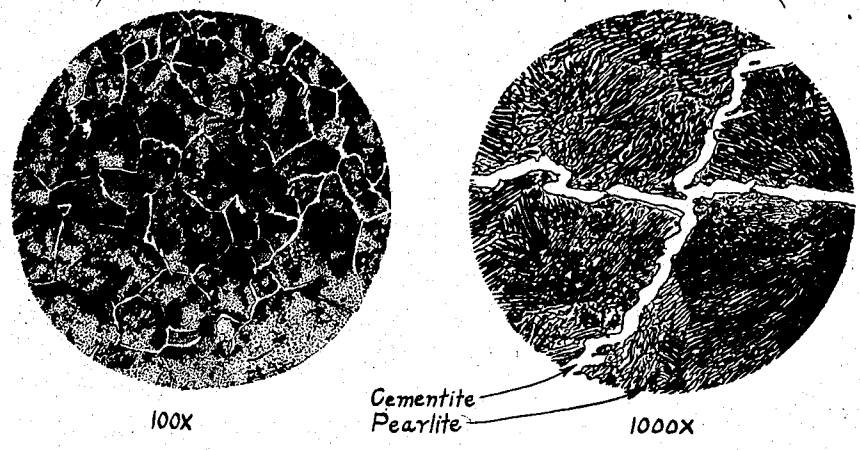
Feb. 26, 1935. C. H. WILLS 1,992,905

ALLOY STEEL

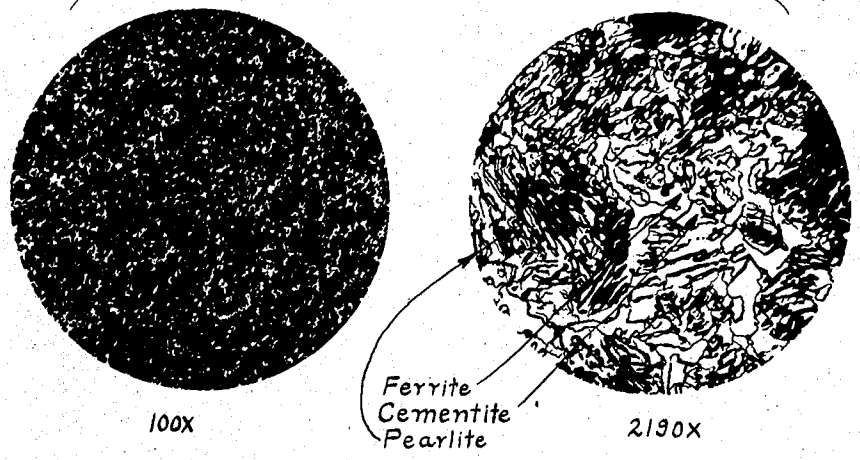
Filed July 17, 1934 4 Sheets-Sheet 1

Fig. 1.



100X 1000X

Fig. 2.



100X 2190X

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ALLOY STEEL

Filed July 17, 1934 4 Sheets-Sheet 2

Fig. 3.

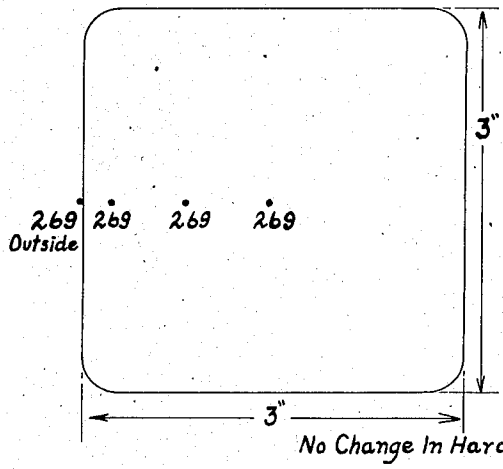


Fig. 4.

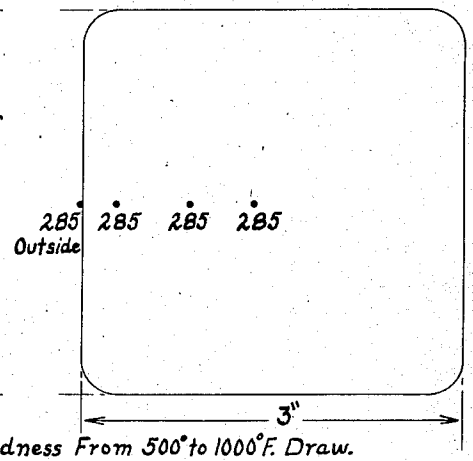
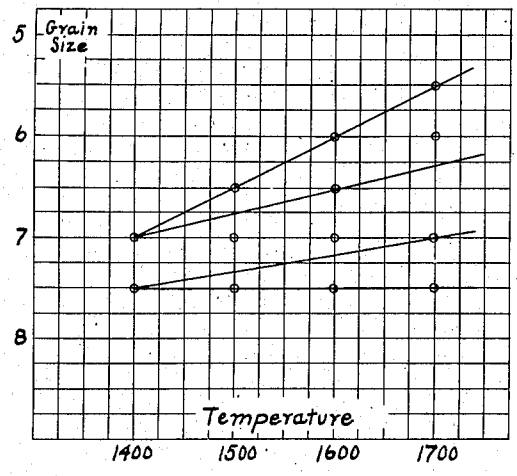


Fig. 5.

