March 1, 1949. C. C. FAWCETT ET AL 2,462,851

STEEL CARTRIDGE CASE MANUFACTURE

Filed May 2, 1945 2 Sheets-Sheet 1

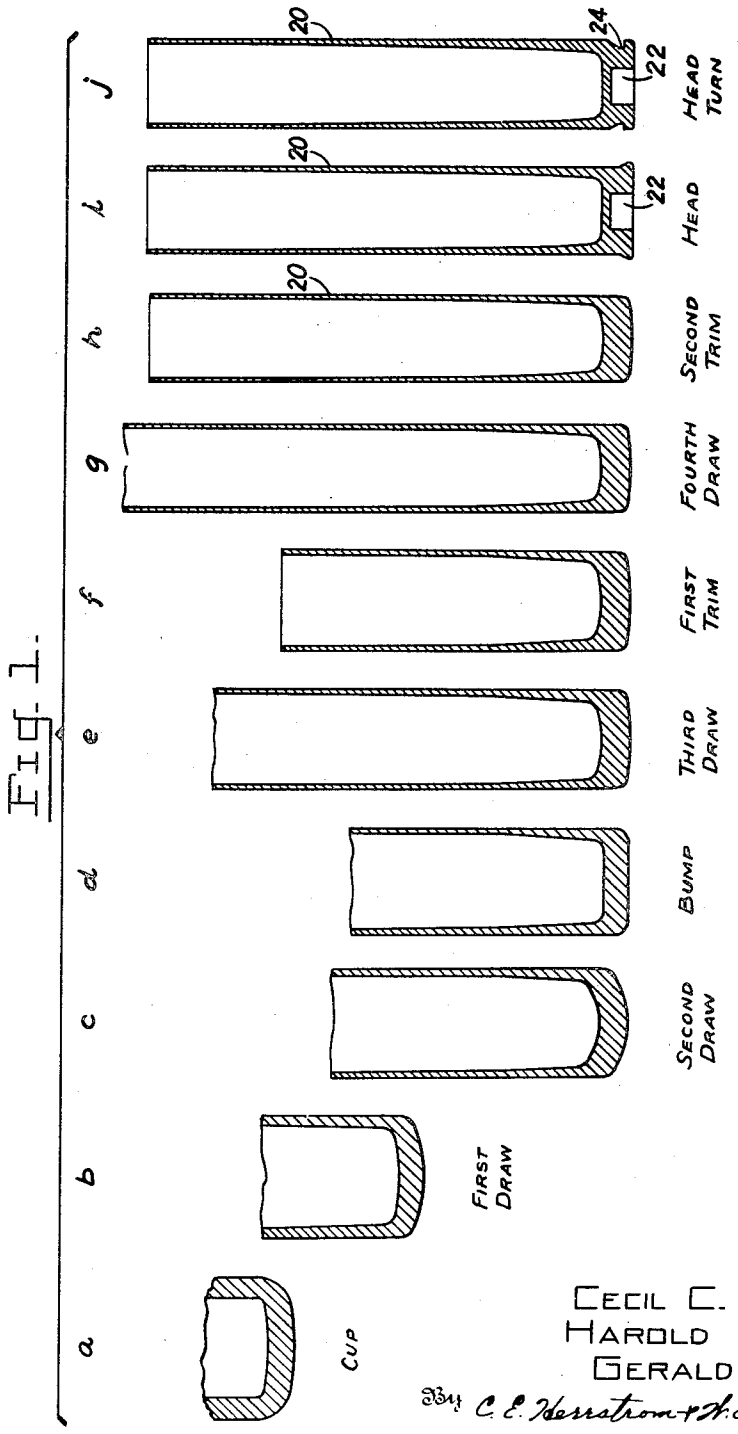


Fig. 1.

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2 Sheets-Sheet 2

Fig. 4.

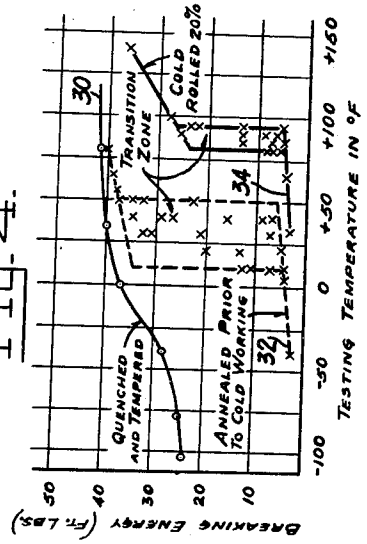


Fig. 3.

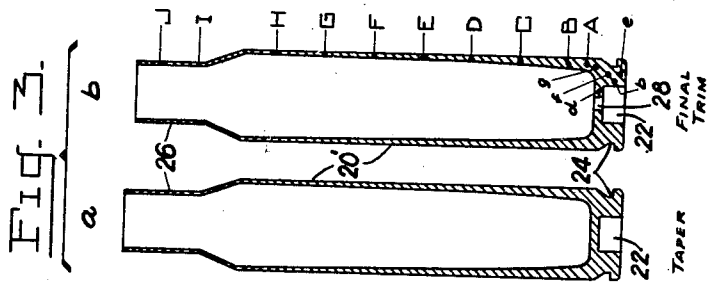
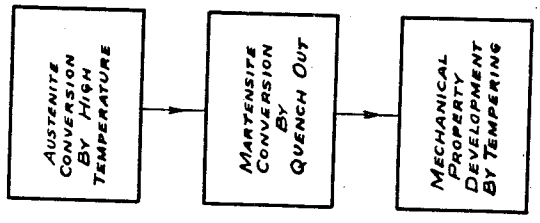


Fig. 2.



