MACHINERY'S REFERENCE SERIES

EACH NUMBER IS A UNIT IN A SERIES ON ELECTRICAL AND STEAM ENGINEERING DRAWING AND MACHINE DESIGN AND SHOP PRACTICE

NUMBER 100

AUTOMATIC SCREW MACHINE PRACTICE

PART II

DESIGNING AND CUTTING CAMS FOR BROWN & SHARPE AUTOMATIC SCREW MACHINES

By DOUGLAS T. HAMILTON

CONTENTS

49-55 Lafayette Street, New York City

Automatic Screw Machine Practice for the Brown & Sharpe automatic screw machines is covered in eight Reference Books, Nos. 99 to 106, inclusive. Reference Book No. 99, "Operation of the Brown & Sharpe Automatic Screw Machines," deals with the construction of these machines and the setting-up of the tools. No. 100, "Designing and Cutting Cams for Automatic Screw Machines," gives detailed instruction on cam design, and describes a simplified method for milling cams. No. 101, "Circular Form and Cut-off Tools for the Automatic Screw Machine," deals with the general arrangement and the calculations of these tools, and describes the different methods employed in their making. No. 102, "External Cutting Tools for the Automatic Screw Machine," deals with the design and construction of box-tools, taper turning tools, hollow mills, and shaving tools. No. 103, "Internal Cutting Tools for the Automatic Screw Machine," deals with centering tools, cross-slide drilling attachments, counterbores, reamers, and recessing tools. No. 104, "Threading Operations on the Automatic Screw Machine," treats on cam design for threading operations, threading dies, taps and tap drills, die and tap holders, and thread rolling. No. 105, "Knurling Operations on the Automatic Screw Machine," describes the construction of knurling holders, and gives directions for the making of knurls and the design of tools and cams used in connection with knurling operations. No. 106, "Milling, Cross-drilling and Burring Operations on the Automatic Screw Machine," describes screw-slotting attachments, index drilling attachments, and burring attachments, giving directions for their use and for the design of cams for them.

CHAPTER I

DESIGNING SCREW MACHINE CAMS

The object of the present chapter is to give the average mechanic and draftsman a clear idea of the methods employed when designing special tools and cams for the Brown & Sharpe automatic screw machine. The first thing to be explained is the change-gear mechanism, as on this are based the fundamental principles used in the construction of the tables for laying out cams. Following this, the construction of the rise and drop on the cams, which is governed by the amount of clearance necessary for one tool to pass another will be treated. Then

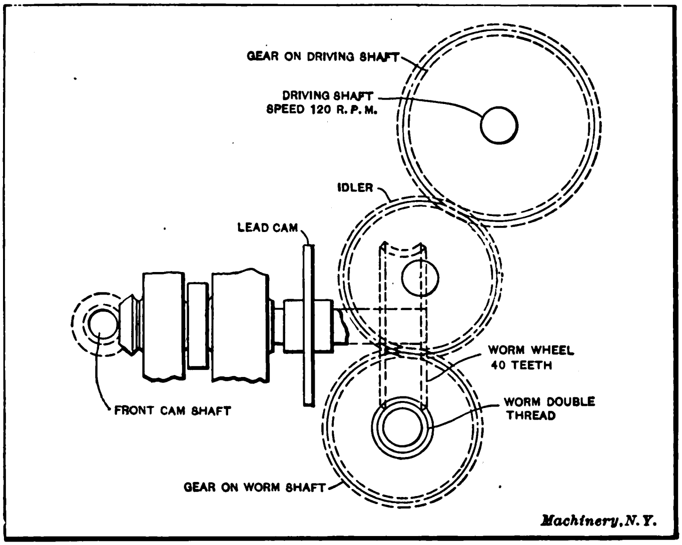


Fig. 1. Diagram of Gearing on the No. 00 Brown & Sharpe Automatic Screw Machine

a number of general points which should be of value especially to those who are not experienced in this class of work, are given.

Change-gear Mechanism

A system of simple gearing is used on the No. 00 Brown & Sharpe automatic screw machine, as clearly shown in Fig. 1. The worm has a double thread; hence for every revolution of the worm, the worm-wheel travels through a distance of two teeth. To find the change gears, assume that it is required to make one piece in 12 seconds. This necessitates that the worm-wheel make one revolution in 12 seconds. As there are 40 teeth in the worm-wheel and the worm has a double thread, the worm shaft will make $40 \div 2$ or 20 revolutions in 12 seconds. The driving shaft runs constantly at 120 R. P. M. or 2 revolutions per second. Then the driving shaft will make 12 × 2 or 24 revolutions in 12 seconds. As, in this case, the driving shaft is required to run the faster, we will put the gear with the smaller number of teeth on that shaft. Now if we have gears having 20 and 24 teeth, respectively, they will "do the trick," but after referring to the gears supplied with the machine we find that a gear with 24 teeth is not available, so multiplying the number of teeth in each by two (which does not change the ratio) the gears will be: 40-tooth gear on driving shaft; 48-tooth gear on worm shaft.

On the No. 0 Brown & Sharpe automatic screw machine there is also one driving and one driven gear, but on this machine the gear

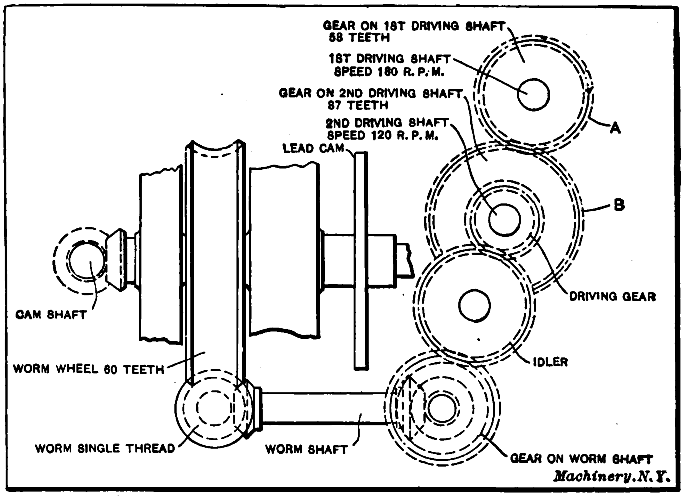


Fig. 2. Diagram of Gearing on the No. 0 Brown & Sharpe Automatic Screw Machine

which is called the driver is placed on the second driving shaft as shown in Fig. 2. Then, before finding the change gears it is necessary to find the speed of the gear on this second driving shaft. The first driving shaft runs constantly at a speed of 180 R. P. M. Then the speed of the second driving shaft $= \frac{180 \times 58}{87} = 120$ R. P. M. To find the change gears, assume that it is required to make one piece in 36 seconds. (To obviate confusion, we will call the second driving shaft, which runs at 120 R. P. M., the main driving shaft). Since the cam shaft is to make one revolution in 36 seconds and as there are 60 teeth in the worm-wheel and the worm has a single thead, the worm shaft will make 60 revolutions in 36 seconds. The driving shaft which runs at 120 R. P. M., or two revolutions per second, will make 72 revolutions in 36 seconds. From this we see that the driving shaft is required to run the faster of the two, and, hence, the smaller gear will be put on this shaft. The gears to use could have 60 and 72 teeth, respectively; or, by dividing the number of teeth in each by two, we have 30 and 36 teeth, respectively.

The gears can also be found directly by the formula:

$$\frac{120 \times D}{W} = \frac{3600}{S} \qquad (1)$$

where D = number of teeth in gear on driving shaft,
W = number of teeth in gear on worm shaft,
S = time in seconds to make one piece.

Then, $\frac{120 \times D}{W} = \frac{3600}{36}$ or $120\ D = 100\ W;\ W = 1.2\ D.$

Let $D = 30$. Then $W = 30 \times 1.2 = 36$.