Grain Size vs. Temperature For Different Steels.



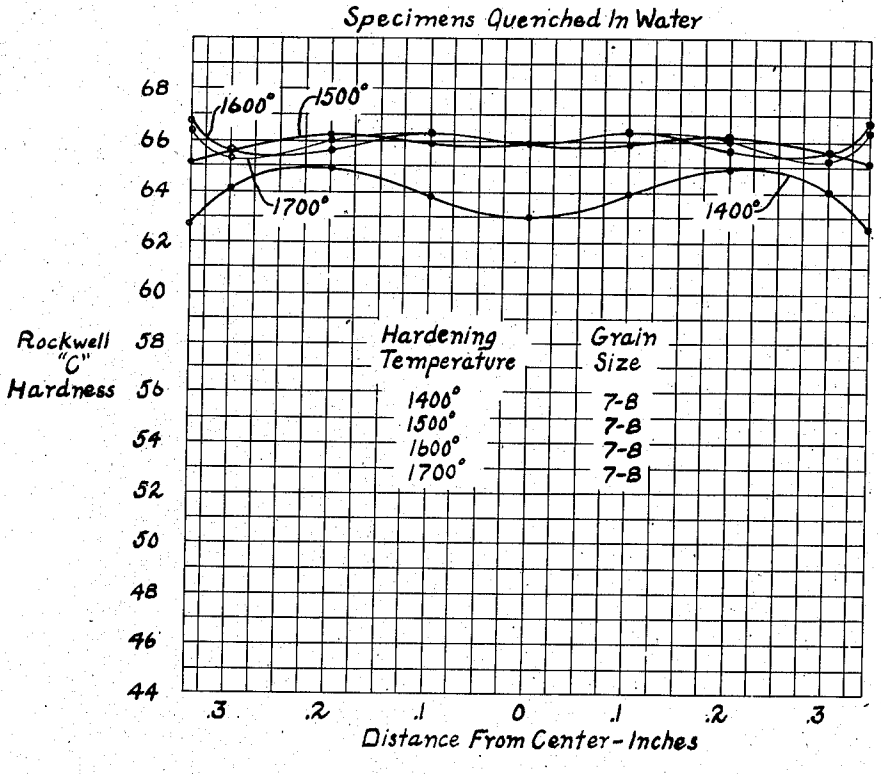
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ALLOY STEEL

Filed July 17, 1934 4 Sheets-Sheet 3

Fig. 6.



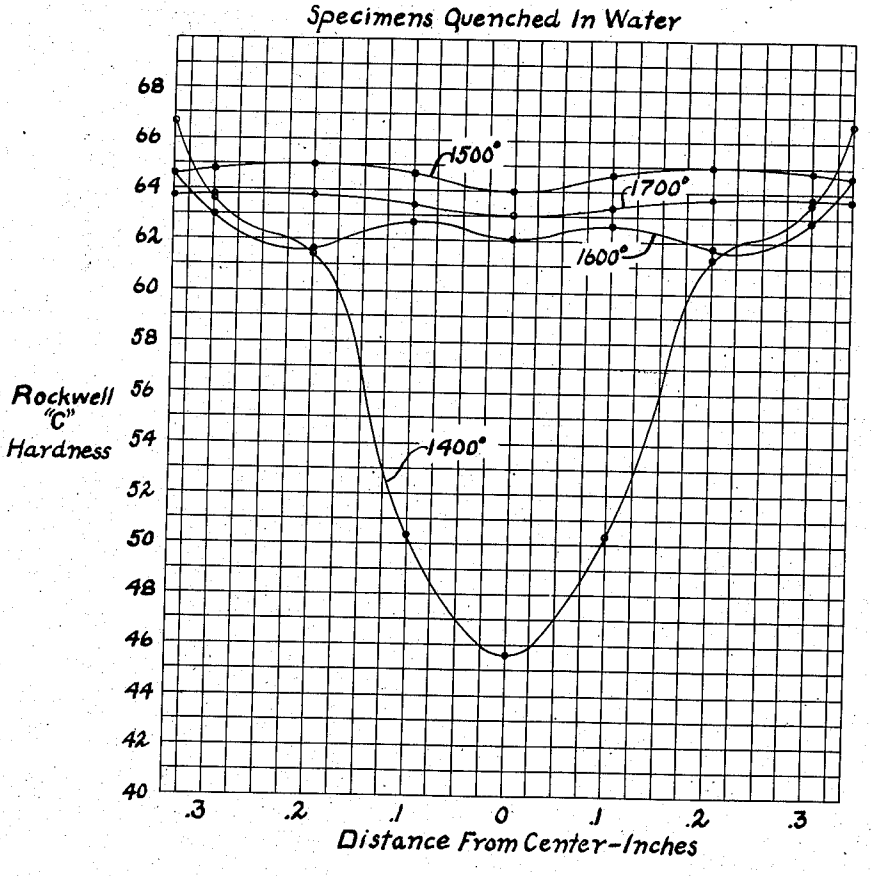
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ALLOY STEEL

Filed July 17, 1934 4 Sheets-Sheet 4

Fig. 7.



