the instrument returns it for another cycle of operation. The instrument has the capacity for about 1,000 tests per hour. The hardness values are indicated on a dial scale graduated from 0 to 140.

There is a relation between Rockwell C and Scleroscope hardness. For 62 Rockwell C, the scleroscope reading is 86; for 65 Rockwell C, the scleroscope reading is 92. The table in Figure 3 compare the various testers.

HEAT FOR HEAT-TREATING

When hardening was mainly confined to certain lock parts on muzzleloading rifles and shotguns (for example, the trigger/hammer mechanism), the pieces were simply heated in a blacksmith's forge and plunged into water. Though a skilled worker can still obtain good results this way, this method is no longer compatible with most modern gunsmithing requirements. Now, torches or heat-treating furnaces are used.

There are two distinct types of heat-treating furnaces: the box furnace (shown in Figure 4) and the pot, or crucible, furnace. Both types can be used for all the heat-treating processes previously mentioned. Sources of heat can be natural gas, LP gas, charcoal, electricity, or oil. Of these fuels, electricity, used in electric furnaces, is most commonly used for heating small gun parts.

For heavier classes of work, where lumps of steel have to be heated for forging and rolling operations (for use in firearm receivers, for example), the pieces are handled in a reheating furnace. The ingots, or billets, are laid on a table and pushed into the furnace by a hydraulic or electric pusher, which regulates the speed of the work through the furnace. During their passage, the pieces are carried on water-cooled rails or skid bars.



Figure 4: *A box furnace.*

With the box furnace, the heat-treating is done directly by the heat that is produced within the chamber. With the crucible furnace, the parts to be treated are immersed in a red-hot lead or salt bath. The size of both types of furnaces will vary from huge devices suitable for heat-treating cannon barrels to small bench-top models used for delicate parts for instruments and firearms.

Heat-treating furnaces range in price from a few hundred dollars to several thousand dollars, depending upon size, types of controls, etc. Investing in an electric heat-treating furnace ensures complete control over hardening, tempering, and annealing such items as drift pins, sears, reamers, springs, and many other gun parts and tools requiring proper hardening.

THERMOCOUPLE PYROMETERS

Many gunsmithing shops build simple heat-treating furnaces for specific projects, and most of these homemade furnaces are equipped with some means of measuring the temperature. The most common means is a thermocouple pyrometer with an automatic heat control to maintain the desired temperature for the entire heating period. In general, t*hermocouple pyrometers* consist of two different types of metal or alloy wires, separated from each other except at one end, where they are securely twisted and welded so that both metals will unite. The free ends of the wires are connected to a DC millivoltmeter, while the welded end is inserted where the temperature is to be measured. The heat at this end causes a difference in electric potential; this is indicated on the millivoltmeter, which is calibrated in degrees.

HARDENING AND TEMPERING

To be successful, any form of heat-treatment on critical parts must be done in strict accordance with the recommendations of the steel makers. However, many experienced gunsmiths are skillful in judging the correct temperature at which certain steels should be quenched to obtain the proper hardness. Gunsmiths sometimes use color charts, such as the ones in Figure 5, to show the different colors steel turns when it is heated to various temperatures. Instructions in some gunsmithing books may read, "Quench from a cherry red and draw to a light straw." But these rules-of thumb are for use only by workers with years of experience — especially when dealing with gun parts that will receive working stresses.

Many gunsmiths are able to quickly harden noncritical parts, such as gun screws or drift pins, by using a torch. Such parts usually can be hardened by the rule-of-thumb methods with satisfactory results.

Carbon and alloy steels normally come in a soft or annealed condition in which they can be machined; if they are forged, they may be further annealed or normalized to correct any adverse effects of the forging operation.

Tool Steels. The common types of straight carbon or low-alloy steels that are intended for water quenching are usually heated to about 1,450° F and then plunged quickly into water. If the entire part is to be hardened, it is important that the heating be uniform and thorough.

On some tools it is common practice to heat only the portion of the tool you want to be hard, or sometimes to heat the whole piece, but quench only that portion that must be hard. However, in doing so, you must take care to ensure that the portion that is only partially hardened has no weak section.

The preferred method for creating different degrees of hardness in the same part is to temper to a higher temperature the portion which you want to be softer than the hard part. Temper the quenched part as soon as it is cool enough for you to handle with your bare hands. Tempering temperatures may vary from 225° F to as high as 800° F, but usually a range of 300°- 400° F is used. In some instances you can judge these temperatures by color, but it is usually best to use a heat-treating furnace so you can accurately control the temperature.

The common types of oil-hardening steels are usually quenched in a special type of quenching oil from a temperature

TEMPER COLORS FOR CARBON TOOL STEEL

Color	Degrees Fahrenheit	Degrees Celsius
Very Faint Yellow	420	215
Light Yellow	440	227
Straw Yellow	460	238
Dark Yellow	480	250
Yellow-Brown	490	255
Spotted Red-Brown	510	265
Brown-Purple	520	270
Full Purple	540	280
Dark Purple	550	288
Full Blue	560	293
Dark Blue	570	300

HEAT COLORS IN MODERATE, DIFFUSED DAYLIGHT

Color	Degrees Fahrenheit	Degrees Celsius
White	2,250	1,230
Light Yellow	2,100	1,150
Yellow	1,950	1,065
Lemon	1,830	1,000
Orange	1,725	940
Dark Orange	1,630	890
Salmon	1,550	840
Bright Cherry	1,450	790
Cherry	1,375	745
Dark Cherry	1,240	670
Blood Red	1,095	590
Faint Red	985	530

Figure 5: *Tables for average temper and heat colors.*

of about 1,475° F. These steels should be tempered as soon as they cool. The temperature range for oil-hardening steels is usually 300°- 450° F. Should any warpage occur, it can usually be corrected while the temperature from quenching is still about 500° F. If you attempt this while the piece is cold, it will probably fracture.

Most high-carbon, high-chrome steels can be quenched in either oil or air. If quenched in oil, the quenching temperature should be about 1,750° F; in air the temperature should be about 1,825° F.

These steels can be drawn over a wide range of temperatures up to about 900° F without a great reduction in hardness. They maintain accuracy in size very well during hardening, especially when air cooled.

Other types of air-hardening steels can be hardened in air from 1,550° to 1,800° F. As stated before, the tempering range for these steels is about 300°-400° F.

High-speed steels are usually hardened in oil or air from about 2,350° F and are almost invariably preheated to about 1,600° F. The time at high heat is limited to just long enough to heat the steel properly, since overheating will cause the steel to expand and can even burn the edges. Tempering is usually done at about 1,050° F. However, a wide variety of quenching temperatures and drawing temperatures are often combined to obtain special values in toughness and hardness. Heating in a special atmosphere, heating in neutral salt baths, quenching in hot lead at about 1,000° F, and other special methods are often used with high-speed steel to obtain good surface results.

When working with tool steels, do not allow undue strains to occur during heating or quenching, or the steel can crack and fracture. Experience and good judgment are very important when working with tool steels. It is always a good idea to preheat tool steel so that it cannot be forced through the range of transformation, or critical range, at a high speed of heat absorption. It is also a good idea to protect the surfaces of intricate parts by packing them in a neutral material such as cast-iron chips or used carburizing compound before the heating operation.

SELF- TEST QUESTIONS

Please check your answers on page 26.

1. ***True or False*. In most cases, once gun parts have been shaped to exact dimensions, no further treatment is necessary.**
2. **What type of instrument are most heat-treating furnaces equipped with to measure the temperature?**
3. ***True or False*. When using a Rockwell Hardness Tester, the harder the material, the higher the Rockwell number.**
4. **To what is the temperature that metal is usually heated before undergoing forging?**

Obtaining Gun Parts

Gun parts for any currently manufactured firearm are usually available from the manufacturer. Manufacturers also keep a supply of parts for discontinued models for as long as their present supply lasts. The Numrich Gun Parts Corporation (located in West Hurley, New York, www.gunpartscorp.com) buys surplus parts from manufacturers and offers parts for most firearms. This is one source to consider when trying to obtain parts for obsolete firearms (Figure 6).

To obtain a catalog and dealer price list, send them a signed copy of your F.F.L. Otherwise, you will receive a retail price list. Below is a list of addresses and websites of companies that deal in obsolete gun parts. *Please note that this listing is current at time of printing but some companies may no longer be in business.*

Bushmaster Firearms International
P.O. Box 556
Madison, NC 2702
800-883-6229
www.bushmaster.com

Caspian Arms, Ltd.
75 Cal Foster Dr.
Wolcott, VT 05680
802-472-6454
www.caspianarmsltd.com

Charles E. Duffy
Williams Lane
West Hurley, NY 12491
(845) 679-2997

Essex Arms
190 Junction Rd.
Hardwick, VT
802-472-3215
www.essexarms.com

Numrich Gun Parts Corp.
226 Williams Ln.
Kingston, NY 12401
866.686.7424
www.gunpartscorp.com

Gunpatch Parts Depot
23393 SW Pilot Pt. Rd.
Douglass, KS 67039
316-746-3071

Hansen and Co.
244 Old Post Rd.
Southport, CT 06890
203-259-7337
hansenguns.com

Hastings Distribution LLC
PO Box 250
Hanover, PA 17331
785-632-3169
www.hastingsbarrels.com

Walter H. Lodewick
2816 N.E. Halsey
Portland, OR 97232-1748
503-284-2554

John V. Martz
8060 Lakeview Lane
Lincoln, CA 95648-9401
916-645-2250

Olympic Arms, Inc.
624 Old Pacific Highway SE
Olympia, WA 98513
(800) 228-3471
www.olyarms.com

Sarco, Inc.
50 Hilton Street
Easton PA 18042
(610) 250-3960
www.sarcoinc.com

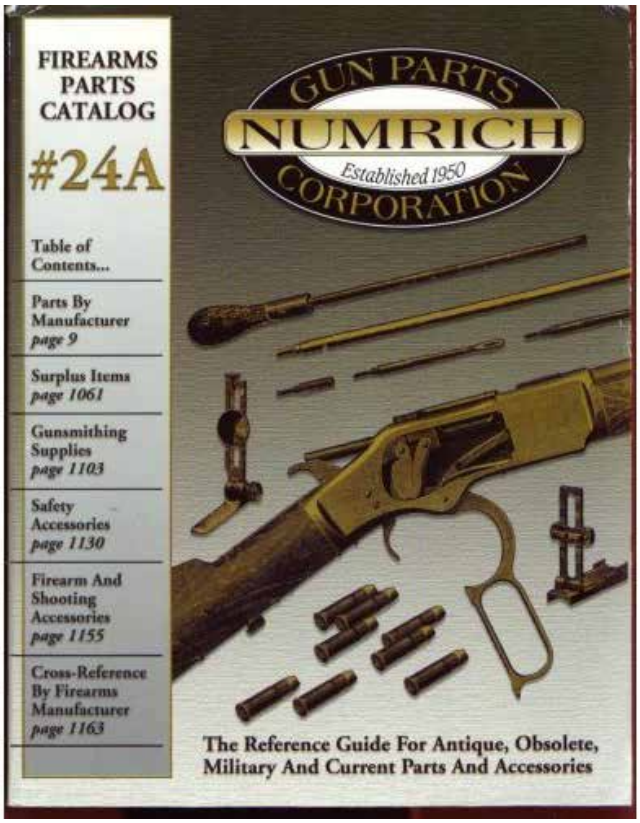


***Figure 6**: The Numrich Gun Parts Corporation has been around for a long time. It has become the "bible" of obsolete gun parts.*

Milling and Grinding

The milling machine is a versatile, power-driven machine tool that performs a variety of machining operations quickly and accurately. It is particularly useful when a large number of interchangeable pieces must be cut to exact dimensions, and it is adaptable to both large and small parts of intricate design. In fact, manufacturing of the modern firearm would not have been practical without the milling machine.

