Aug. 20, 1940. R. P. DE VRIES 2,212,227

HIGH SPEED TOOL

Filed July 8, 1939 2 Sheets-Sheet 1

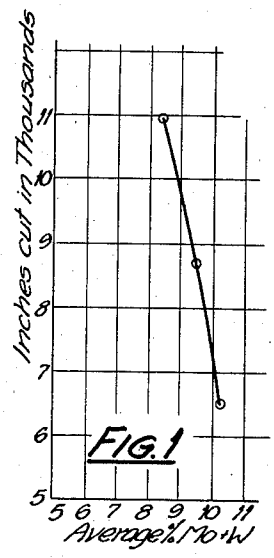


FIG. 1

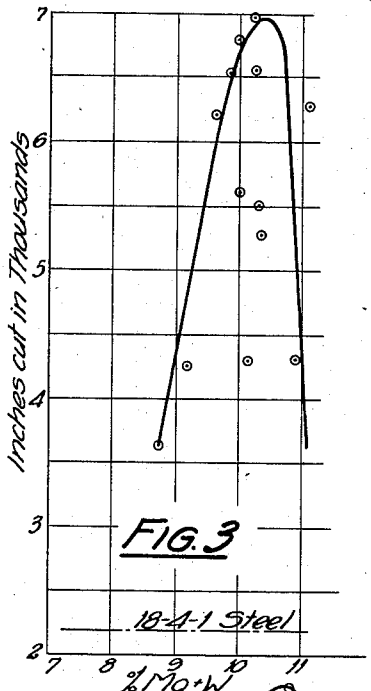


FIG. 3

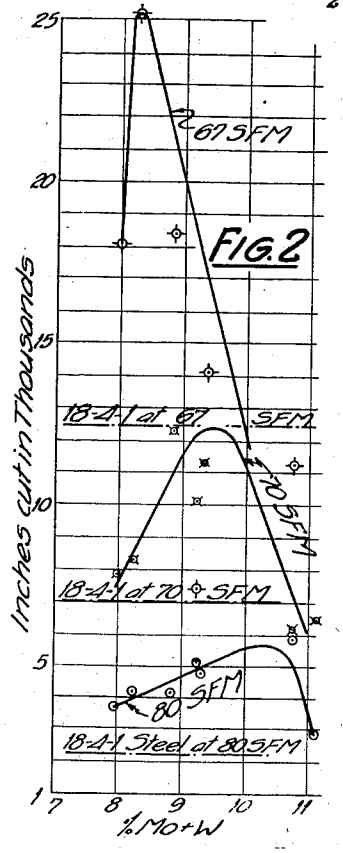


FIG. 2

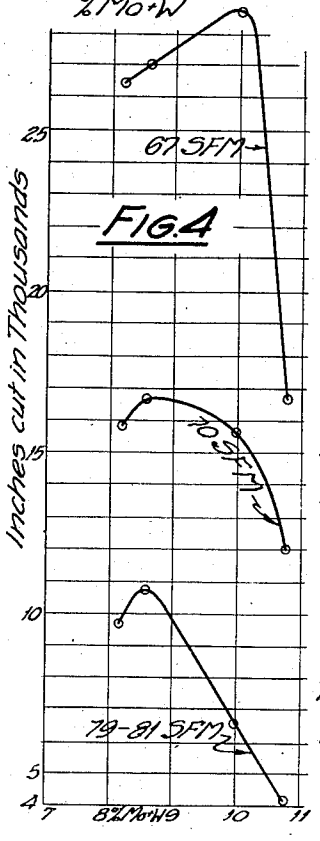


FIG. 4

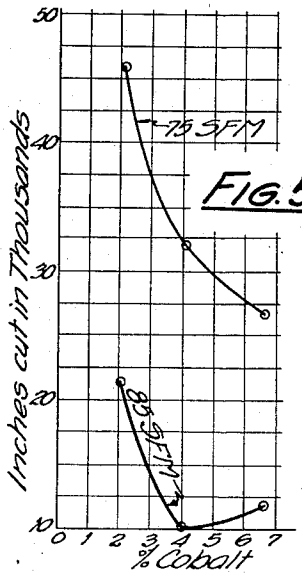


FIG. 5

INVENTOR
Ralph P. DeVries
by
ATTORNEY

Aug. 20, 1940. R. P. DE VRIES 2,212,227

HIGH SPEED TOOL

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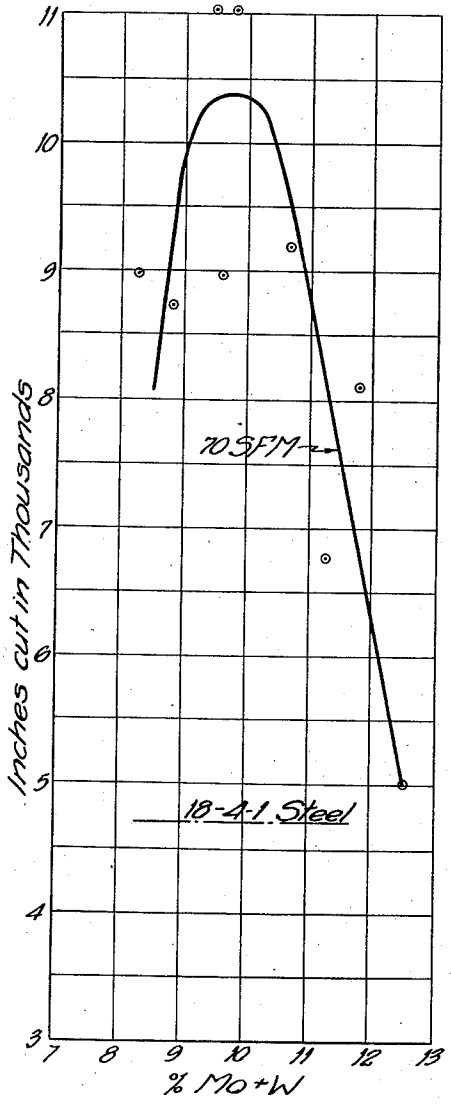


FIG. 6

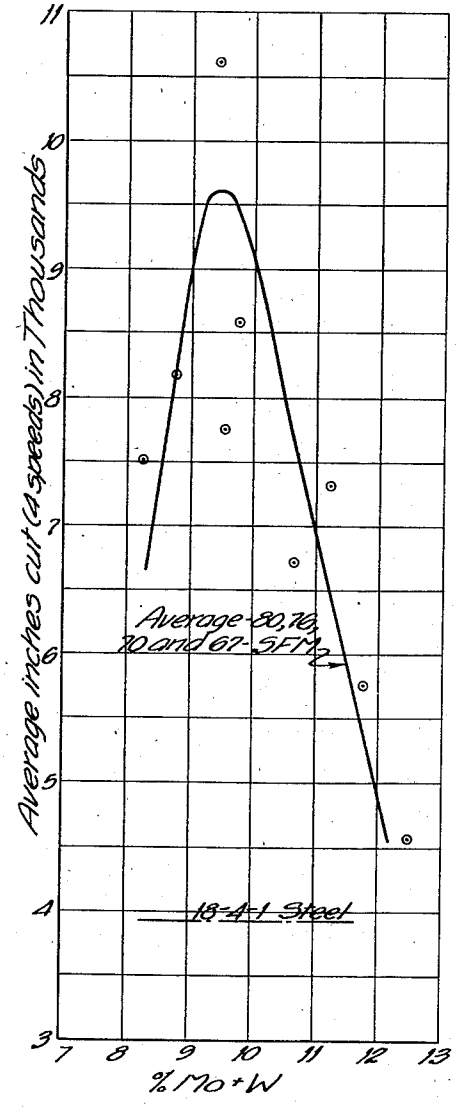


FIG. 7

INVENTOR
Ralph P. DeVries
by
ATTORNEY

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2,212,227

HIGH SPEED TOOL

Ralph P. De Vries, Menands, N. Y., assignor to Allegheny Ludlum Steel Corporation, Pittsburgh, Pa., a corporation of Pennsylvania

Application July 8, 1939, Serial No. 283,338

7 Claims. (Cl. 29—95)

My invention relates to improvements in high speed cutting tools and particularly to tools of this character which, although made from steel having an extremely low alloy content, are far superior to any other high speed tools formed of steel, of which I am aware, irrespective of the alloy content therein.