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UNITED STATES PATENT OFFICE

1,992,905

ALLOY STEEL

Child Harold Wills, Marysville, Mich.

Application July 17, 1934, Serial No. 735,545

7 Claims. (Cl. 75—1)

This invention relates to alloy steels and a method of making the same:

According to one aspect of my invention I propose a general purpose steel of improved properties and characteristics and which is simple and economical to manufacture and effects additional savings by the simplification of the manufacture into the finished product which it makes possible in some instances.

The nature, objects and advantages of my invention will be best appreciated from the following:

What I mean by "general purpose steel" may be illustrated by reference to the automobile. My steel, for example, is suitable for axles, crankshafts, connecting rods, torsion members such as shafts, transmission gears, pinions and ring gears, valves, and springs, coiled or flat. My steel is also useful for large pieces, such as die blocks, piston rods for hammers and locomotives, and the like. My steel is also useful for parts formed from sheet and strip steel, such as braces, brackets and frame members for automobiles, railroad rolling equipment and general structural work. Also for plates, shipplates and deck plates; for I-beams, channels and similar structural members; for rail and angle bars. It is useful for stampings such as kitchen utensils, sinks, lavatories, bath tubs etc., especially when coated with ceramic enamel.

My steel is useful for tubes for various purposes such as axles, bearings and structural members.

My steel may be effectively heat treated and by heat treatment I include not only quenching and drawing operations but also annealing and normalizing or air blast or other cooling.

The steel of my invention has very much increased ductility and toughness and resistance to shock and fatigue above average steels of specific analysis, employed for parts such as above set forth; and these characteristics can be obtained by the regular processing operations of heat treatment such as quenching and drawing, normalizing, etc., without special equipment other than that ordinarily used.

In carrying out my invention I deliberately make the steel abnormal, the extent of the departure from normality being dependent upon the particular use to which the finished piece is to be put. In no case, however, should the abnormality be carried to the point where the ends of my invention are defeated, as will further appear.

I am fully aware that abnormality in steels is known as are many of the factors or conditions which will produce abnormality. Heretofore, however, abnormality has been generally avoided as rendering the steel unfit. Some of the reasons therefor are that abnormality has a marked tendency to decrease the extent of depth hardening, produces soft spots in quenching, lowers the ability to carburize readily, etc.

I have discovered that abnormality together with molybdenum plays a very important part in securing the improved results obtained in my steel. I believe that this is due to the fact that during the transition period through the critical range in the quenching operation, the transition takes place in such a manner that the steel tends to pass from austenite to a mild martensite or possibly even directly to troostite, without the production of the very hard and large amounts of brittle martensite present when ordinary or regular steel of the normal condition is quenched, and which, in the normal steel, has the effect of causing, or the tendency to cause, martensitic fracture or overstrain, which cannot be sufficiently removed by the subsequent drawing operations. In my steel, therefore, martensitic fracture or over-strain, if not entirely eliminated, is at least minimized to the point where the improved properties of increased ductility, toughness and resistance to shock and fatigue are obtained.

Another contributing factor is fine grain size, say from #5 to #8 or finer, of the A. S. T. M. standard chart. I prefer a grain size of from 6 to 8. Fine grain size, as does the abnormality, tends to decrease the depth of penetration of hardening. This otherwise objectionable characteristic, I overcome as will later be described.

I have found that a molybdenum steel which is made abnormal and which has fine grain size gives the remarkable results herein set forth. By control of the degree of abnormality and by maintaining proper balance of the elements in the steel, I find that I can get a steel of the improved properties hereinbefore mentioned, which has the properties needed for the particular use to which the piece is to be put. For example, I can, in both small and large pieces, obtain uniform hardness from the surface to the middle; or I can produce a piece hard at the surface and shading off to a soft but tough core.

An abnormal steel may be readily recognized and for the purposes of this specification it will suffice to say that an abnormal steel is one in which the physical condition, as seen by microscopic examination after carburizing and cooling (McQuaid-Ehn test) is a condition of divorced cementite of greater or less degree. The three constituents will be generally, pearlite, cementite and ferrite, the latter two more or less occurring around the pearlite in such a manner that the original grain borders are not distinct. This structure is thus different from the so-called normal steels which under the McQuaid-Ehn test show distinctly formed grains with sharply outlined borders.