The two main elements of the milling machine are a movable table and a revolving cutter. The table carries the work to a rotating cutter, which remains in a fixed position while the work moves to form the shape or design. You can usually adjust the speed of the cutter from 50 rpm to 500 rpm or more.

To use the milling machine, first secure the workpiece to the milling table with clamps. You can then adjust the table — up or down in a vertical plane, back and forth horizontally, or in a cross-feed manner — to manipulate the work under the cutter. These movements can be made under power by means of rapid-transverse controls, or by duplicate hand controls. In mass-production operations, the table is often manipulated by computer controls that automatically adjust the table to form the desired shape of the workpiece. When precision work is required on only a few pieces, the adjustments are usually made with calibrated hand controls on which each graduation represents 0.001" of table movement.

Depending upon the type of milling machine — horizontal or vertical (Figure 7 and Figure 8) — the operator first selects and adjusts the revolving cutter. For a horizontal milling machine, an arbor shaft is fitted into the power-driven spindle. Spacing collars are used to locate the cutter at any position on the arbor, while additional collars and a key hold the cutter in place when the arbor nut is tightened and locked to provide a positive drive. A large collar is then set on the end of the arbor to act as a bearing for the overarm bracket, which is slid out and locked in place to support the shaft.

The selection and mounting of the cutter depend on the construction of the machine and the type of work to be performed. The relation of the headstock to the table must first be determined; that is, whether it should be on the right side or the left side of the table. Furthermore, the direction of cutting movement and the rotation of the cutter teeth must be determined. In general, the cutter should be as small as the job permits, since a shorter cut will allow for greater feed speeds and will require less power.

On most machines, you can set the cutter in motion by engaging a quick-acting clutch. The work is then carried up to the cutter and is secured against vibration by various levers. You can set a selective feed indicator, graduated in inches per minutes, to govern the speed at which the work is fed.

Successful milling depends upon the flexibility of movement of the table, the accuracy with which the work is adjusted in relation to the cutter, and the use of the correct tools at the proper speeds. Avoid excessive speeds; they dull the cutter and produce a coarse surface. Figure 9, on the next page, shows a gang mill setup with multiple cutters for speed cutting.

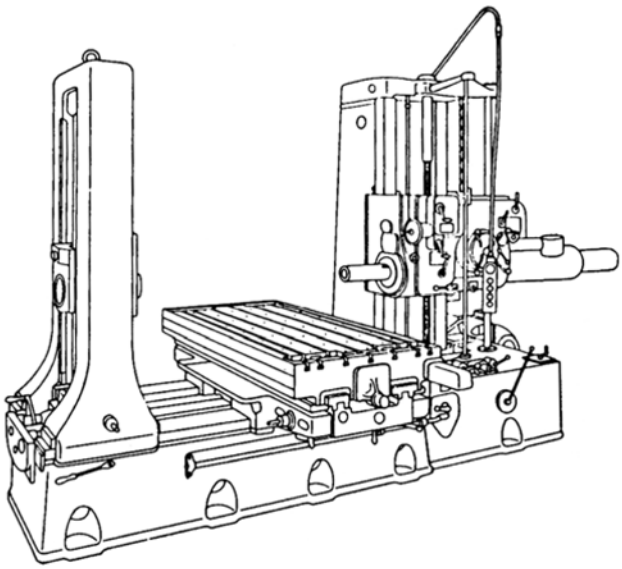


***Figure 7**: Horizontal milling, boring and drilling machine.*

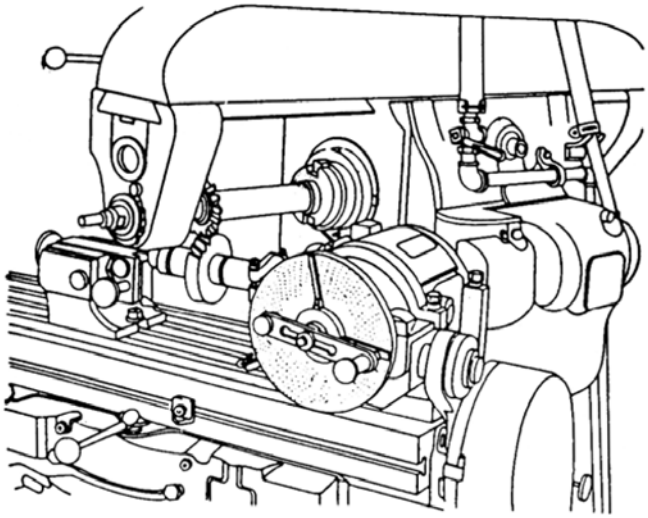


***Figure 8**: Vertical milling machine set up to mill helical gear teeth*

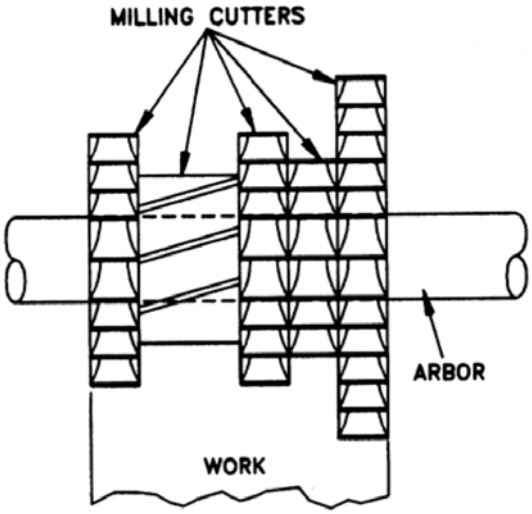


***Figure 9**: Gang-mill setup with multiple cutters.*

SPEED AND FEED

The two most vital factors for effective work are the speed of the milling cutter and the longitudinal feed of the work table. A range of cutting speeds is ordinarily provided by a gearcase on the milling machine, while feed is automatic in three directions.

It is not practical to give strict rules for cutting speeds and feeds on various materials, because these rules depend on shop conditions, the type of work being done, the age and condition of the milling machine, the quality of steel used for the cutters, whether the cutters are solid or inserted-tooth cutters, the skill and experience of the operator, etc. With so many variables, it is impossible to give precise figures that will apply in every case. The best we can offer is a rough guide for you to follow until you have established the best speeds and feeds for a particular job. The table in Figure 10 should get you started.

DEPTH OF CUT

Many beginning milling machine operators seem to believe that the quickest way to finish work is to make heavy cuts. Actually, it is much more effective to use a light cut with a fast feed. Unless the margin of material to be removed is very small, it is better to take numerous cuts with a fast feed than to take one heavy cut with a slow feed. The reason for this is that a heavy cut generates greater heat at the cutting edge, and this heat will draw the temper of the cutting edges of the tool. Even if the tool is made of the finest high-speed steel and will go on cutting steadily when at a red heat, excessive vibration or chatter can occur, damaging the cutting edges. Furthermore, if the cutter is an inserted-tooth cutter, in which the cutting blades or edges are an extremely hard cutting alloy such as tungsten-carbide, the vibration will probably cause fracture. Even if you make only a slightly heavier cut than is desirable, the cutter will probably need much more frequent sharpening, wasting your time and increasing your tool costs.

Another common error is to run the cutter too fast. This shortens the life of the cutting edges and uses more power, while producing an inferior finish. You can usually sharpen the teeth of milling cutters without causing them to lose their form, and frequent sharpening of the teeth is one of the essentials of successful milling.

METAL	TYPE OF CUTTER	
	HIGH-SPEED STEEL	TUNGSTEN- OR TITANIUM-CARBIDE
	ft. per min.	*ft. per min.*
Aluminum	1,300–1,600	2,600–4,900
Brass	160–200	350–380
Bronze	130–165	250–330
Cast Iron	50–65	200–230
Duralumin	980–1,300	1,960–2,450
Electron	980–1,300	1,960–2,450
Malleable Cast Iron	60–65	200–230
Mild Steel	50–65	130–200
Nickel Chrome Steel	25–45	100–130

***Figure 10**: Rule-of-thumb feeds for various types of metal and cutters.*

MEASURING CUTTING SPEED

When a workpiece is fed to the rotating cutter, the rate at which the metal shaving or chip is removed is the *cutting speed*. Cutting speed is expressed in feet per minute of the tooth edge of the milling cutter as it removes a shaving. To arrive at the correct rpm of a cutter, divide the cutting speed by the circumference in feet of the cutter. For example, if the cutter measures 2' around the circumference, and a speed of 40' per minute is desired, it will take 20 revolutions of the cutter per minute to give this rate of speed.

Feed is the distance the work advances against each successive tooth of the cutter. It is governed by the depth and width of the cut, the type of cut, the size of the cutter, the number of teeth on the cutter, the pro- portion of the thickness to diameter, the rpm of the cutter, the manner in which the cutter is mounted, the condition and power of the milling machine, and the rigidity with which the work to be milled is held.

With such a long list of variables, it is difficult to give specific recommendations regarding feed. However, in general, a roughing cut is intended solely to remove surplus metal before the final, or finishing, cut is taken, and it should have a coarse feed. Leave about $^{1}/_{64}$" for the finishing cut.

The rate of feed has a noticeable effect on the surface finish. Slower feeds usually produce a smoother surface.

In setting up a job on the milling machine, the operator should have everything at hand before starting the machine. While no great skill is required to operate a milling machine, extreme accuracy in setup is essential, and this depends on correct calculations.