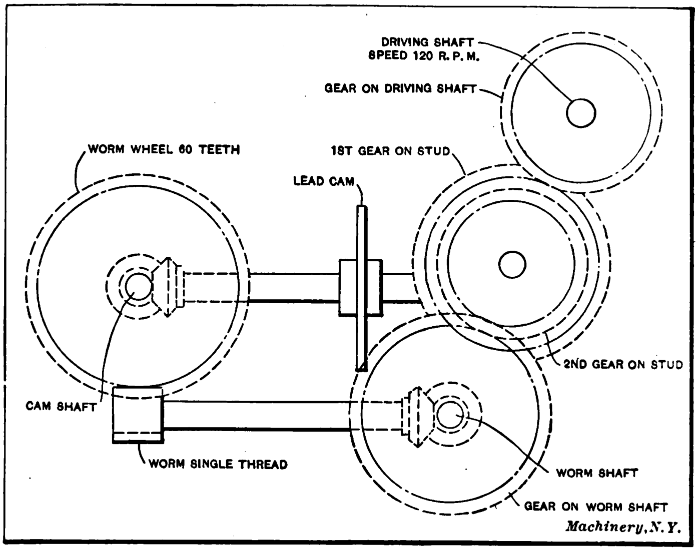


Fig. 3. Diagram of Gearing on the No. 2 Brown & Sharpe Automatic Screw Machine

A system of compound gearing is used on the No. 2 Brown & Sharpe automatic screw machine making it necessary to find the various gears by factoring. To explain the method of finding the gears we will take a practical example. Let it be required to find the gears to make one piece in 28 seconds. Referring to Fig. 3 we find that the speed of the driving shaft is 120 R. P. M. There are 60 teeth in the worm-wheel and the driving worm has a single thread. Thus the cam shaft must make one revolution in 28 seconds. The worm shaft will make 60 revolutions in 28 seconds as the worm has a single thread. The driving shaft makes 2 revolutions per second or 56 revolutions in 28 seconds. It will thus be seen that the worm shaft (or driven shaft) is required to run the faster of the two. Therefore, the product of the number of teeth in the driven gears should be smaller than the product of the number of teeth in the driving gears. The ratio of the gearing equals $\frac{60}{56}$. By dividing the numerator and denominator into factors and multiplying each pair of factors by the same number we find the gears:

$$\frac{60}{56} = \frac{10 \times 6}{4 \times 14} = \frac{(10 \times 8) \times (6 \times 6)}{(4 \times 8) \times (14 \times 6)} = \frac{80 \times 36}{32 \times 84}.$$

Then the gears are as follows:

80, gear on driving shaft; 36, second gear on stud; 32, first gear on stud; 84, gear on worm shaft.

How Tables for Laying out Cams are Constructed

Before a table can be constructed it is necessary to know the range of spindle speeds obtainable and also the speed of the driving shaft. Then the number of seconds to make one piece is placed in the first column of the table, and the number of revolutions to complete one piece is placed under the various spindle speeds as shown in Table I. The total number of revolutions to make one piece is found by the following formula: $r = \frac{R \times S}{60}$, where R = revolutions of spindle per minute (R. P. M.), S = time in seconds to make one piece, and r = total number of revolutions to make one piece. The total number of revolutions to complete one piece can also be found by adding together the number of revolutions required for each operation plus the revolutions required for clearance, feeding the stock, and revolving the turret. The number of seconds to make one piece is found by the following formula:

$$S = \frac{r \times 60}{R}. \qquad (2)$$

The time required to feed stock and revolve the turret on the various Brown & Sharpe automatic screw machines is as follows: No. 2 machine, 1 second; No. 0 machine, 2/3 seconds; No. 00 machine, 1/2 second. The revolutions of the spindle required to feed stock and revolve the turret on the various machines are found by the following formulas:

No. 2 machine, $r_1 = R \div 60$ (3)

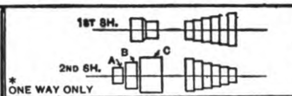
No. 0 machine, $r_1 = R \div 90$ (4)

No. 00 machine, $r_1 = R \div 120$ (5)

where r_1 = revolutions of spindle to feed stock and revolve turret,
R = speed of spindle in revolutions per minute.

Now, to convert the revolutions required to feed stock into hundredths of the cam surface, it is necessary to know the time in seconds required to make one piece and the speed of the spindle. For example, let it be required to construct a table for laying out cams

TABLE I. CHANGE GEARS AND DATA FOR LAYING OUT CAMS. No. 00 BROWN & SHARPE AUTOMATIC SCREW MACHINE



SPINDLE SPEEDS

BELT ON *A	*B	C
420	792	1087
492	927	1273
576	1087	1492
675	1273	1748
792	1492	2048
927	1748	2400

NUMBER OF REVOLUTIONS TO MAKE ONE PIECE.

TIME IN SECONDS TO MAKE ONE PIECE.	GROSS PRODUCT IN TEN HOURS.	NET PRODUCT IN TEN HOURS GROSS MINUS 10%	GEARS ON DRIVING SHAFT.	1ST GEAR ON STUD.	2ND GEAR ON STUD.	GEAR ON WORM SHAFT.	HUNDREDTHS OF CAM SURFACE TO FEED STOCK	SPINDLE SPEEDS MIN. 420, SEC. 7, ½ SEC. 3.5	492, 8.2, 4.1	576, 9.6, 4.8	675, 11.2, 5.6	792, 13.2, 6.6	927, 15.4, 7.7	1087, 18.1, 9.1	1273, 21.2, 10.6	1492, 24.8, 12.4	1748, 29.1, 14.6	2048, 34.1, 17.1	2400, 40., 20.
3	12000	10800	70			21	17	21	25	29	34	40	46	54	64	75	87	102	120
4	9000	8100	50			20	13	28	33	38	45	53	62	72	85	99	117	137	160
5	7200	6400	60			30	10	35	41	48	56	66	77	91	106	124	146	171	200
6	6000	5400	50			30	9	42	49	58	67	79	93	109	127	149	175	205	240
7	5142	4600	60			42	8	49	57	67	79	92	108	127	149	174	204	239	280
8	4500	4000	60			48	7	56	66	77	90	106	124	145	170	199	233	273	320
9	4000	3600	60			54	6	63	74	86	101	119	139	163	191	224	262	307	360
10	3600	3200	40			40	5	70	82	96	112	132	154	181	212	249	291	341	400
11	3272	2900	40			44	5	77	90	106	124	145	170	199	233	274	320	375	440
12	3000	2700	40			48	5	84	98	115	135	158	185	217	255	298	350	410	480
13	2769	2400	40			53	4	91	107	125	146	172	201	236	276	323	379	444	520
14	2571	2300	30			42	4	98	115	134	157	185	216	254	297	348	408	478	560
15	2400	2100	40			60	4	105	123	144	169	198	232	272	318	373	437	512	600
16	2250	2000	30			48	4	112	131	154	180	211	247	290	339	398	466	546	640
17	2117	1900	20			34	3	119	139	163	191	224	263	308	361	423	495	580	680
18	2000	1800	30			54	3	126	148	173	202	238	278	326	382	448	524	614	720
19	1894	1700	20			38	3	133	156	182	214	251	294	344	403	472	554	649	760
20	1800	1600	20			40	3	140	164	192	225	264	309	362	424	497	583	683	800
21	1714	1500	20			42	3	147	172	202	236	277	324	380	446	522	612	717	840
22	1636	1450	20			44	3	154	180	211	247	290	340	399	467	547	641	751	880
23	1565	1400	20			46	3	161	189	221	259	304	355	417	488	572	670	785	920
24	1500	1350	20			48	3	168	197	230	270	317	371	435	509	597	699	819	960
25	1440	1300	20			50	3	175	205	240	281	330	386	453	530	622	728	853	1000
26	1384	1250	20			52	3	182	213	250	292	343	402	471	552	647	757	887	1040
27	1333	1200	20			54	3	189	221	259	304	356	417	489	573	671	787	922	1080
28	1285	1150	20			56	3	196	230	269	315	370	433	507	594	696	816	956	1120
29	1241	1100	20			58	3	203	238	278	326	383	448	525	615	721	845	990	1160
30	1200	1050	20			60	3	210	246	288	337	396	463	543	636	746	874	1024	1200
32	1125	1000	30	30	48	60	3	224	262	307	360	422	494	580	679	796	932	1092	1280
34	1050	950	20	44	50	60	3	238	279	326	383	449	525	616	721	846	990	1161	1360
36	1000	900	30	30	54	60	3	252	295	346	405	475	556	652	764	895	1049	1229	1440
38	947	850	20	30	38	60	3	266	312	365	428	502	587	688	806	945	1107	1297	1520
40	900	800	20	30	40	60	3	280	328	384	450	528	618	724	849	995	1165	1365	1600
42	857	775	20	30	42	60	3	294	344	403	473	554	649	761	891	1045	1224	1434	1680
44	818	725	20	30	44	60	3	308	361	422	495	581	680	797	934	1094	1282	1502	1760
46	782	700	20	30	46	60	3	322	377	442	518	607	711	833	976	1144	1340	1570	1840
48	750	675	20	30	48	60	3	336	394	461	540	634	742	870	1018	1194	1398	1638	1920
50	720	650	20	30	50	60	3	350	410	480	563	660	773	906	1061	1243	1457	1707	2000
52	692	620	20	30	52	60	3	364	426	499	585	686	803	942	1103	1293	1515	1775	2080
54	666	600	20	30	54	60	3	378	443	518	608	713	834	978	1146	1343	1573	1843	2160
56	642	575	20	30	56	60	3	392	459	538	630	739	865	1015	1188	1393	1631	1911	2240
58	620	550	20	30	58	60	3	406	476	557	653	766	896	1051	1231	1442	1690	1980	2320
60	600	525	30	21	54	70	3	420	492	576	675	792	927	1087	1273	1492	1748	2048	2400
63	571	500	30	20	54	70	3	441	517	605	709	832	973	1141	1337	1567	1835	2150	2520
70	514	450	20	20	40	70	3	490	574	672	788	924	1082	1268	1485	1741	2039	2389	2800
77	467	420	20	20	44	70	3	539	631	739	866	1016	1190	1395	1634	1915	2243	2628	3080
84	428	385	20	20	48	70	3	588	689	806	945	1109	1298	1522	1782	2089	2447	2867	3360
91	395	355	20	20	52	70	3	637	746	874	1024	1201	1406	1649	1931	2263	2651	3106	3640