For purposes of illustration a normal steel is shown in Figure 1 and a molybdenum containing abnormal steel of my invention in Figure 2 of the accompanying drawings.

I have found that by adding molybdenum I can overcome or counteract the tendency of abnormality and of small grain size to decrease the depth of hardness, and secure any extent of depth hardness desired. I vary the degree of abnormality and the amount of molybdenum, dependent upon the size of the article to be heat treated and upon the results desired. I also vary the quantity of the other constituents which are preferably carbon, manganese and silicon. This, together with the control of abnormality and of the molybdenum, makes it possible that manufactured parts of any size or kind may be produced in the condition desired. For instance, on parts of relatively small section, say 1" or under, in which medium hardness is desired by heat treating, the abnormality would be increased to a relatively high degree, the manganese and carbon would be relatively low but kept in a balanced relation, while the silicon and molybdenum would in general be kept as usual. If the parts are of large section, say 6" or more, then the abnormality would be decreased, the molybdenum would be increased and the other hardening elements would be varied according to the process of heat treatment and the results desired. In all cases it is the balanced condition of abnormality and molybdenum that is responsible for the unusual ductility, toughness and fatigue resistance results obtained, while the hardness, generally considered, is influenced in the regular manner by the carbon and manganese and sometimes silicon.

The molybdenum makes it possible to secure the desired depth of hardness penetration which, as previously stated, may vary from uniformity throughout from surface to middle or shade off from the surface toward the middle. The manganese, while tending to increase total hardness, and while having some slight effect on depth of hardness, has a tendency to increase outside hardness with inside softness, which means that it has a tendency to produce both external and internal cracking. The carbon has tendency similar to that of the manganese. Hence there should be a balance between the molybdenum and the manganese and carbon so as to get the desired depth of penetration of the hardness without surface embrittlement. In large sections it is ordinarily desirable to increase the molybdenum and also the manganese and the carbon to get the hardness throughout.

I have produced heats of medium abnormality and of the following compositions, for various parts:

No.	Carbon	Manganese	Silicon	Molybdenum	Remarks
1	.70	.80	.25	.25	Pinions and rings
2	.65	.80	.25	.25	Pinions and rings
3	.60	.80	.25	.25	Pinions and rings
4	.55	.80	.25	.25	Transmissions
5	.50	.80	.25	.25	Transmissions
6	.45	.80	.25	.25	Transmissions
7	.40	.80	.25	.25	Structural
8	.35	.80	.25	.25	Bolts
9	.65	.90	.25	.25	Pinions and rings
10	.65	1.00	.25	.25	Manganese for increasing hardness
11	.65	1.10	.25	.25	Manganese for increasing hardness
12	.50	.90	.25	.25	Transmissions. Mn for increasing hardness
13	.50	1.00	.25	.25	Transmissions. Mn for increasing hardness
14	.50	1.10	.25	.25	Transmissions. Mn for increasing hardness
15	.65	.90	.35	.25	Pinions and rings. Si addition for hardness
16	.65	1.00	.35	.25	Pinions and rings. Si addition for hardness
17	.65	1.10	.35	.25	Pinions and rings. Si addition for hardness
18	.50	.90	.35	.25	Trans. Si addition for hardness
19	.50	1.00	.35	.25	Trans. Si addition for hardness
20	.50	1.10	.35	.25	Also for normalize
21	.90	1.10	.35	.25	Normalize
22	.90	1.10	.75	.25	Normalize
515	.657	.66	.27	.26	Structural parts, water quenched
516	.565	.65	.26	.25	Structural parts, water quenched
517	.439	.69	.24	.25	Structural parts, water quenched
518	.370	.67	.24	.25	Structural parts, water quenched

I have also produced heats with the carbon varying from .40% to .70% and with the manganese as low as .40% for pieces shading off from a hard surface to a soft but tough core.

I have produced 6 ton electric furnace heats for many purposes in a medium abnormal condition accompanied with the addition of molybdenum and with the carbon at .65%, .55%, .50%, .45% and 40%. Also open hearth heats in these ranges.

I have produced automobile coil springs for independent suspension of approximately the following analysis: .65% carbon; .80% manganese; .025% each of sulphur and phosphorus; .25% molybdenum; 25% silicon; 5 to 8 or finer grain size; and in an intermediate condition of abnormality between what I choose to call slightly abnormal and fully abnormal. The point to which abnormality can be carried can readily be determined by experiment. It must stop short of the point where the desired results would not be obtained. (Generally speaking, abnormality should stop short of the disappearance of pearlite.) From this condition of material I produce coil springs which are heated at about 1500° F., quenched in oil and drawn at 800° F. with a resultant Rockwell hardness of 42–46 "C". These springs have an unusual amount of toughness, ductility and fatigue resistance.