As a result of the making of many test melts of steel containing the usual elements found in high speed steels, including chromium, molybdenum, tungsten, vanadium and cobalt, in various proportions, and particularly with varying proportions of tungsten and molybdenum, and the study of the life and efficiency of a large number of cutting tools made therefrom, I have discovered that by maintaining the tungsten and molybdenum contents within comparatively narrow ranges, and within very limited proportions within these narrow ranges, it is possible to manufacture cutting tools having extraordinary and quite unexpected cutting properties.

In my copending application Serial No. 181,997, filed December 27, 1937, I have also disclosed an alloy steel having very narrow ranges of tungsten and molybdenum which, if maintained in the specified proportions, form a composition from which high speed cutting tools having a very low alloy content and an unusually long life may be manufactured.

While the alloy described in the aforesaid copending application is quite superior to other high speed steels of which I am aware, I have now discovered that by modifying the tungsten and molybdenum ranges therein disclosed and maintaining the total combined content of these elements within the very limited range of from about 7.0% to about 12.0%, by weight, of the total composition, it is possible consistently to manufacture a high speed steel which when measured by the life and efficiency of cutting tools made therefrom, is several times better than the well known 18–4–1 high speed steel.

In order graphically to indicate the very unusual cutting properties of my steel and to indicate how critically narrow are the ranges and proportions of the tungsten and molybdenum contents within which my present invention lies, reference may be had to the accompanying drawings in which—

Fig. 1 is a graph showing how the average life of twenty-two different tools, divided into three groups, depending on the combined content of molybdenum and tungsten therein, varies with this combined content;

Fig. 2 is a graph showing how the life of a number of tools each having a low and substantially the same content, (2.75% by weight) of tungsten but with varying quantities of molybdenum, varies with the combined tungsten and molybdenum content at different cutting speeds.

Fig. 3 is a graph showing how the life of a number of tools each having a tungsten content in excess of the molybdenum, varies with the combined tungsten and molybdenum content.

Fig. 4 is a graph showing how the life of four different tools containing about 2%, by weight, of cobalt and tested at three different cutting speeds varies with the combined content of tungsten and molybdenum;

Fig. 5 is a graph showing how the cutting life of three different tools when run at two different cutting speeds varies with additions of cobalt above about 2%;

Fig. 6 is a graph showing how the cutting life of nine different tools, each having its tungsten content about equal to its molybdenum content but having varying combined tungsten and molybdenum contents, varies with the total of the tungsten and molybdenum in the steel; and

Fig. 7 is a graph similar to Fig. 6 but in which each tool was run at four different cutting speeds and the average inches cut for each tool plotted.

The essential elements of the steel from which my cutting tool is formed and the percentages, by weight, within which they are employed are as follows—

	Per cent
C	0.20– 1.20
W	2.0 – 6.5
Mo	3.0 – 7.0
Cr	2.0 – 6.0
V	0.50– 3.0
Mo+W	7.0 –12.0

For many years tungsten, chromium and vanadium have been standard elements in high speed tools and the cutting efficiency of tools made from the so-called 18–4–1 steels containing about 18% of tungsten, 4% of chromium and 1% of vanadium has long been an accepted standard of efficiency which workers in the tool steel art have sought to approach with various steels in which the cheaper element molybdenum has been substituted in whole or in part, and in various proportions, for the more expensive tungsten. Such tools, while very much cheaper than the 18–4–1 tools, have only approached the 18–4–1 tools in cutting life and efficiency, and no tools containing comparatively low quantities of tungsten and molybdenum but having a cutting life and efficiency from two to three times greater than 18–4–1 tools have ever been proposed, so far as I am aware. The general assumption in regard to cutting life and efficiency seems to have been that these factors are increased in direct proportion to the tungsten and molybdenum employed, even when these elements are used in particular proportions as recommended by various investigators and patentees.

My investigations quite clearly establish that

while this may be true in respect of tools having a life and cutting efficiency approaching or even approximating an 18–4–1 tool there are, nevertheless, very narrow ranges of tungsten and molybdenum within which, if the total percentage of tungsten and molybdenum is maintained within very narrow limits, the curve of tool life and cutting efficiency rises to heights far transcending the life-efficiency curve of the 18–4–1 tools.