HOLDING THE WORK

There are numerous ways to hold the work when using a milling machine. It can be secured directly to the worktable, gripped in a special fixture, fixed to an angle plate or other tool, held in a vise, held between centers, or held in a chuck. Test the accuracy of the holding arrangement before you begin. A clamp will damage a polished or finished surface unless the jaws are padded. Oil the threads of nuts and bolts on the mill frequently, and use the correct wrenches for tightening or loosening the nuts to prevent rounding their corners. If you use a wrench on a nut with rounded corners, it could slip, possibly injuring you.

After you have secured the job, make sure nothing has been left lying around that will damage the machine or be swept off the table and cause injury. Thin pieces should be clamped down carefully, to avoid distortion caused by excessive pressure. Rigidity of the work is essential. You should support the work with jacks or shims wherever necessary. Try to prevent the work from springing under the cutter.

Set the table as near to the machine column as possible. As you set up the job, loosen the clamping screws, but be sure you tighten them before you begin milling.

ADJUSTING THE CUTTER

The job is usually set up before the cutter adjustment is made, except when end mills or face mills are being used. After the work has been clamped down correctly, make sure the cutter is completely clean. Clean out the tapered hole in the machine spindle or collar and make sure it is dry. Clean the arbor shank of any grease and dirt, which can cause the arbor to slip in the spindle. Thoroughly clean faces before placing the cutter on the arbor. Beginners occasionally run the cutter in the wrong direction. This will smash the teeth. Check for proper direction of cutter rotation by first making sure that the driving spindle revolves in the correct manner in relation to the work, and that the cutter is properly mounted on its arbor and revolves likewise. (Figure 11).

Set the cutter as near to the spindle as the job allows. This lessens strain on the bearings and brings the job closer to the body of the machine. If you have to change the cutter, either for resharpening or because it is worn out, you do not need to take out the arbor, as long as the replacement cutter is of the same diameter. Never hit the cutter with a hammer or other instrument, either to drive it onto the arbor or to remove it. This could damage the teeth and crack the tool.

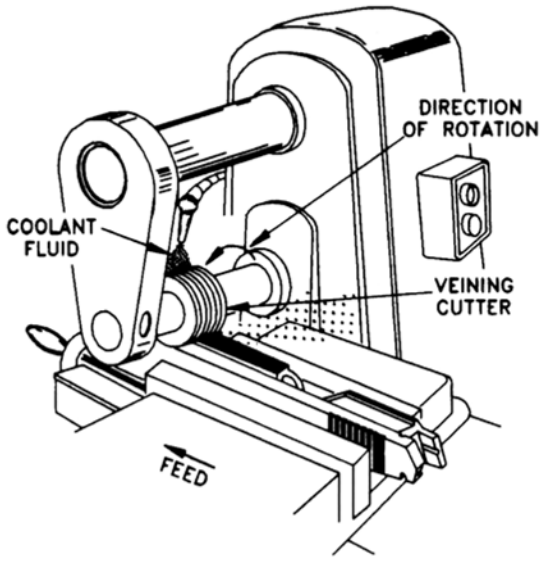


***Figure 11**: Proper direction of cutter rotation is important in milling.*

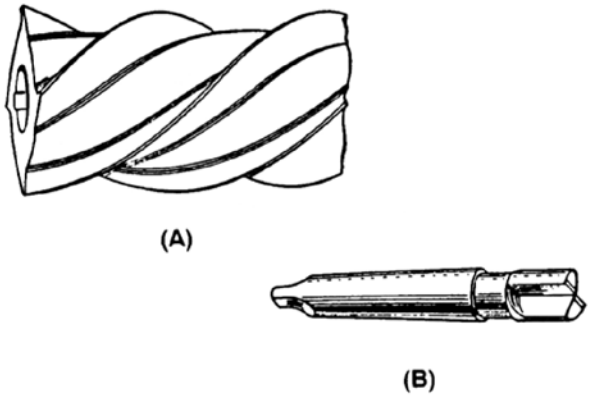


***Figure 12**: (A) A helical or spiral mill, with teeth arranged in a deep spiral around the body. (B) A two-lipped, slotting end mill.*

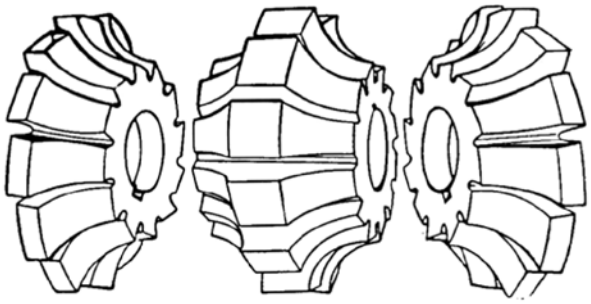


***Figure 14**: Three corner-rounding cutters for finishing edges and corners of gun receivers.*

EXAMINING THE MACHINE

If the part to be milled is small, you should loosen it a little on the worktable after you have completed the roughing cuts. This will relieve the stress caused by the clamping down, and will prevent distortion. If the work is gripped in the milling machine vise, test the zero mark (at which the swiveling angle graduations begin) for accurate positioning by putting a long straightedge in the vise and, by means of a square on the worktable, swiveling the vise until the straightedge is parallel with the slots of the table.

If the part to be milled is delicate and has thin sections, it is best to use a slow feed, even though the job will take longer. Success in milling depends on the condition of the milling machine. Do not neglect regular examination of the machine spindle, arbor, and feed screw, which, if allowed to become worn, will cause wobble or play and affect the work. Do not allow the table guides to become loose, and keep the driving mechanism in good running order.

If the job demands a heavy cut, take great care to prevent chatter. Bad mounting of the cutter on its arbor can cause considerable wear. The arbor is forced out of line under the pressure and blunts the cutter teeth. If you see that the arbor might deflect, remount the cutter close to the spindle nose, or, if it is already in position, support the arbor.

CHOOSING THE CUTTER

The choice of the right type of cutter is important for efficient milling. The cutter must have the proper form of tooth and be made of a suitable material. Several hundred different kinds of cutters are manufactured. The following paragraphs give a brief description of the more common cutters.

Helical, or *spiral*, *mills* have flat ends and their teeth are formed in a steep spiral around the body. The steeper the spiral, the smoother the cutting action (Figure 12(A)). These mills are particularly useful for milling thin metal, copper bars, and other springy materials, because they do not spring away from the work. Helical mills are also good for heavy cuts.

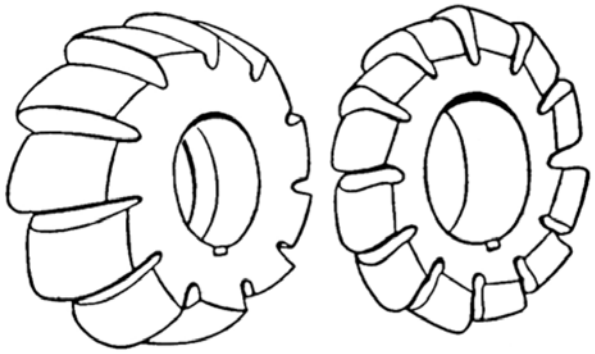


***Figure 13**: Two types of double-angle cutters.*

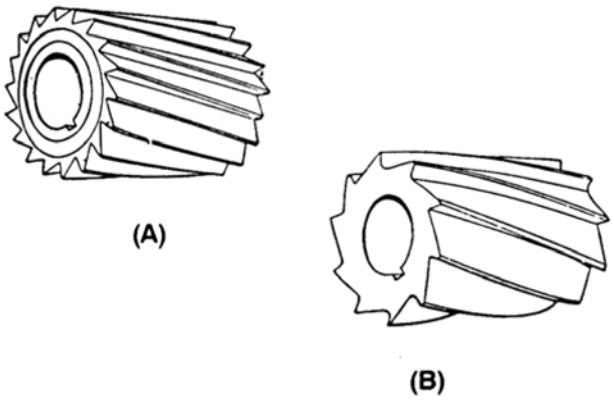


***Figure 15**: Two types of plain cutters. The cutter shown in (A) is for ordinary work, while the coarser-tooth type (B) is for heavy work.*

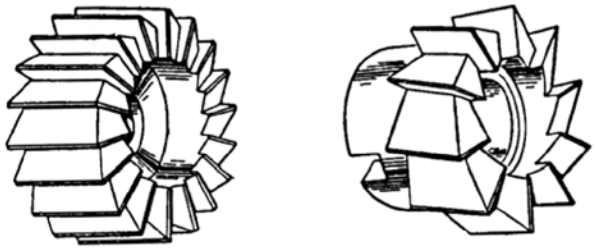


***Figure 16**: Facing cutters.*

Two-lipped, slotting end mills, shown in Figure 12(B), are designed to cut slots and keyways. They have teeth not only on their sides, parallel to the axis, but also on one end. This arrangement enables them to mill deep slots in solid metal. These tools should be run at high surface speeds with either a deep cut and a fine feed, or a rather shallow cut and a medium feed. Ample lubrication is desirable.

Double-angle cutters, shown in Figure 13, are basically the same as plain mill cutters. The only difference is that double-angle cutters are curved on the cutting surface rather than flat. These cutters will make a rounded cut rather than a flat cut.

Corner-rounding cutters, shown in Figure 14, are designed for finishing the edges and corners of a part, and can be manufactured for any required radius. They are available in either right- or left-hand cuts, and either single or double cutters.

Plain cutters, shown in Figure 15, have ends that are ground flat. These tools are used to mill plain surfaces, and they can be used for either right-or left-hand cuts by simply reversing the cutter on the arbor or shaft. Manufacturers usually supply this type of cutter for ordinary work unless you order something different. Whenever possible, use the type with a coarse tooth and a steep spiral.

Facing cutters have teeth on the outer edge and one end (Figure 16). These cutters are not reversible on their arbors, so when you order them, you must indicate whether you want right- or left-hand cutters.

The cutter shown on the left is a right-hand cutter. The coarse-type cutter shown on the right should be used whenever possible, since it cuts more freely and takes less power.

The *slotting cutter*, shown in Figure 17, has teeth on the outer edge only, with the sides ground slightly concave to give clearance when cutting. It is used primarily for accurately milling slots, and is generally made with straight-cut teeth up to ¾" wide and with spiral teeth above this thickness. Standard cutters are made with a thickness tolerance of plus or minus 1/1,000 of an inch. The corners of the teeth on this type of cutter show signs of wear first, so as soon as you notice wear, you should resharpen the teeth.