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STEEL CARTRIDGE CASE MANUFACTURE

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Application May 2, 1945, Serial No. 591,601

2 Claims. (Cl. 148—12.4)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

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The invention described herein may be manufactured and used by or for the Government for governmental purposes without the payment to us of any royalty thereon.

Our invention relates to cartridge cases for small arms and artillery ammunition and it has special reference to the manufacture of such cases from steel.

Broadly stated, the object of our invention is to make possible the production of steel cartridge cases which fire without splitting or other mechanical failure, obturate properly during firing, extract normally after firing, and otherwise prove satisfactory when used in firearms of conventional design.

A more specific object is to develop in steel cases superior combinations of essential mechanical properties such as tensile and yield strengths, elongation and ductility, toughness and impact resistance, and hardness.

Another object is to effect such property development through novel heat treating steps uniquely combined with cup and draw case forming technique.

In practicing our invention, we attain the foregoing and other objects by utilizing plain carbon or other commercially available steel as the case blank material; using cup-and-draw or equivalent technique to form this material into the basic case shape through a series of deep drawing operations; developing desired mechanical properties throughout all of the resulting case piece by applying a controlled quench and temper heat treatment after completion of all drawing operations plus primer pocketing and head turning but before necking and tapering; annealing the case mouth to soften the metal thereof; and then tapering and necking the case body and mouth to desired final configuration.

Such novel manufacturing procedure is illustratively shown by the accompanying drawings wherein:

Fig. 1 depicts case forming steps which precede the quench and temper heat treatment of our invention;

Fig. 2 diagrams the three major phases of that heat treatment;

Fig. 3 indicates succeeding fabrication steps which follow the heat treatment and identifies

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one typical hardness distribution for the finished steel case; and

Fig. 4 compares certain properties of our heat treated cases with those which result from cold working.

Case steel used

In selecting the material for our improved steel cartridge cases we may choose either from "plain" carbon steels or from "alloy" compositions. Much of our work has, however, been with plain carbon compositions as distinguished from the alloy steels. Under wartime conditions particularly the former are more readily available and of relatively lower cost. Hence, even though alloy steels are capable of yielding an equally satisfactory product, the plain carbon compositions will here be used as the basis for explaining our inventive improvements.

Two illustrative examples of plain carbon steel successfully used by us are set forth below:

A first or "Example A" composition is commercially identified as SAE 1030 steel. It is sufficiently deoxidized with aluminum as to have a fine grain. At start of the case forming process this steel preferably is completely spheroidized and rolled with a matte surface finish. Representative analyses thereof in that form are:

	Per cent
(*a*) Chemical:	
Carbon	0.27
Manganese	0.57
Phosphorus	0.017
Sulphur	0.025
Silicon	0.04
(*b*) Spectrographic:	
Copper	0.06
Nickel	0.04
Chromium	0.03
Vanadium	0.005
Molybenum	0.01
Aluminum	0.05

A second or "Example B" composition is commerically identified as SAE 1015 plain carbon steel. It also is sufficiently deoxidized with aluminum as to have a fine grain. At start of the case drawing process this steel also may be completely spheroidized and rolled with a matte sur-

face finish. Representative analyses thereof in that form are:

	Per cent
(*a*) Chemical:	
Carbon	0.18
Manganese	0.49
Phosphorus	0.015
Sulphur	0.035
Silicon	0.05
(*b*) Spectrographic:	
Copper	0.02
Nickel	0.02
Chromium	0.03
Vanadium	0.005
Molybdenum	0.01
Aluminum	0.03

These two examples have been chosen to typify plain carbon steels having the following composition ranges with attendant incidental alloy contents (not here listed):

	Per cent
Carbon	0.15 to 0.45
Manganese	0.30 to 0.90
Phosphorus (maximum)	0.40
Sulphur (maximum)	0.045
Silicon (maximum)	0.25
Aluminum	0.01 to 0.05

Formation of caliber .30 steel cartridge cases from plain carbon steels of the two examples first stated will now be illustratively described. As such description proceeds it will, however, become apparent that our improved techniques may with comparable advantage also be applied to the manufacture of cartridge cases of larger calibers (including 105 mm.) and from steels having compositions other than the two illustratively here listed as Examples A and B.

Fabrication operations prior to heat treatment

Steel strip either of the SAE 1030 composition of "Example A" or of the SAE 1015 composition of "Example B" and having an initial thickness of about 0.140 inch is first blanked from the rough rolled spheroidized strip stock and cupped to the form shown by Fig. 1*a*. This may be done by a conventional punch press of the double acting type equipped with blanking and cupping tools appropriate for caliber .30 cartridge case production. Suitable water-base lubricant containing filler (such as chalk particles) may with advantage continually flood the cupping die, but no plating or film of any type need be used on the strip stock before cupping.

Washing and drying of the Fig. 1*a* cup is then recommended. This may be done either manually or in a machine (as of the continuous screw conveyor type). Water at about 180° F. containing alkaline cleaning compound constitutes a suitable cleansing solution. Washing is followed by a rinse in water at about 180° F. and drying in a hot air blast. Other equivalent forms of cleaning may of course be used.

Preferably the cup of Fig. 1*a* is next annealed to reduce hardness and thereby improve drawability. A recirculating air type electric or other furnace is useful here. The cup may be held below the steel's "AR_1" temperature (such as at about 1250° F.) for approximately 2 hours; cooled (as in the furnace) to about 1000° F. slowly enough to keep the subsequent hardness at a minimum; and further cooled in air to room temperature.

Surface scale removal is now advisable. This may conveniently be done by "pickling" the cup.

Useful apparatus includes a tumbling barrel containing water with about 10% (by volume) sulphuric acid and heated to around 180° F. About ten minutes of tumbling in this solution ordinarily suffices to remove all scale from the cup of Fig. 1*a*. Washing in hot alkaline water and drying as before preferably follows.