In Table 1 below I have set forth a number of steels containing tungsten and molybdenum in various quantities and relative proportions, according to the analyses thereof set forth in Table 2, and which are divided into three groups according to the total combined percentage of the tungsten and molybdenum in the steel. In the first group are all steels having a combined percentage of tungsten and molybdenum less than 9%; in the second group, those steels having a combined percentage of tungsten and molybdenum between 9% and 10%; and in the third group, those having a combined percentage of 10% or more. At the bottom of Table 1 is the average of the (W+Mo) % in each group, and the average of the number of inches cut by each tool before failure. All tools were identical in size and shape, subjected to the same heat treatment, and tested under identical conditions at a cutting speed of 85 surface feet per minute (85 S. F. M.).

TABLE 1

W+Mo=(7.50% to 9%)			W+Mo=(9% to 10%)			W+Mo=(10% and greater)		
Melt No.	W+Mo	Inches cut	Melt No.	W+Mo	Inches cut	Melt No.	W+Mo	Inches cut
T-609	8.48	7,900	T-602	9.54	8,450	T-614	10.33	6,600
T-611	8.48	13,150	T-607	9.41	13,650	T-627	10.70	10,000
T-617	8.54	14,900	T-616	9.40	10,350	T-633	10.04	4,050
T-646	8.96	12,400	T-642	9.34	7,800	T-641	10.54	5,600
T-664	8.10	10,400	T-643	9.44	5,400	T-647	10.31	6,100
T-668	7.75	6,950	T-644	9.72	5,100	T-648	10.09	9,200
			T-645	9.31	10,100	T-650	10.09	5,500
						T-666	10.23	6,900
						T-669	10.23	4,767
Average	8.39	10,950		9.45	8,693		10.28	6,524

TABLE 2

Analyses of melts shown in Table 1

Melt No.	Carbon	Chrome	Silicon	Molybdenum	Tungsten	Vanadium
T-609	.83	3.94	.75	3.64	4.84	1.42
T-611	.83	2.52	.61	5.52	2.96	1.34
T-617	.81	3.90	.24	4.10	4.44	1.32
T-646	.73	3.96	.67	3.20	5.76	1.24
T-664	.81	3.65	.51	5.56	2.54	1.50
T-668	.74	3.70	.70	2.96	4.79	1.52
T-602	.63	3.70	.80	4.12	5.42	1.64
T-607	.78	3.81	.83	5.48	3.93	1.28
T-616	.76	3.92	.67	4.72	4.68	1.30
T-642	.76	3.96	.16	3.70	5.64	1.32
T-643	.75	3.98	.15	3.40	6.04	1.32
T-644	.79	3.96	.74	4.04	5.68	1.22
T-645	.80	4.00	.78	3.72	5.59	1.20
T-614	.76	3.86	.78	6.29	4.04	1.34
T-627	.81	4.05	.17	5.20	5.55	1.24
T-633	.84	4.07	.25	5.76	4.28	1.28
T-641	.67	3.96	.17	4.54	6.00	1.28
T-647	.71	3.98	.16	5.51	4.80	1.27
T-648	.69	4.27	.75	5.39	4.70	1.22
T-650	.70	6.44	.21	5.49	4.60	1.22
T-666	.78	3.50	.87	4.36	5.87	1.50
T-669	.78	3.50	.87	4.36	5.87	1.50

Fig. 1 is a graph in which the average inches cut by each group is plotted as a function of the average (W+Mo) % of each group, and indicates how the average life-efficiency of the tool decreases as the average (W+Mo) % increases from 8.39% to 10.28%.

In order to determine the effect on the life-efficiency of varying quantities of molybdenum with a low and substantially constant quantity of tungsten, a series of steels of the analyses shown in Table 3 below were melted.

TABLE 3

Melt No.	Carbon	Chrome	Silicon	Molybdenum	Tungsten	Vanadium
T-704	.77	4.19	.65	6.15	2.70	1.66
T-705	.82	4.08	.67	5.53	2.80	1.64
T-706	.73	4.19	.63	5.11	2.88	1.70
T-707	.82	3.88	.63	6.92	2.34	1.64
T-708	.80	4.17	.66	6.60	2.72	1.66
T-717	.77	3.72	.75	8.32	2.83	1.58
T-746	.81	3.68	.61	8.12	2.66	1.70

In all these steels tungsten was melted at 2.75% and the molybdenum was varied so as to give a range of (W+Mo) % varying from 8% to 11.15%.