For purposes of comparison I have here tabulated the properties of this steel with a steel of comparable analysis in general use for this purpose, the analysis of this latter steel being as follows:

Acid open hearth	Oscillations of 3¾ dia coil springs	
C —.90% Mn—.45 P —.035 S —.045	Max. 300,000 Min. 23,000 Av. 45,000	40 tests
This steel		
C —.65% Mn—.80 Mo—.25 Si —.25 S —.030 P —.030	Max. 580,000 Min. 125,000 Av. 400,000	30 tests

I have also produced axle shafts according to my invention which, at the same torsional strength as chrome-nickel and chrome-molybdenum steels, show from two to three times the degree of twist at the breaking point. Comparative results are given in the following table in which the material labeled "Mola" is steel of my invention and had the following composition: carbon

.65%; manganese .80%; molybdenum .25%; sulphur .030% phosphorus .03% and the balance iron. The other steel was of the following composition: carbon .40%; manganese .75%; Ni. 1.60%; chrome .80%; sulphur .035% and phosphorus .030%. This steel, in one instance, was given the same heat treatment as that given to Mola and in the other instance it was given the regular heat treatment.

It is also known that certain of these conditions will produce fine grain. The use of finely divided mill scale in a bath of metal tends to produce a fine grained condition. It is also known that aluminum has a decided effect in producing certain conditions of grain size and abnormality.

I prefer to produce the desired condition of abnormality and grain size through the use of aluminum and molybdenum added to the heats

Rear axle shaft test—Model T6 truck

Material	Mola			M. S. 512 same H. T. as Mola		M. S. 512, Reg. H. T.		Specification
	1	2	3	1	2	1	2	
Dia. near fracture	1.362"	1.365"	1.335"	1.347"	1.335"	1.345"	1.342"	1.375-1.32
Smallest dia.	1.342"	1.345"	1.335"	1.347"	1.335"	1.345"	1.342"	
E. L. inch (actual)	63,700	60,700	50,000	62,200	53,200	52,000	50,000	45,000 min.
Figured at 1.365"	63,700	60,700	53,500	64,000	56,500	54,000	52,250	
Max. inch (actual)	88,300	89,150	75,100	79,300	70,900	70,000	69,600	
Figured at 1.365"	88,300	89,150	80,400	82,000	75,500	72,600	71,600	
Angle of twist max	526°	636°	976°	172°	320°	500°	372°	
Angle of twist E. L.	35°	31°	22°	31°	28°	25°	25°	
Hardness:								
Brinell—								
Outside	444	444	387	429	402	375	375	341-387
Halfway	444	429	375	429	375	363	363	
Center	418	363	341	429	352	341	363	
"C" Rockwell—								
Outside	47 46	47 46	41 42	44 44	41 41	39 39	38 39	
	47 47	46 46	41 42	44 44	41 42	40 39	38 39	
	47 47	46 46	39 41	44 45	39 41	39 40	38 39	
	47 46	44 45	38 39	44 45	38 41	38 39	39 40	
	46 46	43 44	37 38	44 45	37 40	37 39	39 40	
	44 44	41 43	36 36	44 45	36 38	36 37	38 39	
Middle	44 44	39 40	35 35	44 45	36 37	36 36	37 38	
	45 46	38 40	35 35	44 45	36 37	36 36	38 39	
	47 46	39 40	36 36	45 45	36 37	36 37	39 39	
	48 48	41 41	37 37	45 45	37 37	37 37	39 39	
	47 47	42 44	38 38	45 45	40 38	38 38	39 39	
Outside	48 47	46 46	42 42	44 44	42 43	39 39	39 40	

I am also applying the combination of varying abnormality and molybdenum content, together with manganese and silicon to large work, such as hammer rods, die blocks and other large sections for both heat treating and normalizing, so that I may use in combination with this abnormal structure, molybdenum up to about 1.50%, accompanied by varying amounts of manganese, not much over 2.50% to 3.0%; silicon not above about 2.50% and carbon up to about 1.25%. For certain special conditions these ranges may go somewhat higher.

I also can control, by the proper balance of abnormality and molybdenum with variation in the other constituents, the depth of hardening to such an extent that I can produce very shallow hardening, thorough or complete hardening or any degree of depth hardening between these extremes.

I produce the steel in electric or open hearth furnaces or by the crucible or any other standard method and the practice principally varies in that I produce the abnormal steel in combination with molybdenum and a controlled balance of other elements, instead of the normal steel that is commonly accepted as that desired. The raw materials used and the alloy additions are made in the same way as general practice has dictated.