Treatment of the cup to supply a lubricant aid during the first draw is next recommended. An immersion copper plating can well be used here. The thin surface film of copper requisite to prevent "pick up" of the case blank steel by the forming tool steel may readily be imparted by immersing the cup for about 30 seconds in a solution of water containing 3 to 4 ounces of acid copper sulphate per gallon and about 2% sulphuric acid by volume. Washing and drying in hot alkaline water as before may again follow.

The first draw is now performed on the cup of Fig. 1*a*. This converts the cup to the elongated shape shown by Fig. 1*b*. Accomplishment may be by any suitable apparatus such as a conventional crank press equipped with punch and die tools of tungsten carbide or other durable steel and of dimensions appropriate for this phase of caliber .30 cartridge case formation. Both the press tools and draw piece may with advantage be flooded with water-base lubricant containing filler (such as powdered chalk) diluted with an equal volume of water.

By this first draw the steel cup's side walls may be elongated to more than double (Fig. 1*b*) their original (Fig. 1*a*) length and correspondingly thinned as indicated. Washing and drying in hot alkaline water as before now preferably follows.

A further anneal may with advantage now be given to the first draw piece of Fig. 1*b* in order to soften the metal and relieve internal strains. Same may satisfactorily duplicate the original anneal earlier applied to the cup and consisting of holding at about 1250° F. for 2 hours, furnace cooling to about 1000° F., and further cooling in air to room temperature.

Surface scale removal is once more desirable. To accomplish this the annealed draw piece of Fig. 1*b* may be pickled by the same tumbling barrel treatment that was earlier applied to the annealed cup. This may well be followed by washing in hot alkaline water and drying as before.

Application of a lubricant aid to the first draw piece of Fig. 1*b* is further desirable at this point. Immersion copper plating as earlier described for the cup of Fig. 1*a* proves satisfactory here. Washing in hot alkaline water and drying as before again follows.

The second draw is now performed on the case piece of Fig. 1*b*. This converts the piece to the further elongated form shown by Fig. 1*c*. Accomplishment may be by any suitable apparatus such as a conventional crank press equipped with punch and die tools appropriate for this phase of caliber .30 cartridge case formation. Lubricant equivalent to that used during the first draw may be employed. By this second draw the piece's side walls may be further elongated to about twice (Fig. 1*c*) their first draw length (Fig. 1*b*) while the average thickness of the case wall is reduced to nearly one half. Washing and drying as before is desirable.

Bumping of the Fig. 1*c* case piece is next recommended to produce the flattened-head shape shown by Fig. 1*d*. This may be done in any suitable manner such as by the aid of a hori-

zontal toggle and crank press equipped with appropriate tools. Lard oil lubricant is satisfactory here. Washing and drying as before follows. Other desirable preparations for the third draw include application of a lubricant aid, such as the immersion copper plating earlier described, plus further washing and drying.

By the third draw the case blank's side walls may still further be elongated to an extent indicated by Fig. 1*e*. Any suitable apparatus such as the same crank press used for the second draw may here be employed with punch and die tools modified to suit this operation and lubricated as before. As much as 50% elongation may satisfactorily be achieved by this operation. Washing and drying as before follows.

A first trim is now recommended for the third draw piece. This removes undesirable metal, shortens the piece as shown by Fig. 1*f*, and makes for easier handling during the fourth draw. Performance may be by any suitable apparatus such as a conventional rotary cutter trimming machine equipped with standard tools. Washing and drying again follow. Other desirable preparations for the fourth draw include application of a lubricant aid, such as the immersion copper plating earlier described, plus further washing and drying.

Purpose of the fourth draw is additionally to elongate the case blank's side walls to the extent generally indicated by Fig. 1*g*. Any suitable apparatus such as the crank press used for the second and third draws may here be employed with punch and die tools modified to suit this operation and lubricated as before. Something less than 50% elongation may satisfactorily here be achieved. Washing and drying as before follows.

A second trim is now recommended. This merely shortens the fourth draw piece as shown at **20** by Fig. 1*h*. Performance may be by the earlier mentioned rotary cutter trimming machine. Case cleansing as by washing and drying is again in order. Further desirable preparations for a case heading operation next to follow include application of a lubricant aid, such as the immersion copper plating earlier described, plus further washing and drying.

Heading of the trimmed case blank of Fig. 1*h* is next in order. This leaves the case piece side walls **20** unchanged as shown in Fig. 1*i* but introduces a primer pocket **22** into the case head metal, somewhat flattens the inside face of the head, and gives the head's outer face a somewhat expanded and slightly concave shape. Such heading has much in common with the "bumping" step earlier described (see Fig. 1*d*).

Performance may be by the same or an equivalent toggle and crank press when appropriate heading tools are installed therein and lubricated with lard oil as before. For reasons later to be explained, the initial primer pocket **22** is made of slightly smaller dimensions than those required in the final cartridge case. Case piece cleaning as by washing and drying is once more proper. Further desirable preparations for a head turning operation next to follow include application of a lubricant aid, such as the immersion copper plating earlier described, plus further washing and drying.

Head turning is now in order. This operation cuts into the case head metal the extractor groove **24** of Fig. 1*j*. Such cutting may be performed in any suitable manner as by a spindle type turning machine having an appropriate cutting tool.

At this point in the fabrication sequence the

steel cartridge case blank has the physical form and dimensions which Fig. 1*j* represents. Illustrative side wall thicknesses for this caliber .30 case piece are about 0.010 inch at the open end; about 0.015 inch midway of the case piece length; about 0.025 inch at one quarter of the piece length from the head; and about 0.035 inch still closer to the head. In the drawing views all of these wall thickness dimensions have been considerably exaggerated in order to provide greater clarity of representation.