Fig. 2 comprises three graphs showing the life-efficiency curves of tools made from these steels when tested at 67 S. F. M., 70 S. F. M. and 80 S. F. M., as compared with an 18–4–1 tool These curves show that the maximum life-efficiency of the tools with low tungsten is attained when the (W+Mo) percentage is between about 8.25% and 9.50% although the general trend of the curves, especially at the higher speeds, indicates that creditable performance superior to 18–4–1 tools is attained with a (W+Mo) % of from about 7.0% to slightly over 11%.

In order to determine the effect of increasing the tungsten content to points above the molybdenum content, the series of steels shown in Table 4 below were melted, tools made therefrom and tested.

TABLE 4

Tool No.	Carbon	Chromium	Molybdenum	Tungsten	Vanadium	Silicon
T-670	.77	3.60	4.72	6.19	1.50	.94
T-712	.77	3.42	3.95	5.99	1.58	.61
T-713	.81	3.48	4.19	6.11	1.56	1.15
T-714	.80	3.60	4.68	5.57	1.52	.72
T-719	.75	3.99	3.56	5.63	1.56	.74
T-720	.83	3.93	4.00	6.15	1.56	.72
T-721	.72	4.00	4.53	5.08	1.46	.82
T-722	.84	3.82	4.40	6.70	1.62	.72
T-723	.82	4.01	3.60	5.15	1.62	1.21
T-725	.82	3.46	4.62	5.39	1.54	.61
T-726	.84	3.40	4.29	5.95	1.58	.61
T-727	.82	3.44	4.61	5.23	1.48	.24
T-728	.80	3.36	5.51	5.35	1.50	.25

The life-efficiency curve of these tools is plotted in Fig. 3, and, for comparative purposes the average life-efficiency of 18–4–1 tools under the same test conditions is also plotted as a horizontal line. Here, the maximum of performance is clearly limited to those tools in which the total tungsten and molybdenum content combined is between about 9% and 11% although the general trend of the curve indicates that creditable perform-

ance superior to the 18–4–1 tools is attained when the total molybdenum and tungsten combined is between about 8.5% and 11.25%.

All of my steels have the advantage that they may be hardened from very high temperatures in the range of 2275° F. to 2325° F. In fact the life-efficiency curves (shown in the drawings) are all based on a hardening temperature of 2325° F. with a reheating to 1025° F. The hardness of these tools is at a maximum when the tungsten and molybdenum content combined is between 9% and 11%. Although a hardness from 64 to 65 Cone Rockwell is common, tools made from preferred composition such as T–726 and T–727 show higher hardnesses going into the range of 67 to 68 Cone Rockwell and approaching sintered carbide tools in their extreme hardness.

Since all of the foregoing steels were manufactured under laboratory conditions where the size of the ingot and the forging reduction were necessarily small and therefore might not be directly representative of heats made on a commercial scale, two two-ton heats were made of the following analyses. In one, the combined content of tungsten and molybdenum was melted for 9%, and in the other 11.5%.

	Steel 282	Steel 283
Carbon	.77	.85
Chrome	3.97	4.18
Molybdenum	3.98	5.84
Silicon	.59	.21
Tungsten	4.83	5.57
Vanadium	1.55	1.02

A very extensive series of lathe tests of tools made from each of these steels was carried out at three different speeds and comparative tests of 18–4–1 tools were also made under the same conditions. The results showed grand averages of 22,161 inches cut by steel 282; 15,415 inches cut by steel 283 and 11,317 inches cut by the 18–4–1 steel.

These same steels were also made up into twist drills of various sizes from 1" down to $\frac{3}{16}$" and tested with 18–4–1 twist drills as a control. Taking the performance of the tools made from steel 282 as a hundred, Table 5 below shows the summary of these tests.

TABLE 5

Summary of lathe and drill tests

(Performance given in percent)

No.	Type	Steel 282	Steel 283	18–4–1	Lubricant
1	Lathe	100	78	65	No.
3	Drill	100	81	92	Yes.
4	do	100	80	89	Do.

The above tests were conducted under strictly shop conditions; dry cutting in the lathe test and fully lubricated in the twist drill tests. In many individual cases the performance of tools made from steel 282 exceed the performance of standard 18–4–1 tools in a ratio of 2 to 1.