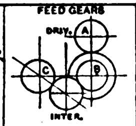
The number of hundredths given is always sufficient for feeding stock, but it is usually best to add 1-100 for revolving the Turret.

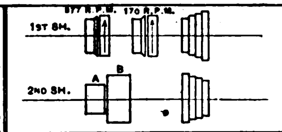
for the No. 2 Brown & Sharpe automatic screw machine. For a spindle speed of 182 R. P. M., as shown in Table III (assuming that it takes 10 seconds to make one piece), we find:

$$r = \frac{R \times S}{60} = \frac{182 \times 10}{60} = 30.3$$

or approximately 30 revolutions. We now put 30 revolutions in the

TABLE II. CHANGE GEARS AND DATA FOR LAYING OUT CAMS.
No. 0 BROWN & SHARPE AUTOMATIC SCREW MACHINE





SPINDLE SPEEDS — BELT TO MACH. ON PULLEY	A				B			
FAST	445	543	663	810	988	1207	1474	1800
SLOW	200	244	298	364	445	543	663	810

Time in Seconds to Make One Piece	Gross Product in Ten Hours	Net Product in Ten Hours Gross Minus 10%	Gear on A	1st Gear on B	2nd Gear on B	Gear on C	Hundredths of Cam Surface to Feed Stock	Spindle Speeds: Min. 200 / Sec. 3.3 / ⅔ Sec. 2.2	Min. 244 / Sec. 4.1 / 2.7	Min. 298 / Sec. 4.9 / 3.3	Min. 364 / Sec. 6.1 / 4.	Min. 445 / Sec. 7.4 / 4.9	Min. 543 / Sec. 9.1 / 6.	Min. 663 / Sec. 11.1 / 7.3	Min. 810 / Sec. 13.5 / 9.	Min. 988 / Sec. 16.4 / 10.9	Min. 1207 / Sec. 20.1 / 13.4	Min. 1474 / Sec. 24.5 / 16.3	Min. 1800 / Sec. 30 / 20.
								NUMBER OF REVOLUTIONS TO MAKE ONE PIECE											
5	7200	6400	58	86	120	20	14	17	20	25	30	37	45	55	67	82	101	123	150
6	6000	5400	58	86	120	24	12	20	24	30	36	44	54	66	81	99	121	147	180
7	5142	4600	58	86	120	28	10	23	28	35	42	52	63	77	94	115	141	172	210
8	4500	4000	58	86	120	32	9	27	33	40	49	59	72	88	108	132	161	197	240
9	4000	3600	58	86	80	24	8	30	37	45	55	67	81	99	121	148	181	221	270
10	3600	3200	58	86	120	40	7	33	41	50	61	74	90	110	135	165	201	246	300
11	3272	2900	58	86	60	22	7	37	45	55	67	82	100	122	148	181	221	270	330
12	3000	2700	58	86	60	24	6	40	49	60	73	89	109	133	162	198	241	295	360
13	2769	2400	34	110	120	24	6	43	53	65	79	96	118	144	175	214	262	319	390
14	2571	2300	58	86	60	28	5	47	57	70	85	104	127	155	189	231	282	344	420
15	2400	2100	58	86	60	30	5	50	61	74	91	111	136	166	202	247	302	368	450
16	2250	2000	58	86	60	32	5	53	65	79	97	119	145	177	216	263	322	393	480
17	2117	1900	58	86	60	34	4	57	69	84	103	126	154	188	229	280	342	418	510
18	2000	1800	58	86	40	24	4	60	73	89	109	133	163	199	243	296	362	442	540
19	1894	1700	58	86	60	38	4	63	77	94	115	141	172	210	256	313	382	467	570
20	1800	1600	58	86	60	40	4	67	81	99	121	148	181	221	270	329	402	491	600
22	1636	1450	58	86	30	22	4	73	89	109	133	163	199	243	297	362	443	540	660
24	1500	1350	58	86	40	32	3	80	98	119	146	178	217	265	324	395	483	590	720
26	1384	1250	34	110	60	24	3	87	106	129	158	193	235	287	351	428	523	639	780
28	1285	1150	58	86	30	28	3	93	114	139	170	208	253	309	378	461	563	688	840
30	1200	1050	58	86	60	60	3	100	122	149	182	222	271	331	405	494	603	737	900
32	1125	1000	58	86	30	32	3	107	130	159	194	237	290	354	432	527	644	786	960
34	1059	950	58	86	30	34	3	113	138	169	206	252	308	376	459	560	684	835	1020
36	1000	900	58	86	20	24	3	120	146	179	218	267	326	398	486	593	724	884	1080
38	947	850	58	86	30	38	3	127	155	189	231	282	344	420	513	626	764	934	1140
40	900	800	58	86	30	40	3	133	163	199	243	297	362	442	540	659	805	983	1200
44	818	725	34	110	32	22	3	147	179	218	267	326	398	486	594	725	885	1081	1320
48	750	675	58	86	20	32	3	160	195	238	291	356	434	530	648	790	966	1179	1440
52	692	626	34	110	30	24	3	173	211	258	315	385	471	575	702	856	1046	1277	1560
56	642	575	58	86	32	60	3	187	228	278	340	415	507	619	756	922	1127	1376	1680
60	600	525	58	86	30	60	3	200	244	298	364	445	543	663	810	988	1207	1474	1800
65	553	490	34	110	60	60	3	217	264	323	394	482	588	718	877	1070	1308	1597	1950
70	514	450	34	110	80	86	3	233	285	348	424	519	633	773	945	1153	1408	1720	2100
75	480	430	58	86	24	60	3	250	305	372	455	556	679	829	1012	1235	1509	1842	2250
80	450	400	58	86	30	80	3	267	325	397	485	593	724	884	1080	1317	1609	1965	2400
90	400	360	58	86	20	60	3	300	366	447	546	667	814	994	1215	1482	1810	2211	2700
100	360	320	58	86	24	80	3	333	407	497	607	742	905	1105	1350	1647	2012	2457	3000
110	327	290	58	86	30	110	3	367	447	546	667	816	995	1215	1485	1811	2213	2702	3300
120	300	270	58	86	20	80	3	400	488	596	728	890	1086	1326	1620	1976	2414	2948	3600
135	266	235	58	86	20	90	3	450	549	670	819	1001	1222	1492	1823	2223	2716	3316	4050
150	240	215	58	86	24	120	3	500	610	745	910	1112	1358	1658	2025	2470	3017	3685	4500
165	218	195	58	86	20	110	3	550	671	819	1001	1224	1493	1823	2228	2717	3319	4053	4950
180	200	180	58	86	20	120	3	600	732	894	1092	1335	1629	1989	2430	2964	3621	4422	5400
195	184	165	34	110	30	90	3	650	793	968	1183	1446	1765	2155	2633	3211	3923	4790	5850
210	171	150	34	110	28	90	3	700	854	1043	1274	1557	1901	2321	2835	3458	4224	5159	6300
225	160	140	34	110	26	90	3	750	915	1117	1365	1669	2036	2486	3038	3705	4526	5527	6750
240	150	135	34	110	24	90	3	800	976	1192	1456	1780	2172	2652	3240	3952	4828	5896	7200
270	133	120	34	110	22	90	3	900	1098	1341	1638	2002	2444	2984	3645	4446	5431	6633	8100
300	120	105	34	110	26	120	3	1000	1220	1490	1820	2225	2715	3315	4050	4940	6035	7370	9000
330	109	100	34	110	24	120	3	1100	1342	1639	2002	2447	2987	3647	4455	5434	6638	8107	9900
360	100	90	34	110	22	120	3	1200	1464	1788	2184	2670	3258	3978	4860	5928	7242	8844	10800
390	92	80	34	110	20	120	3	1300	1586	1937	2366	2892	3530	4310	5265	6422	7845	9581	11700