Side and *face cutters*, also shown in Figure 17, have teeth on the face and both sides. They are sometimes called straddle mills. For heavy work, the coarse-tooth side cutter is recommended. These cutters are supplied with a width tolerance of +0.005 and -0.001 inch. They can, of course, be used for milling slots, but they are not designed for this type of work, and their suitability for it depends on how accurate the slots need to be.

The cutter for sawing metal, or *metal slitting saw* as it is commonly called, has teeth on the edge only, with the sides ground concave for clearance when cutting (Figure 18). It is used for a variety of jobs, from putting deep slots in heavy sections of steel to cutting through thin tubes. However, a single saw is not capable of covering this range of work satisfactorily, for while a fairly large pitch, or spacing of teeth, is required for solid work, it is of very little use for thin sections of work.

When ordering new saws, specify the class of work they will be used for or the required pitch, or number of teeth. These saws are regularly made with diameters ranging from 2½" to 8" and come in thicknesses ranging from $^1/_{32}$" to ¼ inch. For sawing off large pieces of metal, it is not economical to use the thinnest saw listed ($^1/_{32}$"), since it is a delicate tool that requires

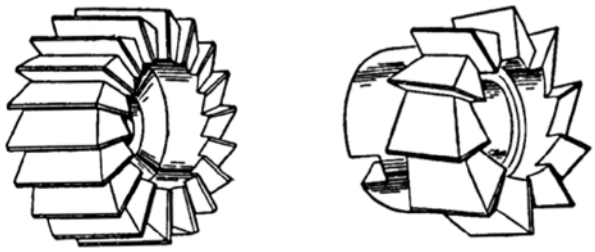


***Figure 17**: From left to right: a slotting cutter, a side cutter, and a face cutter.*

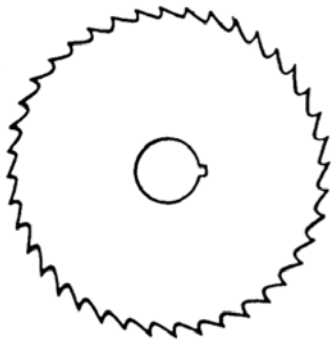


***Figure 18**: The metal-sitting saw has slightly concave sides.*

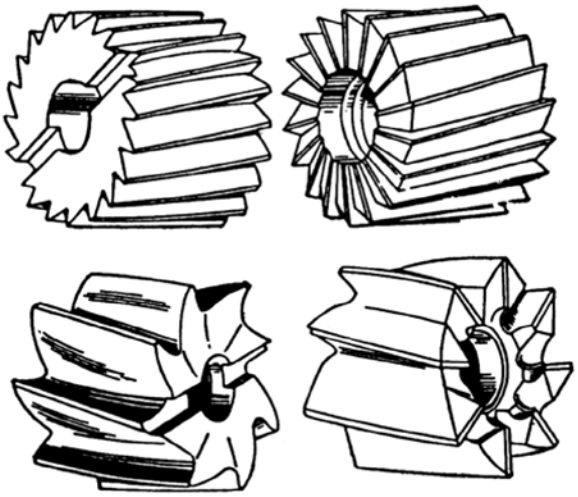


***Figure 19**: Shell-end mills have teeth on the outer edge and one end.*

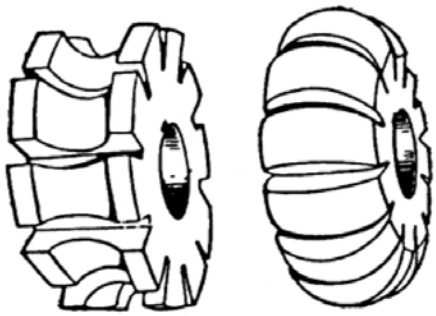


***Figure 21**: Concave (left) and converse (right) milling cutters are used to make many types of gun parts. The front faces only are resharpened when they are ground.*

careful handling. Slitting cutters are also made with side chip clearance.

Shell end mills, shown in Figure 19, have teeth on the outer edge and one end, and are designed for mounting on an arbor. Beginners often confuse them with facing cutters; the difference is that shell end mills have cutting edges greater in length than half the diameter of the cutter, whereas facing cutters have cutting edges less than half the diameter of the cutter. Since shell end mills are not reversible on their arbors, they are made to cut either left-hand or right-hand cuts. In principle, these tools are exactly the same as ordinary solid end mills, but they are marketed in the shell form for the larger sizes in order to reduce expense. Manufactured with a diameter tolerance of +0.010" and -0.001", they are made for ordinary work and also for especially heavy work.

Ordinary reamers are designed to enlarge the diameters of holes already made by another tool, such as a twist drill or punch. A part is often cast with holes made by cores inserted in the mold. The *shell reamer* serves exactly the same purpose as the ordinary reamer, but was introduced to save expense in enlarging deep holes or holes of large diameter, where the cost of ordinary reamers would be excessive. This type of tool is manufactured with a diameter tolerance of +0.0006" and +0.0012" for the smaller sizes and +0.0007" and +0.0014" for the larger sizes. They are made with either straight or spiral flutes (Figure 20). The most commonly used reamer is that with spiral flutes, as shown in Figure 20(A), with spiral flutes.

The reamer shown in Figure 20(B), a *rose shell reamer*, has straight flutes. This type of reamer enlarges from a smaller diameter and is easy to resharpen. However, it is not quite as adaptable to the same class of finish. Made with either parallel or taper holes, these tools must not be confused with shell end mills; they are not accurate enough to meet the same requirements as the shell end mill. You can avoid this confusion by remembering that standard shell reamers have flutes greater in length than the diameter, and have no teeth on the end.

Concave and *convex milling cutters*, shown in Figure 21, are used on the milling machine in order to produce either concave slots or convex edges. They are almost always made of the same machine-relieved type, so resharpening is simple, with only the front faces being ground. This design also enables the

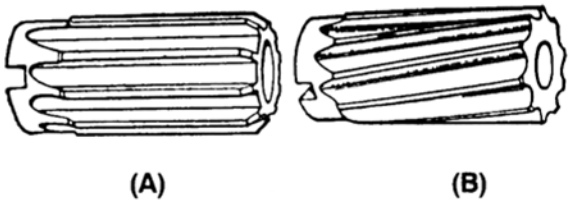


***Figure 20**: Shell reamers are used to enlarge deep or wide holes more cheaply than by an ordinary reamer. Flutes may be either (A) spiral or (B) straight*

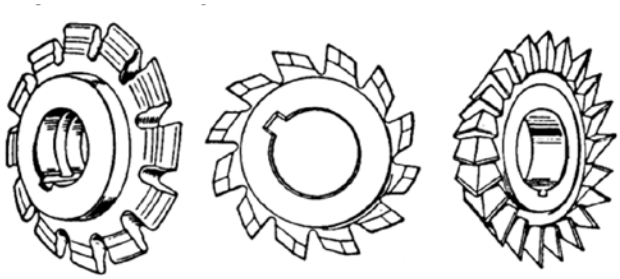


***Figure 22**: Rough and finish gear cutters: a single-angle cutter is shown on the far right.*

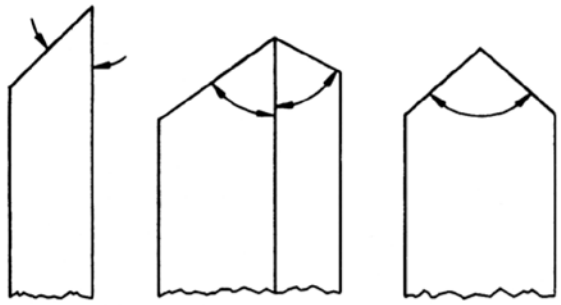


***Figure 23**: Method of measuring angles on a single-angle cutter.*

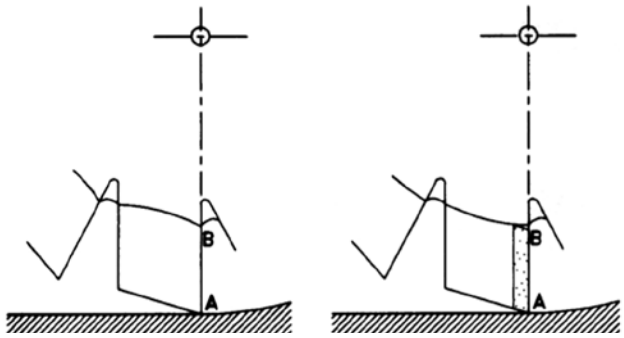


***Figure 25**: The straight-tooth cutter at left shows how the effect of rubbing is eliminated, while the one at the right will receive a certain amount of rubbing.*

cutters to reproduce the same profile, within very narrow limits, until worn out.

Figure 22 shows a gear cutter used in the milling machine to produce gear teeth. There are usually 8 cutters to a set, enabling gears with from 12 to any number of teeth to be cut. These cutters should always be kept well-sharpened, because on the sides of some of them only a small cutting clearance can be allowed. Unless they are kept in good condition, rubbing or grinding in the cut will occur. This is detrimental to cutter life. They must be sharpened only on the front faces, and this operation must be done carefully. Otherwise, the cutter will not produce the same outline after sharpening as it did before.

Wherever possible, the sharp comers of the teeth should be beveled off. This increases the life of the cutters and at the same time enables a heavier feed to be employed. The angles of these cutters are measured as shown in Figure 23, and are either right-hand or left-hand. The cutters can be made to any desired angle.

Equal angle cutters, shown in Figure 24, are similar in design to double angle cutters, but in this instance both angles at the intersection are the same. The nominal angle of the cutter is the angle between the two sides. This cutter can be made to all angles.

Relief is the bevel-off of the teeth of a cutter. Relief is used to prevent the teeth from rubbing. Generally, there are two types of relief — straight and curved.

Straight tooth cutters have less rubbing than curved tooth cutters, as shown in Figure 25, on the next page. They cut more freely, because each tooth is cutting with line or point contact only. The teeth not only last longer, but also will stand from two to five times more regrinding. Clean, sharp-edged teeth with strictly constant profile or form and ample support behind the cutting edges eliminate rubbing on the back and sides.

Except in a few cutters where the teeth are comparatively short, cutters have what is termed double relief. As shown in Figure 26, the front of the tooth is given approximately 17° clearance, and at a point approximately midway in the useful cutting zone of the tooth there is a change in direction of the relief; this again gives approximately 17° clearance to the teeth.