The results of the comparative tests of tools made from steels 282 and 283 were quite unexpected and further tests were run to determine which of these steels had the greater hardness when measured in the temperature ranges at which high speed steels often operate. The results which are shown below in Table 6 indicate that the steel containing the lesser quantity of alloy, namely steel 282, has a greater hardness than the steel 283.

TABLE 6

Hot Brinell Hardnesses

° F. temp.	Steel 282		Steel 283	
	2320° F. oil	2320° F. oil, —550° F. air	2320° F. oil	2320° F. oil, —550° F. air
750	555	555	512	512
1000	555	532	512	512
1100	512	512	495	512
1200	444	418	387	402

The foregoing results of tests of tools conducted under actual commercial conditions and which said tools were made from two heats of steel melted under actual production conditions confirm the conclusion reached from a great many laboratory tests that the ranges of tungsten and molybdenum and the combined total thereof within which peak efficiency is attained are quite critical, and that when the combined content of tungsten and molybdenum is maintained well within the limits which I have prescribed, the results are markedly better than when the total of these elements is close to said limits.

The possibility of increasing the cutting efficiency of the tools with the addition of cobalt in small quantities was investigated by testing tools made from four different steels all containing tungsten and molybdenum with the ranges above set forth. The analyses of these steels are given in Table 7 below—

TABLE 7

Tool No.	Carbon	Chrome	Molybdenum	Tungsten	Vanadium	Silicon	Cobalt
T–710	.82	3.42	3.19	5.35	1.58	.72	1.97
T–711	.78	3.39	3.21	4.92	1.70	.73	2.00
T–715	.82	3.46	4.70	5.27	1.52	.66	2.08
T–716	.77	3.52	4.40	6.34	1.54	.80	2.14

In Fig. 4 the total cut in inches by tools made from each of these steels and at 3 different speeds is plotted as a function of the combined molybdenum and tungsten contents. The life-efficiency curves of these cobalt-containing tools shown in Fig. 4 have their peak when the combined percentage of molybdenum and tungsten is between about 8% and 11%. In other words, these tools exhibit the same type of life-efficiency curve as the other tools without cobalt. If, however, the combined content of tungsten and molybdenum is maintained within the above limits, which provides maximum cutting efficiency, the addition of higher quantities of cobalt does not improve the cutting performance as will be apparent from a consideration of the following tests.

The effect of cobalt additions above about 2% on the cutting efficiency of the tools was investigated by making and running tools of each of the 3 analyses given in Table 8 below—

TABLE 8

Steel No.	Carbon	Silicon	Chrome	Tungsten	Molybdenum	Vanadium	Cobalt
T–697	.74	.99	3.45	4.24	3.83	1.62	2.06
T–698	.77	.89	3.29	4.68	3.85	1.76	3.96
T–699	.81	1.06	3.39	4.64	3.72	1.64	6.59

In Fig. 5 of the drawings the cutting efficiency, at 2 different speeds, is plotted as a function of the percentage of cobalt in the tool. These life-efficiency curves show that at the lower cutting speed the efficiency falls rapidly as the cobalt

quantity is increased. At the higher speeds the efficiency drops as cobalt is added from 2% to 4% and then appears to rise as the cobalt is added up to between 6% and 7%. It would appear, therefore, that cobalt in quantities in excess of about 2% not only does not improve the efficiency but seriously detracts therefrom. This result had been observed before but was difficult of explanation since it was not known that high speed alloys containing a comparatively low percentage of molybdenum and tungsten had very distinct maxima of cutting efficiency and that if the percentages of molybdenum and tungsten were raised the cutting efficiency of the tools was lowered. The foregoing tests indicate that while cobalt in comparatively low percentages does not deleteriously affect the cutting efficiency, additions over about 2% seriously detract from the best cutting performance.

In order further to demonstrate the extremely narrow and critical ranges of elements within which my invention lies, nine different steels were melted having a molybdenum content between 4% and 6% and a tungsten content between 4.26% and 6.50%, the tungsten content in each case being slightly in excess of the molybdenum. The analyses of these steels are shown in Table 9 below together with the analysis of a standard 18–4–1 steel used as a control. Tools made from each of these steels were tested at a cutting speed of 70 surface feet per minute and the results are shown in Fig. 6 of the drawings. Tools from these steels were also tested at four different cutting speeds, namely, 80, 76, 70 and 67 surface feet per minute and the average performance of each tool is plotted in Fig. 7.