Fabrication to this Fig. 1*j* stage may be effected not only by the illustrative procedure just described for plain carbon steel cases of caliber .30 size but also by any other equivalent procedure which satisfactorily converts the original steel stock into a case piece of the Fig. 1*j* type. Thus, in accordance with conditions and convenience, either more or less than four drawing steps may be employed; the described annealing steps may or may not be necessary; lubrication aids other than immersian copper plating on the steel can be utilized; drawing lubricants of other than water-base and lard-oil types can be substituted; and washing can be in solutions other than hot alkaline water.

Moreover, the case blank's side walls may be given a thickness variation taper either more or less than that indicated at **20** by Figs. 1*h* to 1*j*. These walls can, in fact, be of uniform thickness throughout a substantial portion of the total case length. Case head thickness and juncture with the side walls can likewise be proportioned in any manner which provides strength adequate to withstand firing pressures.

In overall diameter the head and lower side walls of the Fig. 1*j* case piece may at this point be slightly smaller than their finally desired size in order that a slight "growing" of the piece during subsequent heat treatment will yield the exact dimensions needed in the finished case. We have observed the degree of such growth to be greatest for the larger size cases (20 mm. and above) and to be relatively less marked in the smaller calibers (caliber .50 and below).

Even in the smaller caliber cases, however, we find it highly desirable to allow for diameter increases in the primer pocket **22**. Such allowance properly chosen affords positive assurance of the desired tight fitting of the primer (not shown) in the finished case. Thus a caliber .30 steel case of the type here illustrated can be expected to experience about 0.50% "growth" in primer pocket diameter during the subsequent quench and temper heat treatment which Fig. 2 diagrams. The primer pocketing operation of Fig. 1*i*, therefore, preferably should produce a cavity **22** which initially is about 0.50% undersize.

Mechanical properties of the Fig. 1j case piece prior to heat treatment

In the new manufacturing technique evolved by us the initial mechanical properties of the Fig. 1*j* case piece are relatively unimportant. Same may therefore fall far short of those required for final cartridge case use since development of acceptable properties in the finished cartridge case is effected by our novel quench and temper heat treatment diagrammed by Fig. 2 and later to be described.

The illustrative case forming steps thus far set forth do in fact give to the Fig. 1*j* case piece initial mechanical properties which are relatively inadequate as will now be outlined. These initial properties are, moreover, found to differ some-

what with the carbon content of the steel, the higer carbon compositions showing higher rates of cold work hardening than do the lower carbon compositions. Ranges are therefore given to cover variations from the minimum to the maximum acceptable carbon content.

In tensile strength and hardness, the case piece of Fig. 1*j* shows properties considerably below those required for final cartridge case use. Representative Vickers hardness values for the case side wall are observed for the lower carbon steels, such as SAE 1015 of Example B, to fall within the range of about 180 to about 210; for the higher carbon steels, such as SAE 1030 of Example A, the range is observed to be from about 200 to about 250. Tensile strengths for these hardness ranges have respectively been found to be from 80,000 to 110,000 and from 105,000 to 140,000 pounds per square inch (p. s. i.).

In yield strength, the case piece of Fig. 1*j* further fails to meet requirements found essential for satisfactory cartridge case extraction. Steels of compositions identical to those formed into the case blanks but cold rolled to the same thickness reduction percentage and to similar hardness values show yield strengths of from 70,000 to 95,000 p. s. i. for the lower carbon steels and from 90,000 to 130,000 p. s. i. for the higher carbon steels. As is later indicated, higher side wall values are needed to assure easy withdrawal of the empty case from the gun chamber.

In elongation properties (one measure of ductility), the case piece of Fig. 1*j* likewise is not adequate for satisfactory cartridge case obturation and extraction. Specimens of the case piece metal which were cold rolled to the same thickness reduction and similar hardness values showed elongations of only 2.5 to 3.5 percent for the lower carbon steels and of only 1.5 to 3.0 percent for the higher carbon compositions.

In impact resistance and toughness the case piece of Fig. 1*j* is further found to fall short of required standards. Exhibited "notch" sensitivities are typified by curves **32** and **34** of Fig. 4. The attendant low "breaking energies," particularly at low temperatures, make the case metal brittle (quite like glass) and hence easily fracturable at folds, die marks or other imperfections both in the case head and in the side walls. Tensile specimens of the higher carbon material in strip form cold rolled to the same thickness reduction and similar hardness values show 10 to 15 foot pounds tensile impact resistance when elongated at the high rate of about 18 feet per second. Freedom from ruptures in steel case walls that have no imperfections is found to call for substantially higher tensile impact resistance values.

Quench and temper heat treatment

The unique "quench and temper" heat treatment of our invention is applied to the Fig. 1*j* case piece following all of the fabricating operations which Fig. 1 diagrams. Purpose is to improve all of the piece's just outlined initial physical properties. By such improvement the final steel cartridge case is enabled to fire without splitting or other mechanical failure, to obturate properly during firing, to extract normally after firing, and otherwise to prove satisfactory when used in firearms of conventional design.

In this heat treatment: (1) the case blank of Fig. 1*j* is heated to and held at a temperature sufficiently above the steel's "upper critical" or "AR_3" point to transform the steel into its uniform "austenitic" phase; (2) the blank is then

severely quenched into either water or brine at approximately room temperature in order to insure a complete "quench out" which converts the entire structure into "martensite" (hardest possible form of a given steel); and (3) the blank is next tempered by heating to below the "lower critical" or "AR_1" point in order to produce the final mechanical properties desired.