column under 182 as shown, and proceed to find the revolutions to feed stock, which according to Formula (3) equals:

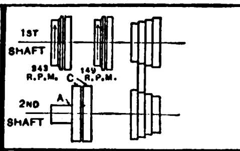
$$R \div 60 = 182 \div 60 = 3.03 \text{ revolutions.}$$

Now, to find the hundredths of the cam surface to feed stock, divide the revolutions to feed stock by the total revolutions of the spindle required to make one piece. In this case we find that it requires

$$\frac{3.03}{30.3} = 0.099$$

or approximately 10 hundredths. It is always advisable

TABLE III. CHANGE GEARS AND DATA FOR LAYING OUT CAMS. No. 2 BROWN & SHARPE AUTOMATIC SCREW MACHINE



SPINDLE SPEEDS	BELT TO MACH. ON PULLEY A				BELT TO MACH. ON PULLEY C			
FAST	277	342	421	519	640	789	973	1200
SLOW	120	148	182	225	277	342	421	519

TIME IN SECONDS TO MAKE ONE PIECE	GROSS PRODUCT IN 10 HOURS	NET PRODUCT IN 10 HOURS GROSS MINUS 10%	GEAR ON DRIVING SHAFT	1ST GEAR ON STUD	2ND GEAR ON STUD	GEAR ON WORM SHAFT	HUNDREDTHS OF CAM SURFACE TO FEED STOCK	NUMBER OF REVOLUTIONS TO MAKE ONE PIECE — SPINDLE SPEEDS SEC. 2 / MIN. 120	SEC. 2.467 / MIN. 148	SEC. 3.033 / MIN. 182	SEC. 3.75 / MIN. 225	SEC. 4.617 / MIN. 277	SEC. 5.7 / MIN. 342	SEC. 7.017 / MIN. 421	SEC. 8.65 / MIN. 519	SEC. 10.667 / MIN. 640	SEC. 13.15 / MIN. 789	SEC. 16.217 / MIN. 973	SEC. 20 / MIN. 1200
6	6000	5400	80	32	80	40	17	12	15	18	22	28	34	42	52	64	79	97	120
7	5142	4600	80	32	72	42	15	14	17	21	26	32	40	49	61	75	92	114	140
8	4500	4000	80	32	72	48	13	16	20	24	30	37	46	56	69	85	105	130	160
9	4000	3600	80	32	72	54	12	18	22	27	34	42	51	63	78	96	118	146	180
10	3600	3200	80	32	72	60	10	20	25	30	37	46	57	70	86	107	131	162	200
11	3272	2900	80	32	84	77	10	22	27	33	41	51	63	77	95	117	145	178	220
12	3000	2700	80	32	60	60	9	24	30	36	45	55	68	84	104	128	158	195	240
13	2769	2400	80	32	72	78	9	26	32	39	49	60	74	91	112	139	171	211	260
14	2571	2300	80	32	60	70	8	28	35	42	52	65	80	98	121	149	184	227	280
16	2250	2000	80	32	60	80	7	32	39	49	60	74	91	112	138	171	210	259	320
18	2000	1800	80	32	48	72	6	36	44	55	67	84	103	126	156	192	237	292	360
20	1800	1600	80	32	48	80	5	40	49	61	75	92	114	140	173	213	263	324	400
22	1636	1450	80	32	42	77	5	44	54	67	82	102	125	154	190	235	289	357	440
24	1500	1350	80	32	40	80	5	48	59	73	90	111	137	168	208	256	316	389	480
26	1384	1250	80	32	36	78	4	52	64	79	97	120	148	182	225	277	342	422	520
28	1285	1150	80	32	36	84	4	56	69	85	105	129	160	196	242	299	368	454	560
30	1200	1050	60	60	80	80	4	60	74	91	112	138	171	210	259	320	394	486	600
35	1028	925	60	60	72	84	3	70	87	106	131	162	199	246	303	373	460	568	700
40	900	800	60	60	54	72	3	80	99	121	150	185	228	281	346	427	526	649	800
45	800	700	60	60	48	72	3	90	111	136	169	208	256	316	389	480	592	730	900
50	720	625	60	60	48	80	3	100	124	152	187	231	285	351	432	533	657	811	1000
55	654	575	60	60	42	77	3	110	136	167	206	254	313	386	476	587	723	892	1100
60	600	525	40	80	60	60	3	120	148	182	225	277	342	421	519	640	789	973	1200
70	514	450	40	80	60	70	3	140	173	212	262	323	399	491	605	747	920	1135	1400
80	450	400	40	80	54	72	3	160	198	243	300	369	456	561	692	853	1052	1297	1600
90	400	350	40	80	48	72	3	180	222	273	337	415	513	631	778	960	1183	1459	1800
100	360	300	40	80	48	80	3	200	247	303	375	462	570	702	865	1067	1315	1622	2000
110	327	290	40	80	42	77	3	220	272	334	412	508	627	772	951	1173	1446	1784	2200
120	300	270	40	80	40	80	3	240	296	364	450	554	684	842	1038	1280	1578	1946	2400
135	266	240	36	72	40	90	3	270	333	409	506	623	769	947	1168	1440	1775	2189	2700
150	240	210	36	80	40	90	3	300	370	455	562	692	855	1052	1297	1600	1972	2432	3000
165	218	190	36	77	35	90	3	330	407	500	619	752	940	1158	1427	1760	2170	2675	3300
180	200	180	36	84	35	90	3	360	444	546	675	831	1026	1263	1557	1920	2367	2919	3600
195	184	160	32	78	36	96	3	390	481	591	731	900	1112	1368	1687	2080	2564	3162	3900
210	171	150	24	80	40	84	3	420	518	637	788	970	1197	1474	1817	2240	2762	3406	4200
225	160	140	32	90	36	96	3	450	555	682	844	1039	1283	1579	1946	2400	2959	3649	4500
240	150	135	24	80	40	96	3	480	592	728	900	1108	1368	1684	2076	2560	3156	3892	4800
270	133	120	32	72	24	96	3	540	666	819	1013	1247	1539	1895	2336	2880	3551	4379	5400
300	120	105	24	80	32	96	3	600	740	910	1125	1385	1710	2105	2595	3200	3945	4865	6000
330	109	95	24	88	32	96	3	660	814	1001	1238	1524	1881	2316	2855	3520	4340	5352	6600
360	100	90	22	88	32	96	3	720	888	1092	1350	1662	2052	2526	3114	3840	4734	5838	7200
390	92	80	24	78	24	96	3	780	962	1183	1463	1801	2223	2737	3374	4160	5129	6325	7800
420	85	75	24	84	24	96	3	840	1036	1274	1575	1939	2394	2947	3633	4480	5523	6811	8400
450	80	70	24	90	24	96	3	900	1110	1365	1688	2078	2565	3158	3893	4800	5918	7298	9000
480	75	65	24	88	22	96	3	960	1184	1456	1800	2216	2736	3368	4152	5120	6312	7784	9600

to add one hundredth for revolving the turret so that it will be securely locked in position before the tools advance on the work; then in this case it will require 11 hundredths to revolve the turret. Owing to the diameter of the cam roll there should never be less than three hundredths allowed for revolving the turret, irrespective of the speed at which the cam shaft is running.