TABLE 9

Steel No.	Analysis							In. cut at 70 S.F.M.	Average in. cut at four different S.F.M.
	C	Cr	Si	Mo	W	Va	W–Mo		
729	.77	3.42	.23	4.00	4.26	1.42	8.26	8,976	7,639
730	.83	3.36	.79	4.16	4.60	1.48	8.76	8,736	8,200
731	.81	3.42	.25	4.53	4.90	1.36	9.43	11,027	10,612
732	.84	3.34	.70	4.76	4.80	1.36	9.56	8,953	7,771
733	.77	3.38	.26	4.60	5.15	1.36	9.75	11,026	8,600
734	.84	3.38	.74	5.12	5.55	1.38	10.67	9,196	6,725
735	.80	3.38	.29	5.40	5.83	1.28	11.23	6,756	7,324
736	.81	3.56	.74	5.71	6.07	1.40	11.78	8,105	5,784
737	.80	3.44	.70	6.00	6.50	1.44	12.50	5,003	4,594
18–4–1	.75	4.20	.37	----	18.00	1.25	-------	4,719	3,900

It will be noted that the peak of the life-efficiency curve is reached when the combined tungsten and molybdenum content is between 9% and 10% although all of the tools which had a combined content of tungsten and molybdenum varying from 8.26% to 12.50% are markedly superior to the 18–4–1 tools.

My investigations indicate that where the tungsten content is in excess of the molybdenum content the highest efficiencies are attained. It also appears that when the tungsten is in excess of molybdenum, the peak efficiency is found in those tools having a slightly higher combined content of tungsten and molybdenum than is the case with tools in which the molybdenum exceeds the tungsten. In either case, however, it will be noted that where the combined tungsten and molybdenum content is less than about 7.0% or more than about 12.0%, the cutting efficiency of the tool falls rapidly and is not substantially better than the standard 18–4–1 tools. I believe, however, that the very best cutting tools are obtained with a molybdenum content between 4% and 6%, preferably nearer 4% than 6%, with tungsten between 5% and 6%.

While all the tools in any single group above mentioned were subjected to the same test under precisely identical conditions so that the results are strictly comparative, it should be pointed out that the logs used in making the various series of tests illustrated in the drawings differed in composition so that the number of inches cut by the tools, as indicated in one figure of the drawings, cannot fairly be compared with the number of inches cut, as indicated in another figure. In commercial practice a high speed tool must cut all kinds of steels and it is the common experience among manufacturers of high speed tools to find that while an outstanding record may be made when their tools are used to cut a certain grade or kind of steel, a very poor record may be made when the same tools with the same treatment are used in cutting tests on a different alloy steel.

For this reason different logs were used in the foregoing tests. The tests shown in Fig. 1 were obtained on a carbon steel log; the tests shown in Figs. 2 and 3 were obtained on a chrome-nickel steel log known for its toughness and hard cutting properties; the tests shown in Figs. 4 and 5 were obtained on a carbon steel log; and the tests shown in Figs. 6 and 7 were obtained on a high carbon-chrome log containing no nickel.

For comparative purposes, three different tools made from 18–4–1 steel were run at three different speeds on a chrome-nickel steel log such as used for the tests plotted in Figs. 2 and 3, and the average life of the three tools at each speed is plotted. These averages are as follows:

S.F.M.	Average inches cut
80	2,185
70	7,007
67	12,435

The apparent inconsistencies that have appeared when high speed steels containing relatively small proportions of molybdenum and tungsten are tested for cutting efficiency have heretofore been explained as being due to the great difficulties encountered in consistently manufacturing tools of uniform quality, such, for example, as the difficulty in melting steel to the precise specification desired, giving the tools exactly the same heat treatment or the difficulty in grinding tools exactly alike. All of these difficulties are more or less real but no one, so far as I am aware has discovered that a very high peak of cutting efficiency existed and could be consistently attained by maintaining the molybdenum and tungsten and the total combined content thereof within the very narrow limits herein disclosed.