With respect to abnormality it is known that there are several ways in which it has been produced, although it has been the general intention in steel manufacture to produce only normal steels for consumption. For example, it is known that if the amount of the deoxidizer (usually ferro-silicon) is not sufficient the steel may be abnormal. Also that under certain conditions, the addition of vanadium and sometimes of tungsten may produce abnormality.

at the proper time and under the proper conditions. This is particularly true of the aluminum which I generally add at the end of, or toward the end of the heat. I produce the bath of metal in the regular manner, adding the various elements as they are generally added, slagging in the usual way, and in the case of electric furnaces, I prefer to add the aluminum to the bath while in the furnace after the heat has been killed (by ferro-silicon) and about thirty minutes before the heat is poured, and in sufficient amount and under conditions of temperature and deoxidation of the heat, to produce the abnormality that I desire. I have found that the best temperature for the time of the addition of the aluminum is about 2800° F., in order to get the best results. This sometimes may be varied 100 to 150° F. up or down without objectionable results. It will be observed that the addition is to be usually made after the deoxidation of the heat is complete. It is also to be noted that it is best to employ the usual amount of deoxidizer (ferro-silicon). In fact I prefer to go a little bit toward the high side in the amount of ferro-silicon employed and produce a normal steel, which I then change to a controlled condition of abnormality by adding aluminum. The aluminum is in addition and not only produces the abnormality but also the fine grain structure. For the open hearth, I add aluminum in the amount of about 1¼ lbs. per ton. This will produce what I term a medium abnormality, i. e., about half-way between slight abnormality and the maximum which I have thus far found to be permissible. To decrease or increase the abnormality, the quantity of aluminum is reduced or increased. Thus far I have found that the aluminum should not be decreased much below 1 lb. per ton or increased

above 2 lbs. per ton in order to get the best results.

The aluminum may be added in the lable and this is particularly true in the case of open hearth practice, where I generally add about one-third of the ferro-silicon first, followed by the aluminum and then by the remainder of the ferro-silicon. In this connection it is to be observed that the quantity of ferro-silicon employed is that required for deoxidation plus the additional amount needed to give the desired silicon content in the finished steel.

For the electric furnace I find that less aluminum is needed and for medium abnormality I usually add about one pound of aluminum per ton, the addition being made about thirty minutes before pouring.

Of course, for different furnace characteristics, it will be found desirable to vary the procedure and the amounts somewhat, in order to get the best results.

The outstanding uniformity of the characteristics of my steel is well illustrated in the following impact tests. A standard Izod machine was changed in the following manner: The upper part of the machine was raised approximately $1\frac{3}{16}$'' so that the edge of the impact blade hits 2'' above the top of the anvil which grips the test piece. The test pieces were made from the original size of the spring steel rods (.689 plus or minus .004 dia.) which were heat treated the same as the springs, i. e., heated to 1600° F., cooled in air for approximately 30 seconds, transferred to a furnace at 1500° F., heated at this temperature for thirty minutes, then quenched in oil followed by an 800° F. draw. The pieces were then ground with a grinding wheel $\frac{1}{8}$'' wide. The diameter across the groove was .650''.

Heat No.	Max. ft. lbs.	Hardness surface	Brinell center	Min. ft. lbs.	Hardness surface	Brinell center	Average ft. lbs.	% Variation from av.	
								Low	High
26450	126	461	444	98	444	444	111	12	14
71697	109	444	444	102	444	444	106	4	3
26469	118	444	444	95	444	444	106	11	10
26474	129	444	444	103	444	444	113	8	14
26457	120	444	444	90	444	429	101	12	19
26580	109	444	444	92	444	444	100	8	9
26455	109	444	444	87	444	444	97	11	12
26378	104	444	444	87	444	444	92	6	13
36595	115	444	444	95	444	444	105	9	10
71645	120	444	444	104	444	444	112	8	7
36394	157	444	444	118	444	444	130	9	21
36350	115	444	444	84	444	444	96	12	20
71765	109	444	444	90	444	444	97	7	13

Average—9%, 13%.

The uniformity of results it will be seen are outstanding. With ordinary steels one expects variations of as high as 100% or more. The analysis of the steels tested was carbon about .60% to about .65%; manganese about .75% to about .82%; molybdenum about .23% to about .25%; silicon about .22% to about .27%; and the balance iron, with the usual traces of phosphorus and sulphur.

To illustrate the ability to obtain uniformity of hardness throughout attention is directed to Figures 3 and 4 showing two pieces of spring steel analysis, the composition of which was carbon .65%; manganese .80%; molybdenum .25%; silicon .25%; and the balance iron with the usual traces of sulphur and phosphorus. These pieces were 3'' square. One was normalized at 1550° F. and the other at 1650° F. It will be seen that in both pieces the hardness was uniform throughout. In these pieces there was no change in hardness from 500° F. to 1000° F. draw.

To illustrate the extremely wide range of heat treatment possible with my steel, without detrimental effect on the properties, I have made numerous tests with both water and oil quenching from 1400° F. up to 1800° F. with no appreciable effect on the properties of the steel. This is remarkable, particularly with respect to water quenching, as one would normally expect that the range in which detrimental effects are avoided, would be very much less.