These three steps are diagrammed by Fig. 2. Accomplishment of each may be in any manner and by any apparatus which satisfies the requirements above stated. In applying the treatment to the illustrative caliber .30 case piece of Fig. 1*j* formed from the higher carbon steel of Example A: (1) heating of the case blank is satisfactorily effected in an electric furnace (as of the atmosphere-controlled, conveyor type) at about 1550° F. for an "at temperature" period of 5 to 7 minutes; (2) quenching of the heated blank is satisfactorily accomplished by dropping into a 6% brine bath at room temperature and there leaving until cooled; and (3) tempering of the hardened blank is satisfactorily effected by heating in an electric recirculating air furnace at about 750° F. for 1 hour and then cooling either by air or by water.

When the case piece of Fig. 1*j* is formed from the lower carbon steel of Example B, substantially the same procedure may be employed. The initial heating of step (1) is, however, raised to about 1700° F. for an "at temperature" period again of 5 to 7 minutes; the quenching step (2) is duplicated without change; and the tempering step (3) is conducted at about 650° F. for 1 hour.

Heating step (1) can be carried out not only in an atmosphere-controlled, conveyor type furnace but also by less expensive and more readily available apparatus such as a gas flame body annealer. High frequency inductive electrical heating also gives satisfactory results. Case-metal temperature can be measured either by an optical pyrometer or by placing on the metal surface a substance which melts at the desired heat intensity.

Quenching step (2) can satisfactorily be carried out in still brine, in a brine spray, or in turbulent brine. Ordinary water sometimes is adequate but its efficiency as a quenchant frequently is too low for the low carbon steel. Oil is not satisfactory for any of the plain carbon steels. Alloy steels, however, sometimes respond properly to oil.

Tempering step (3) can satisfactorily be carried out in any type of furnace which will produce uniform temperature of requisite intensity controllable within about ±25° F. Such furnaces are usually part of conventional cartridge case production lines and availability thereof ordinarily presents no problem.

Case piece's mechanical properties after quench hardening and tempering

Our novel quench and temper heat treatment just described improves all of the mechanical properties earlier listed and produces a case piece of uniformly tempered "martensite" structure throughout. Mechanical properties are therefore also uniform throughout the entire Fig. 1*j* case piece. Same will now be described.

In tensile strength and hardness the "heat treated" case piece of Fig. 1*j* shows substantial improvement over its former "as drawn" condition. Vickers hardness values for the case side wall (and all other parts) thus are found to have been elevated to 325 p. s. i. and above for both

the higher (SAE 1030 of Example A) and the lower (SAE 1015 of Example B) carbon steels. Tensile strengths for these hardnesses are found to have been raised to 150,000 pounds per square inch and above.

In yield strength, the heat treated case piece shows comparable improvement. New values of above 140,000 p. s. i. are typical for both the higher and the lower carbon steels. These in combination with the improved tensile strengths assure easy extraction of the finished case from the gun chamber.

In elongation (one measure of ductility) properties, the heat treated case pieces of the higher carbon steel show an improvement to new values of 5 or 6%. The lower carbon steel elongation is less but still somewhat improved by the heat treatment.

Impact resistance and toughness are found to have been remarkably improved by our quench and temper technique. Higher carbon steel case pieces so treated and subjected to Charpy Notch bar tests show elevated values of about 41.0 foot pounds at a temperature of 80° F. and about 29 foot pounds at —40° F. In tensile impact resistance 25 to 30 foot pounds are shown at a temperature of 80° F. Freedom from case metal fracture is therefore greatly enhanced.

Case piece processing following heat treatment

Upon completion of our quench and temper heat treatment the case piece of Fig. 1*j* has been wholly converted to martensite and hence has uniform mechanical properties throughout. The upper and body side walls **20**, moreover, are substantially parallel, except for slight distortions which may have occurred during the heat treatment; the lower side walls, case head and primer pocket **22** have "grown" to the exact dimensions needed in the finished case.

To be useable in the chambers of conventional caliber .30 firearms of military design the final cartridge case must have the slightly tapered body and necked-down mouth shape which Fig. 3 shows. Preparatory to receiving this tapering and necking the heat treated case piece of Fig. 1*j* is now given a body anneal.

This anneal is confined to the mouth end of the case piece in order that the desirable combination of mechanical properties already developed in the head and lower side walls will in no way be diminished or altered. A gas flame annealing machine is satisfactory for this operation.

In using such a machine, caliber .30 case pieces of either the SAE 1030 steel of Example A or the SAE 1015 steel of Example B have their heads submerged in water while the mouth ends thereof are passed through the gas flame. That flame should be adjusted to raise the mouth metal to slightly above 1600° F., as checked with an optical pyrometer, and should permit gradual temperature decrease until discoloration of the case ceases at a distance of 1⅛ to 1¼ inches from the mouth. The time cycle here required is very short, an "at temperature" period of only a few seconds ordinarily being adequate.

Surface scale removal is now advisable. This may conveniently be done by pickling. The same tumbling barrel treatment earlier applied to the annealed cup of Fig. 1*a* and to the first draw piece of Fig. 1*b* may here be repeated. This is preferably followed by washing in hot alkaline water and drying.

Application of a lubricant aid to the so treated case piece of Fig. 1*j* is further desirable at this

point. Immersion copper plating as earlier described for certain of the case pieces of Fig. 1 proves satisfactory here. Washing in hot alkaline water and drying as before once more follows.

Tapering of the case body and necking of the case mouth are next in order. This operation converts the case piece to the conventional caliber .30 shape which Fig. 3*a* shows at **20'–26**; it at the same time corrects any distortions which may have been experienced during heat treating and thereby establishes final mouth and body dimensions.