CHOICE OF MACHINE

You should give a lot of thought to your choice of a milling machine. Keep in mind how many parts are to be milled, the type of work to be milled, the amount of power necessary, and the means of power transmission—by individual, group, or lineshaft drive. These factors govern the decision of whether

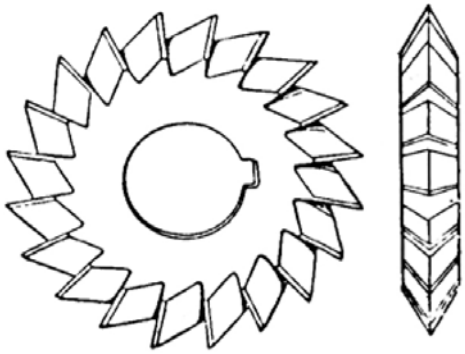


***Figure 24**: Two views of an equal-angle cutter.*

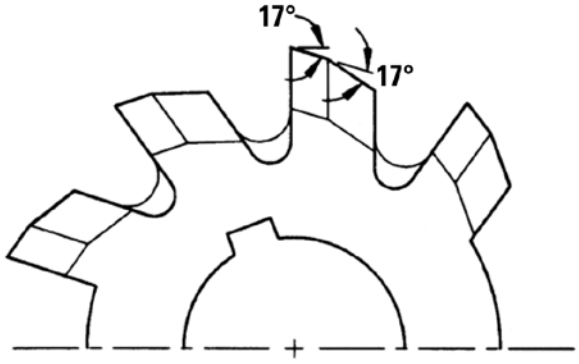


***Figure 26**: Cutters used over the past 30 years always have double relief as indicated above. The clearance angle is usually 17 degrees.*

the machine should be cone-driven or constant-speed driven. The choice of a plain, universal, or vertical type of machine depends on whether or not it will be the sole milling machine in the shop, by the amount of time it will be used for spiral cutting, and by whether it will be employed for jobbing or for manufacturing. Other concerns are the need to mill plane surfaces, and to do die sinking or gang milling. Finally, the decision between automatic or non-automatic hinges on the number of pieces you expect to produce.

INDEXING

Indexing means rotating the work on its axis to an exact indicated amount. There are many indexing operations involved in milling, fluting, and gear cutting. If you want to cut a gear, each tooth must be an exact and identical distance from its neighbor. The same is true of the flutes of a reamer or a milling cutter. You must calculate the required setting of the machine to give the proper spacing. Index tables are usually provided to help you with these calculations.

Indexing can be plain or universal. In plain indexing the index plate has three circles of holes — 24, 30, and 26 — and will index any number that divides evenly into anyone of these. Universal indexing gives divisions of all types up to 400, which meets the needs of most shops. If larger numbers have to be indexed, the manufacturer of the milling machine provides a high-number indexing attachment.

SELF-TEST QUESTIONS

Please check your answers on page 26.

5. **Name the two types of milling machines in common use.**
6. **What is the clearance angle normally used on milling cutters with double relief?**
7. ***True or False*. A milling cutter with straight teeth eliminates rubbing of the cutter more than one with curved teeth.**
8. **What type of reamer is used in the milling machine to enlarge deep or wide holes?**

Making Springs

Whenever possible, you should use ready-made springs. Ready-made springs are inexpensive when compared to the time you would spend making one from scratch. However, manufactured replacement springs are not available for every firearm, which means that you may have to hand-fashion a spring if such a firearm is to be put back into service.

It is not difficult to make a useful replacement spring for a firearm, provided you understand certain basic techniques.

The type of spring that you will most often have to make is the mainspring used in some of the older shotguns (Figure 27). There is so much variation in these springs that it is extremely difficult to find factory-made replacements that will always fit exactly. Even the replacement springs that are manufactured for a specific gun will almost always have to be modified and fitted to the individual gun.

Next in line are the springs for box lock shotguns, which are also difficult to obtain. Then come the frizzen springs, sear springs, and trigger springs. The techniques in this section will show you how to make all of them.

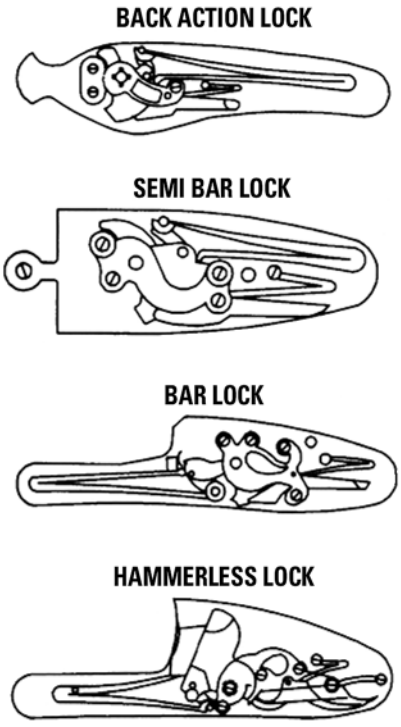


***Figure 27**: Some typical mainsprings used in older shotguns.*

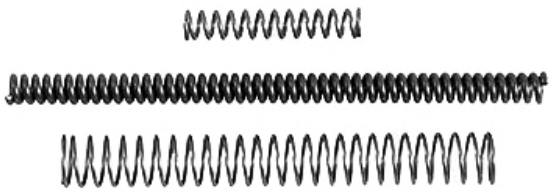


***Figure 28**: A few of the many types of coil springs sold by Brownells.*

SPRING STOCK

Various assortments of spring stock are available from gunsmithing supply houses, such as Brownells, Inc. Coil springs, like the ones shown in Figure 28, or compression gun springs, like the ones in Figure 29, on the next page, are normally available already tempered, so you only have to cut them to the required length. For example, Brownells No. 69 coil springs are packed several sizes to the carton and are cut in 12" lengths. This assortment is designed primarily for the softer-acting gun springs.

Next is the Brownells No. 150 kit, which contains small spring wire in diameters from 0.020 to 0.120 inch. The spring stock in this assortment is ready to make into springs, or any piece that can be annealed and retempered.

Flat spring stock is available in the Brownells No. 149 kit, which contains 12 assorted pieces in widths from $^{3}/_{16}$" to $^{3}/_{8}$", and in thicknesses from $^{1}/_{16}$ to $^{1}/_{8}$ inch. This assortment is annealed, and you purchase it in a soft state, but you can forge and temper it into gun-quality springs.

Brownells also carries extra-wide, flat spring stock and music wire spring stock in a variety of sizes. These combinations should suffice for 99% of the gunsmith's needs.

Do not overlook the possibility of good spring stock lying around your shop or home. Old clock springs, for example, can be used as raw material for gun springs once they have been cleaned up and annealed. You can then forge and temper them for practically any use. However, be cautious of modern springs. Modern metallurgy has developed certain steels for specific applications, many of which are not suitable for gun springs. Regardless of the type of raw material obtained, it will have to be annealed or softened so that it can be readily worked with a file, hacksaw, and other tools necessary to obtain the required shape prior to tempering.

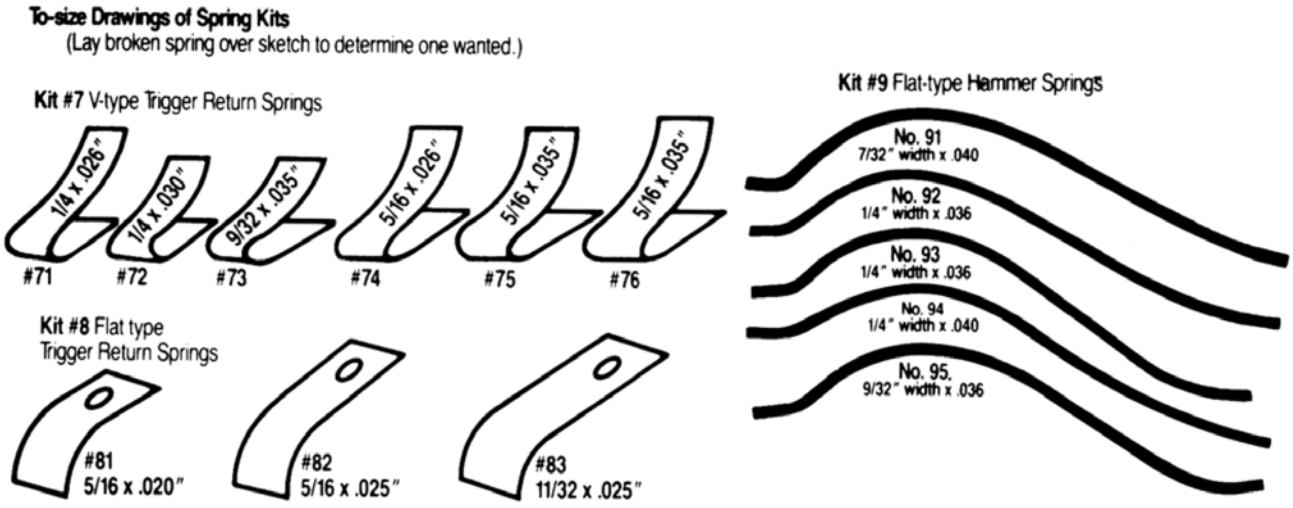


***Figure 29**: Replacement springs for almost all of the older revolvers are available from Brownells.*

INITIAL PREPARATION

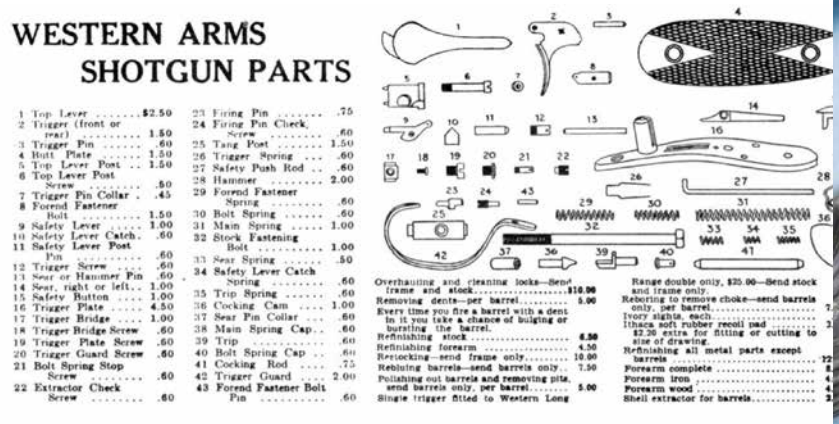
It is always best to have the broken spring close at hand when preparing to make a new one. If this is not possible, be prepared for a lot of time-consuming research and work that must be done on a trial-and- error basis.

Here are a few suggestions:

Try to locate a drawing of the spring in either a sectional or perspective view. Drawings can usually be found in old parts catalogs. Back issues of the *Shooter's Bible* are good sources for these drawings, like the one shown in Figure 30.