In Figure 5 I have reproduced a graph showing the effect on four different but comparable steels, of temperature on grain growth. The first steel was a standard 1095; the second was a molybdenum steel, normal; the third was a chrome-vanadium steel; and the fourth is a molybdenum steel of my invention, abnormal. It will be observed that the grain steadily grew in size in the first three steels, whereas in my steel the grain size remained substantially the same from 1400° to about 1700°.

To illustrate how the molybdenum carries in the depth of hardening and how slightly, in my steel, this condition is affected by temperature, I have reproduced in Figure 6 a graph of the depth hardness curves of the fourth steel of Figure 5. This graph needs no explanation. By way of comparison, in Figure 7 I have reproduced a graph of depth hardness curves of a standard SAE #1095 electric steel. It will be observed how at 1400° the hardness toward the center drops.

To be a little more specific as to the control of abnormality and grain size in the electric furnace. The steel is produced in the regular manner with the exception that I reduce the ferrous oxide—which is judged either by the appearance and action of the sampled slag, or by a quantitative estimation of the ferrous oxide in the bath—by the addition to the bath of first, ferro-manganese, followed by ferro-silicon, after which I add about 1 pound to 1¼ pounds of aluminum per ton of steel which hould be approximately 2800° F. when poured. In the case of electric furnace heats, the aluminum is added to the bath about thirty minutes before pouring, by attaching pig or cast aluminum in forms to a bar and pushing it through the slag and below the surface of the steel until the aluminum is completely melted. The reaction that occurs is between the aluminum and any ferrous oxide that remains and also with the other oxides that are present wherein the affinity of the metal for oxygen is less than that of aluminum for the same oxygen, and this reaction that occurs I believe to be the formation of alumina under a condition that affords ex-

treme dispersion as against any other condition or larger amounts of aluminum wherein solution of aluminum instead of dispersion of alumina would be effected.

I can also produce similar results from electric furnace heats by adding the aluminum in the ladle, although the conditions are somewhat harder to control. The method then is as follows: The electric furnace heat is carried through the regular slagging and the addition of ferro-manganese is made and sometimes but not always, enough ferro-silicon is added to the bath sufficient to kill or deoxidize the heat, but no excess is used. In general it would be better to leave the heat under-killed. The analyses, except for silicon, are balanced, and the heat poured at about 2800° F. As the first metal hits the ladle a part of the ferro-silicon necessary to bring the heat to the desired silicon analysis and the oxidation condition is added and then from 1 to 1¼ pounds of aluminum per ton is added, after which the remainder of the ferro-silicon is added and the pouring of the heat finished.

With respect to open hearth furnace, I have only added the aluminum to the steel in the ladle, although I can use another method of adding the aluminum as hereinafter shown. After the heat has been properly melted and carried through as any regular heat of open hearth steel, the analyses, with the exception of silicon, are balanced and the heat adjusted to a temperature of approximately 2800° F. The heat is then poured. After the pouring starts, I add part of the ferro-silicon necessary to balance the silicon analysis and then add the aluminum, about 1¼ pounds per ton, then the remainder of the ferro-silicon and continue the pouring to the end.

If the steel is in such a condition at the time of the addition of the aluminum, or the amount of aluminum is not in the right amount so that the solution occurs instead of thorough alumina dispersion, then the proper grain size will not be produced and the steel may not be abnormal but normal, which latter is the condition I wish to avoid. If solution occurs instead of dispersion, then there is a tendency toward normality and large grain.

As an alternative method for adding the aluminum to the open hearth furnace, I can embody a method similar to what I use in the electric furnace, namely, adding the ferro-silicon following the addition of ferro-manganese until the heat is killed to the right degree for adding aluminum, about 1¼ to 1½ pounds per ton, to the bath by attaching a pig or casting of aluminum to a heavy rod and pushing one or more of such castings quickly through the slag and down through and nearly to the bottom of the bath. This operation may either be performed by hand or by a mechanical device made to operate through the doors or through the top of the furnace. It is sometimes necessary to add in the ladle some ferro-silicon to complete the required silicon analysis.

I find that very satisfactory steel can be produced with the following analysis: carbon from about .60% to about .70%; manganese from about .70% to about .90%; silicon from about .20% to about .30%; molybdenum from about .20% to .30% and the balance iron with the usual traces of sulphur and phosphorus.

I have also found it useful to operate at about the following range: carbon from about .15% to about 2.0%; manganese from about .30% to about 3.0%; silicon from about .15% to 2.50%; molybdenum from about .20% to about 1.50%; and the balance iron with the usual traces of sulphur and phosphorus.