Performance may be by any suitable apparatus such as a vertical double action crank press operating at appropriate speed. Such a machine accomplishes the necking and tapering in two stages. This is accompanied by a "sizing" of the case mouth **26** by means of a plugging stem (preferably chromium plated) or other suitable tool. Lard-oil lubricant proves satisfactory here. Washing and drying of the case piece completes the operation.

A final trim of the Fig. 3*a* case piece follows. This shortens the piece to the final or finished cartridge case length of Fig. 3*b*. Accomplishment may be by any suitable apparatus such as an automatic trimming machine having a spindle or other type cutting tool capable of accurately removing excess metal from the case mouth end.

Primer venting is the next fabrication step. This forms the small opening **28** of Fig. 3*b* to interconnect the primer pocket **22** with the case interior. That venting opening **28** may be made in any suitable manner such as on a standard primer inserting machine with only the vent station and vent-detect station in operation.

Application to the case piece of Fig. 3*b* of a zinc or other protective coating completes the manufacturing process. One zinc plating procedure successfully used by us consists in removing all copper deposit from the case piece by immersing same in alkaline cyanide solution in a tumbling barrel; water rinsing; cleaning (if necessary) by light pickling in a 1 to 1 solution of hydrochloric acid; water rinsing; depositing zinc to a thickness of 0.0002 inch from an electrolytic cyanide zinc plating bath in a tumbling barrel; water rinsing; centrifugally air drying; baking at 400° F. for 1 hour; water dipping; dipping for 10 to 20 seconds in a solution of sodium dichromate in dilute sulphuric acid to improve corrosion resistance; water rinsing; and air drying.

In design and dimensions the finished steel case of Fig. 3*b* is closely similar to conventional caliber .30 brass cartridge cases of equivalent form. Thus our Fig. 3*b* steel case may have exactly the same outside dimensions and tolerances, primer pocket and mouth contour. The inside dimensions may also be the same, apart from the base to side wall juncture which preferably is proportioned in the slightly distinctive manner shown. Illustrative wall thicknesses (again exaggerated by the drawings) are tabulated in the succeeding section. In size, shape and general appearance our new steel case thus is scarcely distinguishable from a conventional brass case.

In mechanical characteristics, however, substantial differences do exist. The modulus of elasticity of steel is about twice that of brass; the ductility of steel is less than that of brass; and the attainable yield strength of steel is considerably higher than that of brass.

Hardness distribution in finished case

The processing operations just described (by

reference to Fig. 3) as following our quench and temper heat treatment (of Fig. 2) in no way detract from the desirable mechanical properties that were earlier imparted to the case head and lower side wall. The upper or mouth end of the case has, however, been initially softened and then slightly work hardened by the annealing, tapering and necking operations exemplified by Fig. 3.

In consequence the finished steel case has a hardness distribution pattern such as is shown by Fig. 3*b* in conjunction with the following tabulation. This tabulation is representative of steel cases made by our improved technique from the SAE 1030 "higher carbon" composition of Example A.

	Case Metal Location	Inches from Head Face	Vickers Hardness	Approx. Wall Thickness
				Inches
Side Wall	A	0.200	325 to 375	
	B	0.305	325 to 375	0.041
	C	0.555	325 to 375	0.030
	D	0.805	325 to 375	0.022
	E	1.055	325 to 375	0.019
	F	1.305	250 to 325	0.016
	G	1.555	220 to 300	0.013
	H	1.805	160 to 180	0.010
	I	2.200	160 to 225	0.012
	J	2.400	160 to 225	0.012
Head	*b*	As Shown	325 to 375	
	d	do	325 to 375	
	e	do	325 to 375	
	f	do	325 to 375	
	g	0.187	325 to 375	

From the foregoing data it will be seen that the upper or mouth portion of the case (locations J–I–H) has been softened to about 160 to 225 Vickers; that the case body side walls (locations G and F) have been less softened and show Vickers hardnesses graduated from 220 to about 325 towards the head; that the lower side walls (locations A to E) are substantially uniform at from 325 to 375 Vickers; and that the case head metal also is uniform at from 325 to 375 Vickers.

Accompanying physical properties from A to G are substantially uniform and as described previously; the upper and softened side wall G to J is more ductile and better suited for obturation; metal around the primer pocket **22** is sufficiently hard to prevent primer leaks and blows; the head flange back of extractor groove **24** is sufficiently tough to resist shear on extraction; and the finished case's lower side walls (A to D) have high enough yield strength to experience permanent deformation so low that the case does not stick in the gun chamber from expansion due to firing pressures.

Satisfactory functioning as shown by proof firing

Steel cartridge cases made as aforesaid prove eminently satisfactory when assembled into complete caliber .30 ammunition rounds and fired in military rifles of conventional design. Performance is found to be substantially on a par with conventional brass case ammunition and far superior to steel case ammunition wherein mechanical properties are developed by cold working methods of the past.

Complete obturation is achieved by our improved steel cases. Prior to firing there exists between the mouth and side walls of the cartridge case and the gun chamber's wall a small clearance just sufficient to permit easy introduction of the round into the gun. It has been seen (from Fig. 3*b*) that the mouth **26** (Fig. 3) of our improved case is softer and relatively more ductile than the balance of the case. The degree of these qualities is such that upon firing of the powder charge the internal pressure immediately forces the mouth metal into intimate contact with the chamber wall.

This forcing precedes expansion of the rear and stronger chamber wall **20'** into contact with the chamber interior and thereby seals against pressure leakage between the cartridge case and chamber rearwardly to the breech opening. Upon release of the pressure through expulsion of the projectile the elastic qualities of the case mouth release the just named intimate contact of obturation.