Tables I to III give the change gears and data for laying out cams for the Nos. 00, 0 and 2 automatic screw machines. When the speed at

TABLE IV. CHANGE GEARS AND DATA FOR LAYING OUT CAMS. No. 00 TURRET FORMING AND CUTTING-OFF MACHINE

TIME IN SECONDS TO MAKE ONE PIECE.	GROSS PRODUCT IN TEN HOURS.	NET PRODUCT IN TEN HOURS. GROSS MINUS 10%	GEAR ON DRIVING SHAFT.	1st GEAR ON STUD.	2nd GEAR ON STUD.	GEAR ON WORM SHAFT	HUNDREDTHS OF CAM SURFACE TO FEED STOCK.	SPINDLE SPEEDS. ½ SEC.	3½	4½	6	7½	9½	12	15½	20
								SEC.	7	9	11½	15	19	24½	31	40
								MIN.	420	540	690	890	1140	1460	1870	2400
								NUMBER OF REVOLUTIONS TO MAKE ONE PIECE								
3	12000	10800	70			21	17		21	27	34	44	57	73	93	120
4	9000	8100	50			20	13		28	36	46	59	76	97	125	160
5	7200	6400	60			30	10		35	45	58	74	95	122	156	200
6	6000	5400	50			30	9		42	54	69	89	114	146	187	240
7	5142	4600	60			42	8		49	63	81	104	133	170	218	280
8	4500	4000	60			48	7		56	72	92	119	152	195	249	320
9	4000	3600	60			54	6		63	81	104	134	171	219	280	360
10	3600	3200	40			40	5		70	90	115	148	190	243	312	400
11	3272	2900	40			44	5		77	99	127	163	209	268	343	440
12	3000	2700	40			48	5		84	108	138	178	228	292	374	480
13	2769	2400	40			52	4		91	117	150	193	247	316	405	520
14	2571	2300	30			42	4		98	126	161	208	266	341	436	560
15	2400	2100	40			60	4		105	135	173	222	285	365	467	600
16	2250	2000	30			48	4		112	144	184	237	304	389	499	640
17	2117	1900	20			34	3		119	153	196	252	323	414	530	680
18	2000	1800	30			54	3		126	162	207	267	342	438	561	720
19	1894	1700	20			38	3		133	171	219	282	361	462	592	760
20	1800	1600	20			40	3		140	180	230	297	380	487	623	800
21	1714	1500	20			42	3		147	189	242	311	399	511	654	840
22	1636	1450	20			44	3		154	198	253	326	418	535	686	880
23	1565	1400	20			46	3		161	207	265	341	437	560	717	920
24	1500	1350	20			48	3		168	216	276	356	456	584	748	960
25	1440	1300	20			50	3		175	225	288	371	475	608	779	1000
26	1384	1250	20			52	3		182	234	299	386	494	633	810	1040
27	1333	1200	20			54	3		189	243	311	400	513	657	841	1080
28	1285	1150	20			56	3		196	252	322	415	532	681	872	1120
29	1241	1100	20			58	3		203	261	334	430	551	706	904	1160
30	1200	1050	20			60	3		210	270	345	445	570	730	935	1200
32	1125	1000	30	30	48	60	3		224	288	368	475	608	779	997	1280
34	1050	950	20	44	50	60	3		238	306	391	504	646	827	1060	1360
36	1000	900	30	30	54	60	3		252	324	414	534	684	876	1122	1440
38	947	850	20	30	38	60	3		266	342	437	564	722	925	1184	1520
40	900	800	20	30	40	60	3		280	360	460	593	760	973	1247	1600
42	857	775	20	30	42	60	3		294	378	483	623	798	1022	1309	1680
44	818	725	20	30	44	60	3		308	396	506	653	836	1071	1371	1760
46	782	700	20	30	46	60	3		322	414	529	682	874	1119	1434	1840
48	750	675	20	30	48	60	3		336	432	552	712	912	1168	1496	1920
50	720	650	20	30	50	60	3		350	450	575	742	950	1217	1558	2000
52	692	620	20	30	52	60	3		364	468	598	771	998	1265	1621	2080
54	656	600	20	30	54	60	3		378	486	621	801	1026	1314	1683	2160
56	642	575	20	30	56	60	3		392	504	644	831	1064	1363	1745	2240
58	620	550	20	30	58	60	3		406	522	667	860	1102	1411	1808	2320
60	600	525	30	21	54	70	3		420	540	690	890	1140	1460	1870	2400
63	571	500	30	20	54	70	3		441	567	725	935	1197	1533	1963	2520
70	514	450	20	20	40	70	3		490	630	805	1038	1330	1703	2182	2800
77	467	420	20	20	44	70	3		539	693	886	1142	1463	1874	2400	3080
84	428	385	20	20	48	70	3		588	756	966	1246	1596	2044	2618	3360
91	395	355	20	20	52	70	3		637	819	1047	1350	1729	2214	2836	3640

which the spindle is to be run for any certain job, and the number of revolutions required to complete one piece, are known, the gears, product in ten hours and the time in seconds to make one piece as well as the number of hundredths of the cam surface required to feed the stock and revolve the turret, are found in the left-hand columns of the table, the total revolutions required to make one piece being given in the