Determine the approximate physical dimensions of the spring you need. For example, if a sidelock on a double shotgun on which you are working is 4" in actual length, and the length of the same sidelock in the drawing is 1", then the drawing has been reduced in scale to one-fourth of the original. Keeping this in mind, you can obtain the approximate dimensions of a spring in the drawing; that is, obtain all actual dimensions in the drawing and then multiply each by four (in this case). Of course, you will still have to do some trial- and-error fitting, but at least you will have a starting point.

On many sidelock shotguns requiring the replacement of a broken mainspring, one of the mainsprings will still be intact within the mechanism. This is also true for boxlock actions. The remaining good spring can be used as a template to make a duplicate of the broken spring. In this case, curvatures and retaining nipples will have to be reversed (like a mirror image); however, anyone capable of making a spring should experience little difficulty in laying out these changes.


WESTERN ARMS
SHOTGUN PARTS

1 Top Lever	$2.50	23 Firing Pin	.75
2 Trigger (front or rear)	1.50	24 Firing Pin Check Screw	.60
3 Trigger Pin	.60	25 Tang Post	1.50
4 Bolt Plate	1.50	26 Trigger Spring	.60
5 Top Lever Post	1.50	27 Safety Push Rod	.60
6 Top Lever Post Screw	.50	28 Hammer	2.00
7 Trigger Pin Collar	.45	29 Forend Fastener Spring	.60
8 Forend Fastener Bolt	1.50	30 Bolt Spring	.60
9 Safety Lever	1.00	31 Main Spring	1.00
10 Safety Lever Catch	.60	32 Stock Fastening Bolt	1.00
11 Safety Lever Post Pin	.60	33 Sear Spring	.50
12 Trigger Screw	.60	34 Safety Lever Catch Spring	.60
13 Sear or Hammer Pin	.60	35 Trip Spring	.60
14 Sear, right or left	1.00	36 Cocking Cam	1.00
15 Safety Button	1.00	37 Sear Pin Collar	.60
16 Trigger Plate	4.50	38 Main Spring Cap	.60
17 Trigger Bridge	1.00	39 Trip	.60
18 Trigger Bridge Screw	.60	40 Bolt Spring Cap	.60
19 Trigger Plate Screw	.60	41 Cocking Rod	.75
20 Trigger Guard Screw	.60	42 Trigger Guard	2.00
21 Bolt Spring Stop Screw	.60	43 Forend Fastener Bolt Pin	.60
22 Extractor Check Screw	.60		

Overhauling and cleaning locks—Send frame and stock $10.00
Removing dents—per barrel 5.00
Every time you fire a barrel with a dent in it you take a chance of bulging or bursting the barrel.
Refinishing stock 6.50
Refinishing forearm 4.50
Restocking—send frame only 10.00
Reboring barrels—send barrels only. 7.50
Polishing out barrels and removing pits, send barrels only, per barrel 5.00
Single trigger fitted to Western Long Range double only, $25.00—Send stock and frame only.
Rebering to remove choke—send barrels only, per barrel ..... 7.
Ivory sights, each ..... 3.
Ithaca soft rubber recoil pad ..... $2.25 extra for fitting or cutting to size of drawing.
Refinishing all metal parts except barrels 12
Forearm complete ..... 6.
Forearm iron ..... 4.
Forearm wood ..... 4.
Shell extractor for barrels ..... 2.

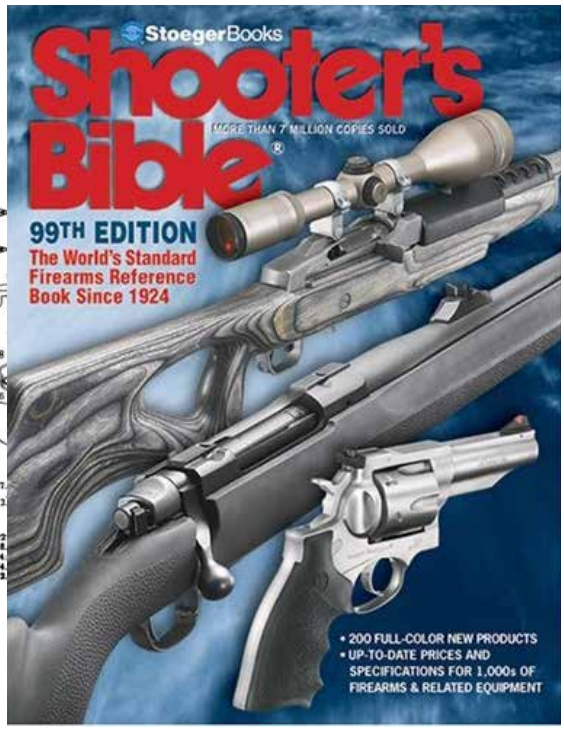


***Figure 30**: This parts list —from an old Stoger Shooter's Bible — can tell the gunsmith a lot about the shape of missing springs when the original cannot be located.*

Try to find another firearm like the one you are working on. Disassemble the good weapon, then take measurements of the good spring to use in making a new one for the broken gun.

Assuming that all the pieces of the broken spring are in your possession, reconstruct them (using epoxy glue to hold them in place) to obtain the overall shape to act as a guide for making the new spring. Study the broken spring carefully, observing the shape of the taper. In the case of a fiat leaf spring, the arms are tapered to withstand considerable movement. This taper should be even, so that the strain on the whole arm will be constant. If a section changes too abruptly from thick to thin, then all the strain will fall on the thin part, especially at the point where the difference occurs. Heavy mainsprings must always taper evenly from the fold to the hook; otherwise you can expect an early breakage. Frizzen and sear springs are not quite as critical; the arms on these springs do not receive the great amount of deflection that the arms on main-springs do.

An experienced springmaker can apply a quick heat, give two or three blows with a hammer, and form a hook or an eye that will make up part of a flat spring. It looks easy, but it is extremely difficult to accomplish without many years of experience. The beginner will need considerable time to accomplish the same thing, and should not be discouraged by initial failures.

MAKING THE V SPRING

Two types of stock may be used to make a V spring, flat stock and drill rod of high carbon content. Either can be hardened and tempered. If the latter is used, select a rod of sufficient diameter to allow the round edges to be squared off with either a grinder or a file. Once selected, measure the distance from the end of the broken spring arm (the one you are copying) to the bottom of the V. Then, with a hacksaw, slit the rod to a little more than the depth required. For example, if your measurement was 1¾", make the slit about 1$^{7}/_{8}$"so you will have a little to spare.

Again, take measurements of the existing broken springs and then square up the rod with the slit on a grinding wheel to within about $^{3}/_{32}$" of the finished width and thickness at the bottom of the V. Be careful not to overheat the metal. This calls for very slow grinding; if you see any colors start to form, stop immediately and let the steel cool.

Use a pair of calipers to check the width and thickness constantly at the bottom of the V; or you might want to use a combination of grinding and filing, as the situation dictates.

At this point the arms of the new spring, formed by the slit in the middle of the rod, are bent, as shown in Figure 31, and cut to the exact length. Some gunsmiths like to do this bending while the spring is hot, but usually it can be done when the spring is cold, if you are careful. Frequently match the existing broken spring to ensure that the arms, or leaves, are bent to the exact shape as the original. To ensure even pressure throughout the entire lengths of these leaves, the arms must be tapered evenly. For this operation, the use of flat files and a small grinding wheel in a Moto-Tool is ideal. Take care not to heat or burn the metal. Try to obtain the exact taper (or close to it) of the original spring. When the leaves have been shaped and tapered, all dimensions should be double-checked.

Next comes polishing. This may be done with abrasive paper wrapped around files, with a power buffing wheel, or with a combination of the two. There are many reasons for polishing the spring at this point. First, if tool marks are not polished down, the spring will probably break from a stress concentration around such a mark in the spring's surface. Also, the metal must be polished to allow the colors to show through during the heat-treatment.

It is best to use a temperature-controlled furnace for heat-treating springs. However, few professionals — and practically no beginners — have such an apparatus, so you may have to improvise. Set up some fire bricks on your bench. A small stovepipe wire is used to hold the spring against the bricks

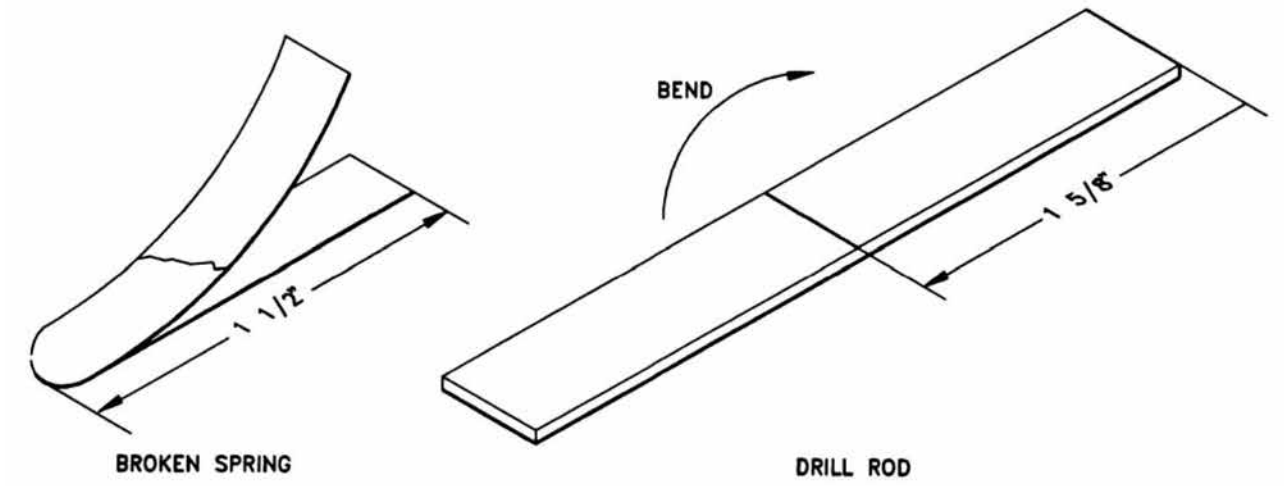


***Figure 31**: Making a V spring*

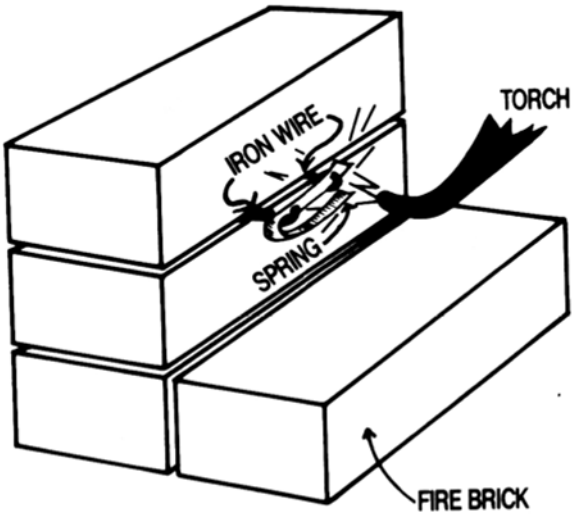


***Figure 32**: Arrangement of fire bricks for tempering gun springs.*

during the heat-treating process. Anything larger than these pieces of wire will draw heat away from the workpiece and cause the spring to temper unevenly, resulting in a poor spring that will probably break after only a few compressions. You will also want another piece of thin wire to lift the spring when it reaches the right temperature in the correct length of time. Attach this wire to the spring before you begin heating the stock.