Ease of extraction likewise is achieved by our improved steel cases. Upon firing of the round the case body side walls **20'** also are forced into intimate contact with the gun chamber interior. This contact transfers a portion of the expansion force to the chamber. After firing, however, the case sidewalls instantly contract away from the gun chamber thereby providing a certain small clearance, so that when the gun's extractor engages the extractor groove **24** the empty case can be removed easily and at once from the chamber.

Such ease of extraction is made possible by the relatively high yield (140,000 p. s. i. and above) and tensile (150,000 p. s. i. and above) strengths possessed by our improved case's body side wall **20'**. Should the side wall yield strength be reduced below a certain minimum, the case will be rendered incapable of fully contracting away from the chamber upon firing pressure release. Property development by cold working is found to be inadequate to even reach this minimum.

It may here be observed that the yield strength required in steel cases is greater than that required in conventional brass cases because of the substantially lower modulus of elasticity of brass (about 15×10^6) as compared with steel (about 30×10^6). It may further be noted that the total clearance (in thousandths of an inch) required in small arms is about as great as in large cases, since both large and small cases are found to require about the same amount of space for extraction. Therefore, the percentage contraction must be greater in small arms, and this means that a higher yield strength is required in small arms cases than in larger sizes.

Requisite base toughness further is exhibited by our improved steel cases. At the junction of the case head with the side wall there exists a region where cracking or other fracture may occur upon firing unless exceedingly high toughness is present. All tendency for failure at this point has been overcome by our quench and temper heat treating technique herein described.

Freedom from sidewall, head and other splits additionally characterizes our improved steel cases. Such splits are most frequently associated with die marks; strings of non-metallic inclusions and variation in side wall thickness also may lead thereto. Occurrence in the steel cases herein described is exceedingly rare, due to the superior impact resistance properties which these cases possess.

All of the foregoing advantages have been convincingly verified by a manufacture of hundreds of thousands of the heated steel cartridge cases of our invention, an assembly thereof into caliber .30 ammunition rounds, and a proof firing testing of those rounds under simulated service conditions. Typical performance is indicated by the following data.

Fifty thousand such ammunition rounds made

up from heat treated steel cases of the SAE 1030 composition of Example A were proof fired in Springfield, Garand, Browning and other standard caliber .30 military weapons at 113% normal pressure (approx. 48,000 p. s. i. as measured by copper pressure cylinders in holes drilled in the case walls). Of this large number all but 171 functioned satisfactorily in every respect. Only 112 or 0.23% of the test lot showed any malfunctioning and this was restricted to minor difficulties of extraction; only 59 or 0.12% of the test lot gave case casualties. Latter included 5 body splits, 23 neck splits, 3 shoulder splits, 27 primer leaks, and 1 rupture.

Advantages over cold worked cases

Our improved steel case manufacturing procedure here disclosed as including novel quench and temper heat treatment offers significant advantages over past steel cartridge case forming techniques wherein mechanical properties have been developed by cold working.

Greater flexibility of case forming operations constitutes one advantage. Cold working techniques of the past are characterized by critical requirements for reduction percentages, number of drawing steps, and the like, and these restrict possibile fabrication procedures to a comparatively narrow range. In our improved technique no such critical requirements apply since, as earlier made clear, the original steel may be brought to the Fig. 1*j* case piece condition in any one of a wide variety of different manners. Mechanical properties at this point are unimportant since later applied quench and temper heat treatment (Fig. 2) is used to develop same. The accompanying freedom to ignore physical properties up to completion of the final draw vastly extends the range and variety of metal forming operations that may be utilized.

Attainment of a superior combination of mechanical properties constitutes another significant advantage. Cold working can be made to give in the lower side walls of plain carbon steel cases not more than 100,000 p. s. i. as an upper limit of yield strength when ductility and toughness of acceptable values are retained (higher yield and tensile strength values from cold working bring ductility and toughness below acceptable limits); our quench and temper technique produces 140,000 p. s. i. yield strength and above accompanied by acceptable values of ductility and toughness. Whereas the cold worked cases thus are capable of only "border line" yield strength properties and hence offer relatively greater difficulty due to extraction, our heat treated cases exceed the minimum requirements by as high as 25% and show the attendant benefits of easy and reliable extraction already discussed.

Accompanying improvement in "notch" toughness and impact resistance also is noteworthy. Reference to the curves of Fig. 4 show how impact resistance as measured by Charpy notch bar tests varies with changes in temperature from —100° F. to over +100° F. Curve **30** applies to the SAE 1030 steel of Example A after being heat treated by our quench and temper technique of Fig. 2; curve **32** applies to the same steel spheroidized annealed by well known commercial methods as initially received from the steel manufacturer; and curve **34** applies to the steel of curve **32** after same has been cold rolled to 20% thickness reduction.

Deformation by cold working thus serves to shift curve **32**'s "transition zone" to the right as shown at **34**, and into even higher temperature ranges of metal embrittlement and even lower ranges of "breaking energy." Curve **34**, can, therefore, be considered to represent toughness and impact resistance properties more favorable than are produceable in SAE 1030 steel by cold working to the higher percentage reductions typified by the side wall metal of finished cartridge cases. For the head and rim metal which has experienced smaller reductions than the side walls, curve **34** is more directly applicable.

Comparison of curves **30** and **34** strikingly reveals that impact resistance as measured by Charpy notch bar tests is far less sensitive to temperature change when toughness is developed by quench and temper heat treatment than when developed by cold working. At low temperatures particularly, our new technique thus is shown to yield impact resistance properties far superior to the best attainable from cold working. Whereas cold worked steel cases are so brittle at low temperature that they readily fracture at imperfections, our heat treated cases exhibit no such tendency.