TABLE V. CHANGE GEARS AND DATA FOR LAYING OUT CAMS.
No. 0 TURRET FORMING AND CUTTING-OFF MACHINE

TIME IN SECONDS TO MAKE ONE PIECE	GROSS PRODUCT IN TEN HOURS.	NET PRODUCT IN TEN HOURS. GROSS MINUS 10%	GEAR ON DRIVING SHAFT.	1st GEAR ON STUD	2nd GEAR ON STUD	GEAR ON WORM SHAFT	HUNDREDTHS OF CAM SURFACE TO FEED STOCK.	SPINDLE SPEEDS. MIN. 300 / SEC. 5. / ⅔SEC. 3.3	MIN. 429 / SEC. 7.2 / ⅔SEC. 4.8	MIN. 614 / SEC. 10.2 / ⅔SEC. 6.8	MIN. 879 / SEC. 14.7 / ⅔SEC. 9.8	MIN. 1258 / SEC. 21. / ⅔SEC. 14.	MIN. 1800 / SEC. 30. / ⅔SEC. 20.
								NUMBER OF REVOLUTIONS TO MAKE ONE PIECE					
5	7200	6400	58	86	120	20	14	25	36	51	73	105	150
6	6000	5400	58	86	120	24	12	30	43	61	88	126	180
7	5142	4600	58	86	120	28	10	35	50	72	103	147	210
8	4500	4000	58	86	120	32	9	40	57	82	117	168	240
9	4000	3600	58	86	80	24	8	45	64	92	132	189	270
10	3600	3200	58	86	120	40	7	50	72	102	147	210	300
11	3272	2900	58	86	60	22	7	55	79	113	161	231	330
12	3000	2700	58	86	60	24	6	60	86	123	176	252	360
13	2769	2400	34	110	120	24	6	65	93	133	190	273	390
14	2571	2300	58	86	60	28	5	70	100	143	205	294	420
15	2400	2100	58	86	60	30	5	75	107	153	220	315	450
16	2250	2000	58	86	60	32	5	80	114	164	234	335	480
17	2117	1900	58	86	60	34	4	85	122	174	249	356	510
18	2000	1800	58	86	40	24	4	90	129	184	264	377	540
19	1894	1700	58	86	60	38	4	95	136	194	278	398	570
20	1800	1600	58	86	60	40	4	100	143	205	293	419	600
22	1636	1450	58	86	30	22	4	110	157	225	322	461	660
24	1500	1350	58	86	40	32	3	120	172	246	352	503	720
26	1384	1250	34	110	60	24	3	130	186	266	381	545	780
28	1285	1150	58	86	30	28	3	140	200	287	410	587	840
30	1200	1050	58	86	60	60	3	150	215	307	440	629	900
32	1125	1000	58	86	30	32	3	160	229	327	469	671	960
34	1059	950	58	86	30	34	3	170	243	348	498	713	1020
36	1000	900	58	86	20	24	3	180	257	368	527	755	1080
38	947	850	58	86	30	38	3	190	272	389	557	797	1140
40	900	800	58	86	30	40	3	200	286	409	586	839	1200
44	818	725	34	110	32	22	3	220	315	450	645	923	1320
48	750	675	58	86	20	32	3	240	343	491	703	1006	1440
52	692	620	34	110	30	24	3	260	372	532	762	1090	1560
56	642	575	58	86	32	60	3	280	400	573	820	1174	1680
60	600	525	58	86	30	60	3	300	429	614	879	1258	1800
65	553	490	34	110	60	60	3	325	465	665	952	1363	1950
70	514	450	34	110	80	86	3	350	501	716	1026	1468	2100
75	480	430	58	86	24	60	3	375	536	767	1099	1573	2250
80	450	400	58	86	30	80	3	400	572	819	1172	1677	2400
90	400	360	58	86	20	60	3	450	644	921	1319	1887	2700
100	360	320	58	86	24	80	3	500	715	1023	1465	2097	3000
110	327	290	58	86	30	110	3	550	787	1126	1612	2306	3300
120	300	270	58	86	20	80	3	600	858	1228	1758	2516	3600
135	266	235	58	86	20	90	3	675	965	1381	1978	2831	4050
150	240	215	58	86	24	120	3	750	1073	1535	2198	3145	4500
165	218	195	58	86	20	110	3	825	1180	1688	2417	3460	4950
180	200	180	58	86	20	120	3	900	1287	1842	2637	3774	5400
195	184	165	34	110	30	90	3	975	1394	1995	2857	4089	5850
210	171	150	34	110	28	90	3	1050	1502	2149	3077	4403	6300
225	160	140	34	110	26	90	3	1125	1609	2302	3296	4718	6750
240	150	135	34	110	24	90	3	1200	1716	2456	3516	5032	7200
270	133	120	34	110	22	90	3	1350	1931	2763	3956	5661	8100
300	120	105	34	110	26	120	3	1500	2145	3070	4395	6290	9000
330	109	100	34	110	24	120	3	1650	2360	3377	4835	6919	9900
360	100	90	34	110	22	120	3	1800	2574	3684	5274	7548	10800
390	92	80	34	110	20	120	3	1950	2789	3991	5714	8177	11700

right-hand columns. Tables IV to VI give the change gears and data for laying out cams for the Nos. 00, 0 and 2 turret forming and cutting-off machines. The same remarks apply to these as to the preceding tables.

The principal dimensions for the plate cams and the radii of the cross-slide and lead levers on the Nos. 00, 0 and 2 automatic screw machines, are given in Table VII. For notation see the illustration accompanying the table.

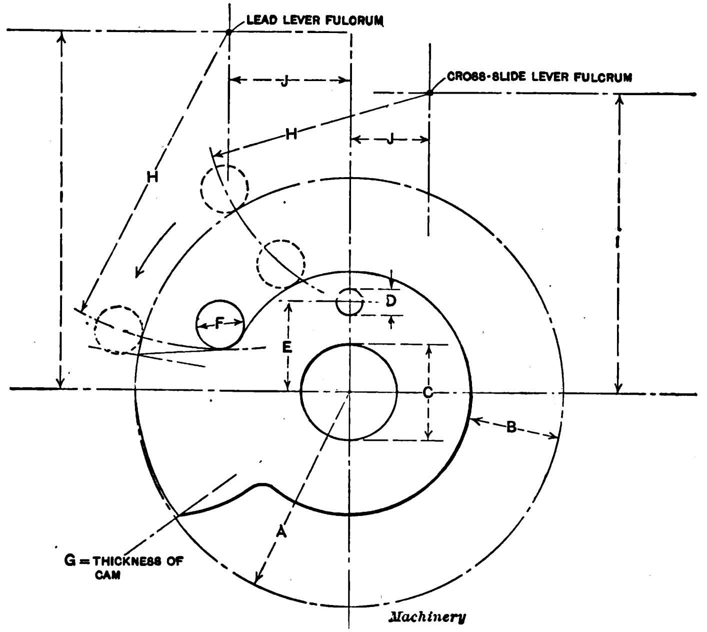
TABLE VI. CHANGE GEARS AND DATA FOR LAYING OUT CAMS. No. 2 TURRET FORMING AND CUTTING-OFF MACHINE

Time in Seconds to Make One Piece.	Gross Product in 10 Hours.	Net Product in 10 Hours-Gross minus 10%	Gear on Driving Shaft.	1st Gear on Stud.	2nd Gear on Stud.	Gear on Worm Shaft	Hundredths of Cam Surface to Feed Stock.	Spindle Speeds. Sec. 3 / Min. 180	Sec. 4.38 / Min. 263	Sec. 6.42 / Min. 385	Sec. 9.37 / Min. 562	Sec. 13.68 / Min. 821	Sec. 20 / Min. 1200
								Number of Revolutions to Make One Piece.					
6	6000	5400	80	32	80	40	17	18	26	39	56	82	120
7	5142	4600	80	32	72	42	15	21	31	45	66	96	140
8	4500	4000	80	32	72	48	13	24	35	51	75	109	160
9	4000	3600	80	32	72	54	12	27	39	58	84	123	180
10	3600	3200	80	32	72	60	10	30	44	64	94	137	200
11	3272	2900	80	32	84	77	10	33	48	71	103	151	220
12	3000	2700	80	32	60	60	9	36	53	77	112	164	240
13	2769	2400	80	32	72	78	9	39	57	83	122	178	260
14	2571	2300	80	32	60	70	8	42	61	90	131	192	280
16	2250	2000	80	32	60	80	7	48	70	103	150	219	320
18	2000	1800	80	32	48	72	6	54	79	116	169	246	360
20	1800	1600	80	32	48	80	5	60	88	128	187	274	400
22	1636	1450	80	32	42	77	5	66	96	141	206	301	440
24	1500	1350	80	32	40	80	5	72	105	154	225	328	480
26	1384	1250	80	32	36	78	4	78	114	167	244	356	520
28	1285	1150	80	32	36	84	4	84	123	180	262	383	560
30	1200	1050	60	60	80	80	4	90	131	193	281	410	600
35	1028	925	60	60	72	84	3	105	153	225	328	479	700
40	900	800	60	60	54	72	3	120	175	257	375	547	800
45	800	700	60	60	48	72	3	135	197	289	422	616	900
50	720	625	60	60	48	80	3	150	219	321	468	684	1000
55	654	575	60	60	42	77	3	165	241	353	515	753	1100
60	600	525	40	80	60	60	3	180	263	385	562	821	1200
70	514	450	40	80	60	70	3	210	307	449	656	958	1400
80	450	400	40	89	54	72	3	240	351	513	749	1095	1600
90	400	350	40	80	48	72	3	270	394	577	843	1231	1800
100	360	300	40	80	48	80	3	300	438	642	937	1368	2000
110	327	290	40	80	42	77	3	330	482	706	1030	1505	2200
120	300	270	40	80	40	80	3	360	526	770	1124	1642	2400
135	266	240	36	72	40	90	3	405	592	866	1265	1847	2700
150	240	210	36	80	40	90	3	450	657	963	1405	2052	3000
165	218	190	36	77	35	90	3	495	723	1059	1546	2258	3300
180	200	180	36	84	35	90	3	540	789	1155	1686	2463	3600
195	184	160	32	78	36	96	3	585	855	1251	1827	2668	3900
210	171	150	24	80	40	84	3	630	920	1348	1967	2873	4200
225	160	140	32	90	36	96	3	675	986	1444	2108	3079	4500
240	150	135	24	80	40	96	3	720	1052	1540	2248	3284	4800
270	133	120	32	72	24	96	3	810	1183	1733	2529	3694	5400
300	120	105	24	80	32	96	3	900	1315	1925	2810	4105	6000
330	109	95	24	88	32	96	3	990	1446	2118	3091	4515	6600
360	100	90	22	88	32	96	3	1080	1578	2310	3372	4926	7200
390	92	80	24	78	24	96	3	1170	1709	2503	3653	5336	7800
420	85	75	24	84	24	96	3	1260	1841	2695	3934	5747	8400
450	80	70	24	90	24	96	3	1350	1972	2888	4215	6157	9000
480	75	65	24	88	22	96	3	1440	2104	3080	4496	6568	9600