You will need to quench the spring in the recommended solution, which will vary depending upon the type of drill rod used. Usually, drill rods from ¼" to ¾" are designed for quenching in oil, while smaller ones are best quenched in water. Some gunsmiths like to use water with a light quenching oil floating on top. It may take some experimenting to determine which solution is best for the spring stock you are using.

With the solution in a suitable container close by, and the spring in position on the wires against the fire bricks, as shown in Figure 32, heat the metal as evenly as possible with a propane or similar torch. When the spring reaches a cherry to bright cherry color (1,400°-1,500° F), hold this color for about 20 seconds. Then, immediately quench the spring in the chosen solution, holding the spring by the long wire attached to the spring before heating it.

At this point, the spring is very hot, so handle it carefully. Be careful if you are using an oil-quenching bath. Some have low flash points, and will ignite when hot metal is dropped in them. It is often easier to work outdoors in the shade than to work inside a building.

After the heated spring cools in the quenching solution, it will be hard, but brittle. It can be easily broken at this stage, so handle it with care, the way you would handle a glass rod. It must now be tempered to produce the toughness required for a good gun spring. But first, the metal must be polished again so that you can detect the colors the metal takes on during heating. You can use the power buffer you used to polish the spring prior to heating; however, since the spring is now very brittle, it is a good idea to do the polishing by hand, using abrasive paper, being very careful not to break the spring.

Tempering temperatures will vary with the type of spring stock used, the length of time the hardening temperature was held, and the temperature used in the hardening. Most texts recommend a temperature between 600° and 650° F, which should give a color between dark blue and gray.

A dark straw to yellow brown, which is produced at between 465° and 500° F, works best on some steels. You might have to do some experimenting, especially if you do not have a temperature-controlled furnace. There is one good thing about such experimenting: If you do not get it right the first time, you can reheat the part to cherry red and try it again. As long as you do not break the brittle part, and you polish it each time you heat it, you can probably try different temperatures many times without having to shape a new spring.

Now that the piece has been polished brightly and is in position on the wires against the fire bricks, use the torch to heat the spring evenly and slowly until it reaches the desired color. Keep the flame moving all over the piece (at this color) for about 15 seconds, then slowly remove the flame and let the piece cool. Protect it against any breeze that might cool it too quickly. Some gunsmiths like to completely cover the spring with lime and let it cool slowly this way.

When the spring is completely cooled to room temperature, again remove all scale and polish the spring. Check the measurements, especially the distance between the two leaves.

Completely compress the spring between the jaws of a bench vise, then release the pressure. Once more, check the distance between the two leaves of the spring. If the leaves return to their original distance and the spring does not break, you have a perfect spring. If not, give it another try .If you get this right on the first try, you did better than most people.

Another approach to this tempering is to use molten lead. Many shooters cast their own bullets and have an electric melting pot on hand, or at least a ladle in which lead can be melted. Pure lead melts at 620° F, so if you heat the lead just until it melts, you should be just about right. At this point, remove the lead from the heat and use a wire to submerge the spring into the molten lead. Be careful not to let the spring touch the sides of the melting pot; the temperature might be hotter there. Hold the spring under the lead for about 15 seconds; then, remove it and let it cool slowly at room temperature.

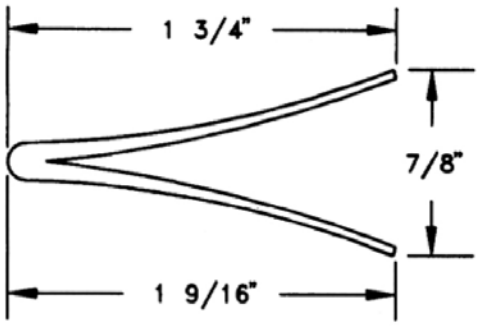


***Figure 33**: A typical V-notch gun spring that can be made.*

Depending upon the metal used to make the spring, a better temper might be obtained by dipping the spring in water after removing it from the lead. Some experimentation may be necessary. We offer these different techniques for you to try so you can find the one that works best for your individual needs. Every springmaker has techniques that work best for him or her. All of these techniques will make a spring, but one technique might suit your situation better.

V-type mainsprings can be made from flat spring stock, such as that offered by Brownells. Examine the broken spring carefully, measuring its thickness, width, and length. Then select a spring stock that comes closest to these measurements to minimize the labor required to shape the spring.

The sharp bend required for the V notch in the spring is difficult to bend cold without cracking or breaking, so it is best to grip the stock in a bench vise and heat the area to be bent to a cherry red; then partially bend the V with pliers. Complete the bend by holding a torch to it and forging it with a hammer. Thus formed, it must be slowly air cooled to remain soft enough for the remaining forming and polishing.

The curved profile required for the spring can then be easily formed by cold bending. At this point, the spring should roughly resemble the finished spring, with the exception of being slightly oversize in thickness, width, and length. Now comes the final shaping to obtain exact dimensions and, most importantly, the proper taper. This portion of the project can be done entirely by hand, using files, a bench grinder, and abrasive paper. Some professional shops use the milling machine for this operation, which is fine if one is available. Once exactly shaped, the entire spring must be polished and free from defects.

Heat-treating is now necessary to give the spring elasticity and resilience. Should the spring crack while testing, try again, using a slightly higher temperature. If the spring remains bent rather than springing back after compression, the spring stock may have too low a carbon content, in which case you will have to look for a different metal. It can also indicate faulty heat-treatment, such as quenching from too low a temperature, quenching too slowly, or tempering at too high a temperature. Fortunately, a soft spring is not ruined; it can be heat-treated again and again until the correct results are obtained.

Figure 33 shows a typical V-notch gun spring that can be made with this procedure.

MAKING COMPLEX SPRINGS

Up to this point, we have only discussed simple V-type mainsprings. These are sufficient for many makes of box lock actions, but mainsprings for sidelocks will be more elaborate. They contain hooks, crooks, pegs, slots, and eyes, all of which are complicated. However, after gaining some experience, you should be able to shape practically any design. The process is going to be time-consuming, but with patience and knowledge you can perfect the technique.

Upon examining designs of sidelock mainsprings, you may find one where the anchor eye is at right angles to the leaves. This type of spring can be made by first making two cuts on each side of the flat stock, heating the area to cherry red, and then turning the end piece 90 degrees. If you take careful measurements and your planning is correct, you will have the leaf just the right width after allowing for the removal of the unwanted part of the back strip, which is removed to form a peg on the side of the spring.

Some of the embellishments found on mainsprings are not really necessary. Many mainsprings will function normally without them. So try to understand the reasoning behind certain shapes, and then simplify your design as much as possible. For example, on certain frizzen springs, the eye is normally as deep as the leaf, but in many cases, this depth is not necessary. Try one with a shallow eye. Chances are it will work just as well, and it is much easier to make. If you have oxyacetylene welding equipment, twist the eyepiece, drill the required hole, and

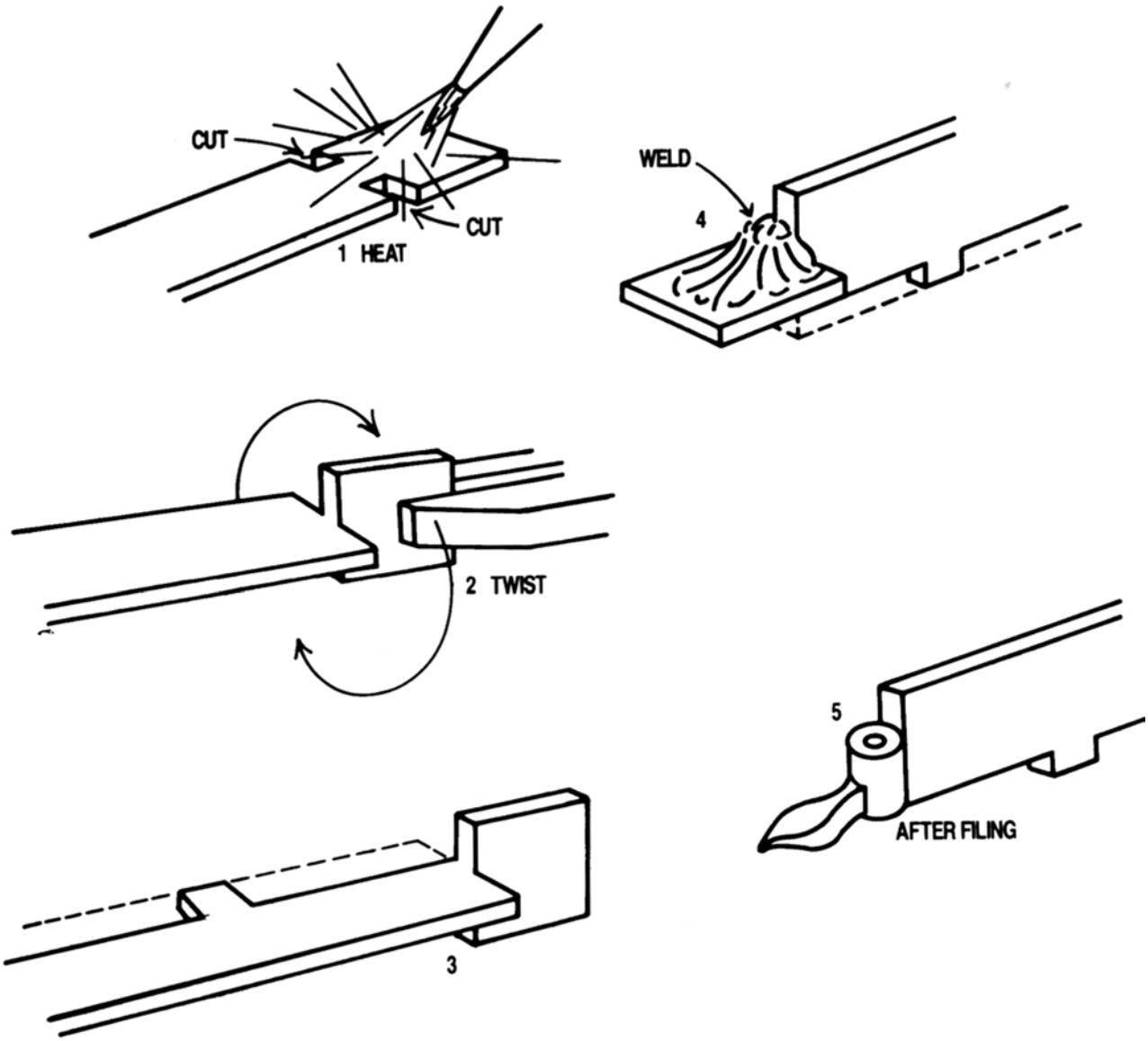


***Figure 34**: Here, a piece of flat stock is first notched and heated; then the end of the stock is twisted, as shown. The stock is revolved to match the spring needed, and the weld is built up, then filed to the exact shape. Note that a small hole has been drilled in this spring to match the original.*

then use a welding rod to build up around the eye, giving it the depth desired. Allow it to cool slowly so it will anneal properly. Then re-drill the hole and shape the area with files. These procedures are shown in Figure 34.