Steel cartridge case difficulties with respect to head splits, side wall splits, rim shears and the like bear a close correlation to the "notch" toughness data of Fig. 4. Regardless of their method of fabrication (deep drawing as herein described or other known cold or hot forming methods), steel cases are found in appreciable percentage to have die marks, seams and laminations in their side walls and also to have certain fold or lap imperfections at their head-to-side wall junctions. Failures of the type just stated usually occur at these marks or imperfections, if at all; and the likelihood of their occurrence is found to be greatest when the "breaking energy" properties of the steel are low and least when those properties are high.

When fired at all temperatures, and especially those below +75° F., steel cases quench hardened and tempered prove much less likely to fail at the named imperfections than do cold worked cases which have not been so heat treated. At —40° F., for example, the likelihood ratio is of the order of about 1 to 15. Since service ammunition finds extensive use at exceedingly low as well as at higher temperatures, the practical significance of the improvement diagrammed by Fig. 4 will at once be apparent.

Summary

By the novel manufacturing technique herein disclosed we have produced successfully workable and thoroughly practical deep-drawn one-piece cartridge cases of the tapered body, shoulder and neck design which Fig. 3 shows. Although our new technique has been explained through reference to such an illustrative case designed for caliber .30 military firearm use, it will be apparent that the manufacturing methods of our invention are not restricted to this size or specific case shape but also may be applied to the production of small arms cases of other shapes and sizes (such as caliber .50) as well as to the production of artillery cases ranging from 20 mm. and below to 105 mm. and above.

Steels of compositions other than the two "plain carbon" examples herein given likewise are useable. Various modifications of our complete procedure's quench and temper heat treatment thus have been tried on "alloy" as well as plain carbon steels, all with consistently equivalent success. These techniques have, moreover, been applied

equally well to steel semi and completely killed with aluminum or other means, by empirically determining the optimum heat treatment necessary.

The metallic structures which result from the indicated treatment, especially in the various forms that develop through the cooling period, are so well known that no elaboration thereon has here been attempted. What is important is the attained superior combination of mechanical properties necessary for good obturation and extraction of the cartridge case plus freedom from physical failure. These properties include the described hard and toughened case head and rear body portion having high yield strength, together with the more ductile forward body portion and mouth end.

Our findings have been that steel cases of a wide variety of necked down and other designs will function satisfactorily when manufactured in the unique manner here disclosed.

From the foregoing it will be seen that we have made highly practical improvements to the manufacture from steel of cartridge cases for small arms and artillery ammunition; that we have made possible the production of steel cartridge cases which fire without splitting or other mechanical failure, obturate properly during firing, extract normally after firing, and otherwise prove satisfactory when used in firearms of conventional design; that we have developed in steel cases superior combinations of essential mechanical properties such as tensile and yield strengths, elongation and ductility, toughness and impact resistance, and hardness; and that we have effected such property development through novel heat treating steps uniquely combined with cup and draw case forming technique.

Our invention is therefore broad in its adaptation and hence is not to be restricted to the specific form here shown by way of illustration.

We claim:

1. In the manufacture from spheroidized plain carbon steel having a carbon content between about .15% to about .45% of a one-piece "bottle-neck" military type cartridge case having a conventional design including a head, an extractor groove, a tapered body, a shoulder and a necked-down mouth portion, the method comprising the steps of processing said steel stock by a series of conventional cupping and drawing operations into a basic-shape tubular case piece whose base and lower sidewall dimensions are a predetermined amount under those desired for the final product, forming on the base of the resulting case piece a head and in said head a primer pocket whose dimensions are a predetermined amount under those desired for the final product, turning an extractor groove into said head, thereafter heat treating the case by a process which consists of transforming all of the steel in said case piece into its uniform austenitic phase by heating to and holding at a temperature above the steel's upper critical or AR3 point, converting the entire case composition into martensite by severely and completely quenching same in a quench medium which has a quenching power equivalent to that of water whereby to harden the steel case and further to cause an initial increase in the undersized dimensions of the case base and lower sidewalls and primer pocket, developing high yield strength and toughness and other desired mechanical properties in the entire case piece by heating to and holding at a tempering temperature below the steel's lower critical or AR1 point whereby to cause a further increase in the undersized dimensions of the case base and lower sidewalls and primer pocket to those desired for the final case product, annealing the mouth end only of the case to impart softness and ductility to the metal comprising the mouth wall without altering the mechanical properties previously developed in the case head and body sidewalls, and then tapering and necking the case body and mouth, respectively, to desired final configuration.

2. In the manufacture from spheroidized plain carbon steel having a carbon content between about .15% to about .45% of a one-piece "bottle-neck military type cartridge case having a conventional design including a head, an extractor groove, a tapered body, a shoulder and a necked-down mouth portion, the method comprising the steps of processing said steel stock by a series of conventional cupping and drawing operations into a basic-shape tubular case piece whose base and lower sidewall dimensions are a predetermined amount under those desired for the final product, forming on the base of the resulting case piece a head and in said head a primer pocket whose dimensions are a predetermined amount under those desired for the final product, turning an extractor groove into said head, thereafter heat treating the case by a process which consists of transforming all of the steel in said case piece into its uniform austenitic phase by heating to above 1500° F. and there holding for several minutes, converting the entire case composition into martensite by severely and completely quenching same in brine and there cooling to below 100° F. whereby to harden the steel case and further to cause an initial increase in the undersized dimensions of the case base and lower sidewalls and primer pocket, developing high yield strength and toughness and other desired mechanical properties in the entire case piece by tempering at below 700° F. for about one hour and then cooling, whereby to cause a further increase in the undersized dimensions of the case base and lower sidewalls and primer pocket to those desired for the final case product, annealing the mouth end only of the case to impart softness and ductility to the metal comprising the mouth wall without altering the mechanical properties previously developed in the case head and body sidewalls, and then tapering and necking the case body and mouth, respectively, to desired final configuration.

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