Constructing the Rise on Cams

The rise on the cam should be such that the tools will gradually slow up as they approach the work. It is not necessary to lay out a uniform curve for the rise, as in most cases the cam rotates slowly, but when the cam is required to make one revolution in less than 5 seconds on the No. 0 or No. 2 screw machine, a curve for a more uniform speed should be constructed.

TABLE VII. DIMENSIONS OF CAMS AND CAM LEVERS



No. of Machine	00		0		2	
Principal Dimensions	Lead	Cross-slide	Lead	Cross-slide	Lead	Cross-slide
	Dimensions in Inches					
A	$2\frac{1}{2}$	$2\frac{1}{4}$	$3\frac{1}{4}$	3	4	$3\frac{1}{2}$
B	$1\frac{3}{8}$	1	2	$1\frac{1}{4}$	$2\frac{3}{4}$	$1\frac{3}{4}$
C	1	1	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{1}{4}$
D	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$
E	$\frac{15}{16}$	$\frac{15}{16}$	1	1	$1\frac{1}{16}$	$1\frac{1}{16}$
F	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{5}{8}$
G	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$
H	$3\frac{5}{16}$	$2\frac{3}{8}$	$3\frac{3}{4}$	$2\frac{3}{4}$	4.5	3.083
I	$3\frac{13}{16}$	$3\frac{1}{8}$	$4\frac{3}{4}$	$3\frac{11}{16}$	4.208	$4\frac{1}{4}$
J	$1\frac{1}{4}$	$\frac{7}{8}$	$\frac{1}{2}$	$1\frac{3}{4}$	$3\frac{1}{2}$	$1\frac{5}{8}$

Generally the rise can be abrupt for about three-quarters of the way, and then gradually slow down as the tool approaches the work. A good method of laying out a curve of this form is shown in Fig. 4. The reason for making a curve of this form is that less time is necessary for one tool to clear another, which sometimes makes quite a considerable difference in the time required to produce one piece

To construct the rise, proceed as follows: Lay off on line H a distance D from the point a. Distance D varies with the clearance necessary between the turret and cross-slide tools. Then draw line BC at right angles to H. With a as a center, and a radius R describe an arc intersecting line BC at point b; again with R as a radius, and a center at b, describe the rise. Join the rise and the small diameter dwell of

TABLE VIII. DIMENSIONS FOR LAYING OUT CAM RISE FOR No. 00 BROWN & SHARPE AUTOMATIC SCREW MACHINE

Number of Seconds to make one Piece	Lead	Front and Back Cams
	D	R
From 3 to 5 seconds............	29/32	1 1/8
From 6 to 12 seconds.......	3/4	1 1/4
From 13 to 30 seconds............	5/8	1 1/4

the cam with a circle having a diameter equal to the diameter of the roll. The distance r should then be measured off and recorded on the drawing to be used by the toolmaker when laying out the cams. The various values for the dimensions given in Fig. 4 for the rise, that have been found suitable, are specified in Tables VIII, IX and X.

Constructing Drop on Cams

The drop on the cams should be such that the cross-slides will drop back without shock. The turret slide drops back on a cushion spring,

TABLE IX. DIMENSIONS FOR LAYING OUT CAM RISE FOR No. 0 BROWN & SHARPE AUTOMATIC SCREW MACHINE

Number of Seconds to make one Piece	Lead		Front and Back Cams	
	D	R	D	R
From 5 to 12 seconds....	1 1/8	15/16	7/8	1 1/2
From 13 to 30 seconds....	1 1/8	2 3/8	7/8	2
From 32 to 60 seconds....	1	3 1/4	1 3/16	3

thus allowing the drop on the lead cam to be more abrupt, on the No. 0 and No. 2 screw machines, than it is on the front and rear cams. This is also true of the No. 00 machine, but as the drop is not great, very little time would be saved by using a smaller angle of drop for the lead than for the cross-slide cams. Referring to Fig. 4, it can be seen that the lever arm swings about a pivot, so that, to have a uniform drop, a special curve should be constructed. But, as this drop would be more difficult to make than a straight drop, a straight or angular drop is adopted. This gives the drop of the arm a variable motion, as can be seen by referring to Fig. 4; the roll will drop quickly to about the point *e*, then slow up and then increase in speed as it approaches the bottom. The cross-slides are forced back by a spring which serves to keep the roll in contact with the cam. The drop on

TABLE X. DIMENSIONS FOR LAYING OUT CAM RISE FOR No. 2 BROWN & SHARPE AUTOMATIC SCREW MACHINE

Number of Seconds to make one Piece	Lead		Front and Back Cams	
	D	R	D	R
From 6 to 14 seconds..	$1\frac{7}{8}$	$2\frac{7}{16}$	$1\frac{1}{2}$	$1\frac{3}{4}$
From 15 to 40 seconds..	$1\frac{3}{4}$	$2\frac{3}{8}$	$1\frac{1}{4}$	$1\frac{13}{16}$
From 45 to 90 seconds..	$1\frac{1}{2}$	$2\frac{1}{2}$	$1\frac{1}{16}$	$1\frac{15}{16}$
From 100 to 180 seconds.	$1\frac{3}{8}$	$3\frac{1}{4}$	$\frac{15}{16}$	$2\frac{3}{16}$

the cam should not be laid off from a circle as shown by the dotted lines at *c*. This would mean that the roll would drop slower when dropping a short distance than when dropping a greater distance. The drop should be laid off from the hundredth line where the operation

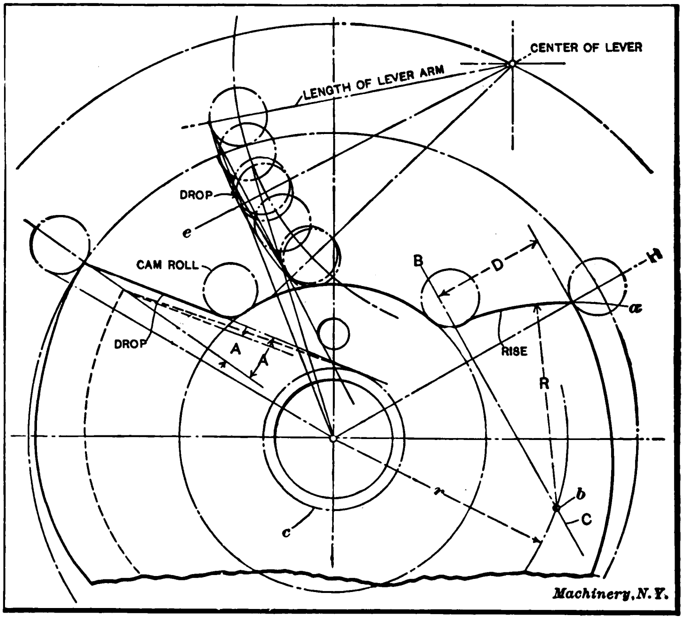


Fig. 4. Method of Laying out Rise and Fall on Cams

finishes as shown by the angle *A*. This assures the drop always being of the same speed, irrespective of the distance through which it has to drop. The following angles of drop have been found suitable for the given number of seconds required to make one piece.