I have also made heats with other elements in addition to the molybdenum. For example:

	Percent	Percent	Percent
Carbon	.53	.53	.53
Manganese	.77	.78	.79
Silicon	.27	.25	.24
Molybdenum	.25	.25	.25
Chromium	.37	.57	.80
Grain-size—Average	6	6	7

Again:—

Carbon	Manganese	Silicon	Molybdenum	Nickel	Chromium
.562	.86	.27	.28	3.62	.038
.542	.84	.27	.26	1.87	.038
.518	.83	.27	.27	1.41	.65
.492	.90	.52	.25	.08	.042
.498	.79	.49	.22	.08	.032
.43	.79	.49	.27		
.680	.79	.25	.25	.08	.032

Made with aluminum, silicon, iron alloy instead of ferro-silicon and aluminum.

It is to be understood that I do not limit myself strictly to the elements and percentages given and that the claims are not to be construed as excluding the range of equivalents for obtaining the same results to which I may be entitled. The degree of abnormality should be at least sufficient to give pronounced increase in properties as compared with a normal steel of comparable analysis. This can be readily determined for any given alloy by experiment. The upper limit of degree of abnormality has been elsewhere given.

This is a continuation in part of my applications Serial Nos. 704,517, filed December 29, 1933 and 715,492, filed March 14, 1934.

What I claim is:—

1. An alloy steel which is abnormal or characterized by a condition of appreciable dispersion or divorcement of cementite and includes the following ingredients substantially in the amounts specified:

	Per cent
Carbon from	.15 to 2.00
Manganese from	.30 to 3.00
Molybdenum from	.20 to 1.50
Iron from	99.20 to 91.00

said steel being characterized by a high degree of ductility, toughness and resistance to shock and fatigue.

2. An alloy steel which is abnormal or characterized by a condition of appreciable dispersion or divorcement of cementite and includes the following ingredients substantially in the amounts specified:

	Per cent
Carbon from	.15 to 2.00
Manganese from	.30 to 3.00
Silicon from	.15 to 2.50
Molybdenum from	.20 to 1.50
Iron from	99.20 to 91.00

said steel being characterized by a high degree of ductility, toughness and resistance to shock and fatigue.

3. An alloy steel which is abnormal or characterized by a condition of appreciable dispersion or divorcement of cementite and includes the fol-

lowing ingredients substantially in the amounts specified:

	Per cent
Carbon from	.60 to .70
Manganese from	.70 to .90
Molybdenum from	.20 to .30
Iron from	98.60 to 97.80

said steel being characterized by a high degree of ductility, toughness and resistance to shock and fatigue.

4. An alloy steel which is abnormal or characterized by a condition of appreciable dispersion or divorcement of cementite and includes the following ingredients substantially in the amounts specified:

	Per cent
Carbon from	.60 to .70
Manganese from	.70 to .90
Silicon from	.20 to .30
Molybdenum from	.20 to .30
Iron from	98.60 to 97.80

said steel being characterized by a high degree of ductility, toughness and resistance to shock and fatigue.

5. An alloy steel which is abnormal or characterized by a condition of appreciable dispersion or divorcement of cementite and comprises the following ingredients substantially in the amounts specified:

	Per cent
Carbon	.65
Manganese	.80
Molybdenum	.25
Iron with traces of impurities	98.30

said steel being characterized by a high degree of ductility, toughness and resistance to shock and fatigue.

6. An alloy steel which is abnormal or characterized by a condition of appreciable dispersion or divorcement of cementite and comprises the following ingredients substantially in the amounts specified:

	Per cent
Carbon	.65
Manganese	.80
Silicon	.25
Molybdenum	.25
Iron with traces of impurities	98.05

said steel being characterized by a high degree of ductility, toughness and resistance to shock and fatigue.

7. An alloy steel which is abnormal or characterized by a condition of appreciable dispersion or divorcement of cementite; which is also characterized by a grain size at least as fine as from #5 to #8 of the A. S. T. M. chart; and includes the following ingredients substantially in the amounts specified:

	Per cent
Carbon from	.15 to 2.00
Manganese from	.30 to 3.00
Molybdenum from	.20 to 1.50
Iron from	99.20 to 91.00

said steel being characterized by a high degree of ductility, toughness and resistance to shock and fatigue.

CHILD HAROLD WILLS.

Certificate of Correction

Patent No: 1,992,905. February 26, 1935

CHILD HAROLD WILLS

It is hereby certified that errors appear in the printed specification of the above-numbered patent requiring correction as follows: Page 2, second column, line 28, for "40%" read *.40%*; and line 33, after the semicolon, for "25%" read *.25%*; page 3, first column, in the table under the boxed heading "Material" the third entry should read *E. L. inch#* (*actual*) and the fifth entry *Max. inch#* (*actual*) instead of as shown; same table, under the heading "Specification" first entry, read *1.375∓1/32* instead of "1.375—1.32"; page 4, first column, line 3, for "lable" read *ladle*; and page 5, second column, line 26, the printed mattef in small type relates only to the last mentioned steel of the table; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 23d day of April, A. D. 1935.

[SEAL]

LESLIE FRAZER,
Acting Commissioner of Patents.