The percentage of the various elements stated above and in the appended claims is to be understood as meaning percentage by weight.

What I claim is:

1. A high speed tool having a low alloy content and characterized by its exceptionally long and efficient cutting life; said tool being formed of an alloy steel containing a plurality of elements of which the following, within the ranges and proportions stated, are the only elements necessary to attain said characteristic, carbon from about 0.20% to about 1.20%, tungsten from about 2.0% to 6.5%, molybdenum from about

3.0% to about 7.0%, chromium from about 2.0% to about 6.0%, vanadium from about 0.50% to about 3.0% and the balance iron; the tungsten and molybdenum combined constituting from about 7.0% to about 12.0% of the alloy.

2. A high speed tool having a low alloy content and characterized by its exceptionally long and efficient cutting life; said tool being formed of an alloy steel containing a plurality of elements of which the following, within the ranges and proportions stated, are the only elements necessary to attain said characteristic, carbon from about 0.20% to about 1.20%, tungsten from about 2.0% to about 6.5%, molybdenum from about 3.0% to about 7.0%, chromium from about 2.0% to about 6.0%, vanadium from about 0.50% to about 3.0% and the balance iron; the tungsten and molybdenum combined constituting from about 8.5% to about 10.5% of the alloy.

3. A high speed tool having a low alloy content and characterized by its exceptionally long and efficient cutting life; said tool being formed of an alloy steel containing a plurality of elements of which the following, within the ranges and proportions stated, are the only elements necessary to attain said characteristic, carbon from about 0.20% to about 1.20%, tungsten from about 4.5% to about 6.5%, molybdenum from about 3.0% to about 5.5%, chromium from about 2.0% to about 6.0%, vanadium from about 0.50% to about 3.0% and the balance iron; the tungsten being in excess of the molybdenum and the tungsten and molybdenum combined constituting from about 9.0% to about 12.0% of the alloy.

4. A high speed tool having a low alloy content and characterized by its exceptionally long and efficient cutting life; said tool being formed of an alloy steel containing a plurality of elements of which the following, within the ranges and proportions stated, are the only elements necessary to attain said characteristic, carbon from about 0.20% to about 1.20%, tungsten from about 2.0% to about 4.5%, molybdenum from about 4.0% to about 7.0%, chromium from about 2.0% to about 6.0%, vanadium from about 0.50% to about 3.0% and the balance iron; the molybdenum being in excess of the tungsten and the tungsten and molybdenum combined constituting from about 7.0% to about 10.5% of the alloy.

5. A high speed tool having a comparatively low alloy content and characterized by its exceptionally long and efficient cutting life; said tool being formed of an alloy steel containing a plurality of ingredients of which the following, within the ranges and proportions stated, are the only elements necessary to attain said characteristic, carbon from about 0.60% to about 1.20%, chromium from about 2.0% to about 5.0%, vanadium from about 0.50% to about 3.0%, tungsten from more than 5.0% to about 6.5%, molybdenum from about 3.0% to about 6.0%, and the balance iron; the combined content of tungsten and molybdenum being from about 8.0% to about 12.0%.

6. A high speed tool having a low alloy content and characterized by its exceptionally long and efficient cutting life; said tool being formed of an alloy steel containing a plurality of elements of which the following, within the ranges and proportions stated, are the only elements necessary to attain said characteristic, carbon from about 0.70% to about 0.90%, tungsten from more than 5.0% to about 6.0%, molybdenum from more than 4.0% to less than 5.0%, chromium from about 3.0% to about 4.0%, vanadium between about 1.0% and 2.0%, and the balance iron; the tungsten and molybdenum combined constituting from about 9.0% to about 11.0% of the alloy.

7. A high speed tool having a low alloy content and characterized by its exceptionally long and efficient cutting life; said tool being formed of an alloy steel containing a plurality of elements of which the following, within the ranges and proportions stated, are the only elements necessary to attain said characteristic, carbon from about 0.20% to about 1.20%, tungsten from more than 2.8% to 6.5%, molybdenum from about 3.0% to about 7.0%, chromium from about 2.0% to about 6.0%, vanadium from about 0.50% to about 3.0% and the balance iron; the tungsten and molybdenum combined constituting from about 7.0% to about 12.0% of the alloy.

RALPH P. DE VRIES.