Many professionals balk at the idea of welding springs, but it can be done, provided the spring is retempered. Even springs that have been in a fire can sometimes be brought back to life by further hardening and retempering. Similarly, a broken peg can be effectively repaired by silver soldering. Merely anneal the spring, drill into the leaf with a slightly smaller drill bit than the old peg (about one-third the depth of the leaf width), turn or file a new peg, and silver solder it in place. You will need a solder with a melting point above 1,500" Fahrenheit for this operation. Then the entire spring can be rehardened and tempered.

FORMING HOOKS

Many mainsprings contain hooks at the end of one leaf. Forming these hooks can be a bit complicated. Once you have formed the basic spring, leave some extra metal on the end of the leaf where the hook will be located. Narrow this widened area further, so that it is the same width as the tumbler. To make the hook, heat the leaf at the end of the taper and turn the thick stub upward. Then heat the upright piece, keeping the actual bend as cool as possible. Next, pull the tip of the metal back down again. This method is similar to forming an eye in the end of an electrical wire for connection to a terminal. Mastering this technique requires some practice. Remember, since you have left some extra thickness in this portion of the leaf, the arc or bend does not have to be too great; you can

obtain further roundness when you shape the hook later on with a file. This procedure is shown in Figure 35.

Cut off any surplus steel from the point of the hook and try the resulting shape with the existing spring. The hook can be adjusted by heating the toe of the hook and then using pliers to close it in or out.

Some hooks also contain a notch. Before the spring is hardened, drill a row of holes at the required location using a small drill bit with light pressure. Then use a set of Swiss files to smooth the interior of the slot.

Mainsprings with lugs on the ends of the leaves are best formed from a solid piece cut compete with the lug intact. Further shaping can be done by forging, using a vise, anvil, or swaging blocks. This takes much practice.

Bear in mind that springmaking, like nearly all gunsmithing techniques, takes considerable practice. Seldom will you obtain perfect results on your first attempt, but once you have learned the technique, you will not forget it.

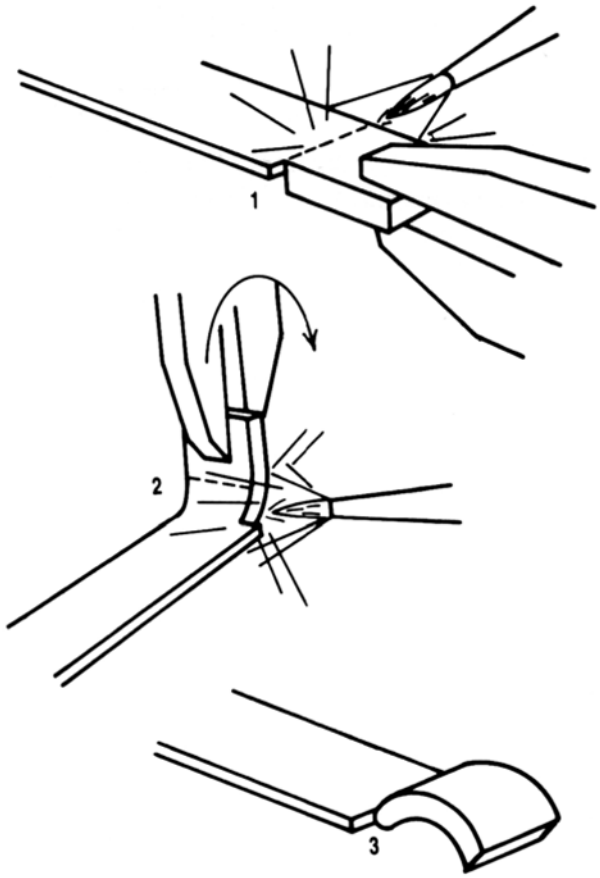


***Figure 35**: To make a hook on the end of flat stock, first heat the piece and bend upward with pliers; then apply heat to the center and bend downward. File to the exact size and shape.*

MAKING GUN PARTS

Gun parts other than springs are usually made on machine-shop tools such as the lathe, milling machine, etc., but if you have patience, you can make almost any small part using a set of metal files. You just need to know the shape and dimensions of the part, and how to take and transfer correct measurements.

When making a new part from scratch, it is always best to have the old part available. If the old part is broken, use glue or epoxy to temporarily hold the pieces together for measuring. If you do not have the part, refer to old parts catalogs for the general shape and appearance.

SELF-TEST QUESTIONS

Please check your answers on page 26.

9. **Why is it important to heat spring stock prior to shaping it?**
10. **If a spring is missing from a firearm and you do not have a replacement, what is one good way to find out the original shape and size of the spring?**
11. ***True or False*. Spring stock should never be welded.**
12. **Name two types of stock that may be used to make V springs.**

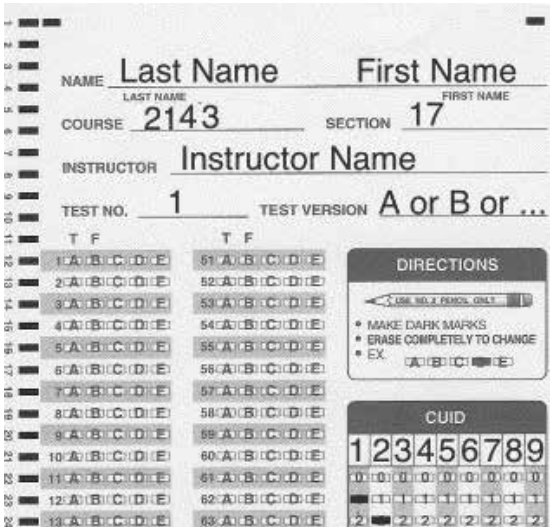
Answers to Self-Test Questions

1. False.
2. Pyrometer.
3. True.
4. 200°-350° F above the critical point.
5. Horizontal and vertical.
6. 17 degrees.
7. True.
8. Shell reamer.
9. To prevent the metal from breaking during bending and shaping.
10. Try to locate a drawing of the spring from old gun parts catalogs.
11. False.
12. Flat spring stock and drill rods.

Lesson Questions

THIS IS LESSON NUMBER 2184.

Make sure you print your name, student number, and lesson number in the space provided on the Lesson Answer Form. Be sure to fill in the circles beneath your student number and lesson number.



REMINDER: A properly completed Lesson Answer Form allows us to evaluate your answers and send the results and additional study material to you. Do not hold your Lesson Answer Forms to send several at one time. You may run out of study material if you do not send your answers for evaluation promptly.

You may also complete your exam online at www.sdi.edu, click on the *online exams* tab.

1. **When tempering a hardened gun part without the benefit of a heat-treating furnace, what color would you heat the part to for a tempering temperature of 460˚ Fahrenheit?**
   a. Very faint yellow.
   b. Light yellow.
   c. Straw yellow.
   d. Yellow-brown.

2. **If you are required to heat a gun part to 1,550˚ F for hardening with a torch, what color should you look for to obtain this temperature?**
   a. Light yellow.
   b. Corn yellow.
   c. Orange.
   d. Salmon.

3. **What is the most common instrument for measuring high temperatures in heat-treating furnaces?**
   a. Thermocouple pyrometer.
   b. Ohmmeter.
   c. Thermocouple thermostat.
   d. Volt-ohm-ammeter.

4. **If you wanted to heat a small gun part to 985˚ F with a propane torch, what color should you look for?**
   a. Bright cherry.
   b. Dark cherry.
   c. Blood red.
   d. Faint red.

5. **If a part is missing from a gun and a replacement is not available, which of the following is the best starting place if you are required to make the part?**
   a. Make several parts until you find one that fits.
   b. Make a wax cast of the action to see how the part is shaped.
   c. Try to locate a drawing of the part in old catalogs.
   d. Redesign the action so it will work without the missing part.

6. **When using one existing spring in a sidelock shotgun action as a template to make a replacement for the missing opposite spring, how should the curvatures, retaining nipple, and similar items be shaped on the replacement spring?**
   a. Exactly like the existing spring.
   b. Like a reversed or mirror image of the existing spring.
   c. Similar to the existing spring, but with less temper.
   d. Similar to the existing spring, but the part must be made harder.

7. **When hardening spring stock, what temperature range is usually correct?**
   a. 1,000˚-1,100˚ Fahrenheit.
   b. 1,200˚-1,300˚ Fahrenheit.
   c. 1,400˚-1,500˚ Fahrenheit.
   d. 1,600˚-1,700˚ Fahrenheit.

8. **What color would you see if you reached the required temperature for the spring in Lesson Question No.7?**
   a. Straw yellow.
   b. Dark red to blood red.
   c. Gray to dark blue.
   d. Cherry to bright cherry.

9. **Once the newly made spring has been hardened, what temperature should it be drawn to?**
   a. 200˚-250˚ Fahrenheit.
   b. 600˚ -650˚ Fahrenheit.
   c. 800˚ -850˚ Fahrenheit.
   d. 850˚-1,000˚ Fahrenheit.

10. **What color would you see if you achieved the desired drawing temperature for the spring in Lesson Question No.9?**
   a. Bright yellow to dark yellow.
   b. Brown to red-brown.
   c. Gray to dark blue.
   d. Blood red to cherry.