DROP ON CAMS FOR No. 00 BROWN & SHARPE AUTOMATIC SCREW MACHINE

Number of Seconds to make One Piece	Lead, Front and Back
From 3 to 5 seconds	$A = 20$ degrees
From 6 to 12 seconds	$A = 15$ degrees
From 13 to 30 seconds	$A = 10$ degrees

DROP ON CAMS FOR No. 0 BROWN & SHARPE AUTOMATIC SCREW MACHINE

Number of Seconds to make One Piece	Lead	Front and Back
From 5 to 12 seconds	$A = 17$ degrees	16 degrees
From 13 to 30 seconds	$A = 14$ degrees	13 degrees
From 32 to 60 seconds	$A = 10$ degrees	9 degrees

DROP ON CAMS FOR No. 2 BROWN & SHARPE AUTOMATIC SCREW MACHINE

Number of Seconds to make One Piece	Lead	Front and Back
From 6 to 14 seconds	$A = 16$ degrees	22 degrees
From 15 to 40 seconds	$A = 14$ degrees	19 degrees
From 45 to 90 seconds	$A = 12$ degrees	16 degrees
From 90 to 180 seconds	$A = 10$ degrees	13 degrees

Clearance for Tools

In laying out a set of cams it is sometimes found necessary to make allowance for one tool to clear another, the amount of clearance necessary being determined by the diameter or width of tool used in the turret and the position of the cross-slide tools relative to the work. When determining the amount of clearance necessary, the rise and drop on the lead cam is disregarded and the rises and drops on the front and rear cams are taken into consideration. To determine the rise and drop to use, make a rough lay-out of the various operations to be performed and also settle upon the approximate number of revolutions to complete one piece. The revolutions are then converted into seconds as was previously explained. To explain clearly the method used, we will take a practical example. Assume that it is required to make a brass screw as shown in Fig. 5. This screw is made from ¼-inch round brass rod, and can be made to advantage on the No. 00 Brown & Sharpe automatic screw machine, using a spindle speed of 2400 R. P. M. backward and forward. Assume that it is required to find the amount of clearance necessary for the die holder to pass the circular form and cut-off tools. Draw in the form tool in position on the screw as shown to the left in Fig. 5, and also an outline of the toolpost. Then lay out the die holder in position to start on the screw, as shown by the dotted lines. If a releasing die holder is used, take the diameter over the heads of the screws in the holder, but if a "draw-out" type is used, the diameter of the cap is taken. In this case, as the screw is threaded up to the shoulder, a releasing die holder will be used. In Fig. 5 it can be seen that the die holder cannot advance on the screw until the form tool drops back a distance *B*, but as *B* is the actual distance, it will be necessary to add an extra amount to insure that the die holder can advance without coming in contact with the circular form tool. The extra amount of clearance necessary varies with the type of tool used. The following dimensions give the approximate amounts that should be added to tne actual clearance for the type of tools specified:

Type of Tool	Extra Amount of Clearance
Drill holders	from 1/8 to 3/16 inch
Box-tools (with V-supports)	from 1/8 to 1/4 inch
Box-tools (with supporting bushing)	from 3/16 to 5/16 inch
Button die holders (draw-out type)	from 3/16 to 5/16 inch
Button die holders (releasing type)	from 1/4 to 1/2 inch

To find the amount necessary for clearance, make a diagram as shown in Fig. 6, laying out the drop on the front cam as shown. Then add, say, ¼ inch, to dimension *B* and measure down from the point where the lobe finishes, scribing an arc of a circle through the point

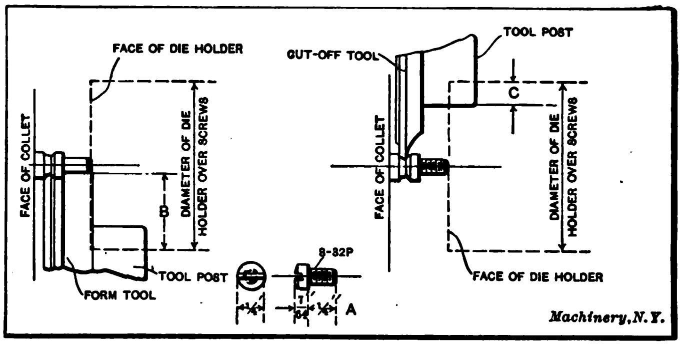


Fig. 5. Diagram illustrating Method of Finding Clearance for Die Holder

thus located, as shown. Then with a radius equal to the radius of the cam roll, describe a circle touching the arc drawn and the drop on the cam. Join the center of the roll with the center of the cam circle by a straight line. The clearance is then measured off in hundredths as shown by dimension *H*. The starting point of the lobe on the lead cam for threading will be at the hundredth line *D* and the intervening space between the lines *D* and *E* will be the amount necessary for clearance.

When the cutting-off operation follows the threading operation it will also be necessary to allow for clearance. To find the amount of clearance necessary for the die holder to clear the circular cut-off tool, proceed as follows: Make a lay-out as shown to the right in Fig. 5 and measure off the distance C. Add ¼ inch to this and lay off this dimension from the starting point *A* of the rear cam as shown in Fig. 6, drawing an arc of a circle as before. Then draw a circle the diameter of which is equal to the diameter of the roll, touching the arc drawn and the rise on the cam, and measure off the clearance *H* as was previously explained. The thread lobe would finish at the hundredth line *F* and the cut-off tool start at the line *A*. Clearance should also be allowed between the dropping back of the cut-off tool and the feeding of the stock. To find the amount of clearance necessary add ⅛ inch to the largest radius of the stock used and proceed as previously explained.

To make this explanation more complete, the various steps followed when designing a set of cams will be given.

Designing and Laying out Cams

When designing a set of cams the speed of the spindle best suited for the size of stock and nature of material should first be decided upon.

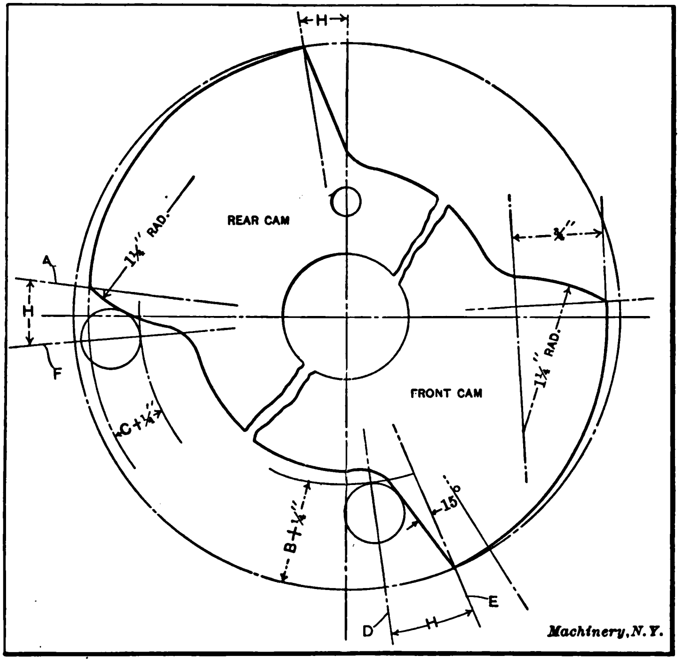


Fig. 6. Method of Determining Clearance on Cross-slide Cams

The tables for surface speeds given in MACHINERY'S Reference Book No. 99, "Automatic Screw Machine Practice—Operation of the Brown & Sharpe Automatic Screw Machine," will be found convenient for this purpose. The quickest and best method of making the piece should next be considered, and a diagram made of the tools to be used in the turret as shown at *A*, Fig. 7, leaving from 1/8 to 3/16 inch clearance between the rear face of the tool-holder and the face of the turret. This amount, of course, varies to a considerable extent, depending on the length of the shank and body of the tool, and also on the distance that the work projects from the chuck. When the shank of the tool is short, care should be taken to see that the clamping devices in the turret have a good grip on the shank of the tool. The diagram of the circular tools applied to the work should also be made as shown at *B*, Fig. 7. The feeds for the various operations are then decided upon and divided into the length of cut which will give the number of revolutions required for the various operations. The total number of revolutions to complete one piece is found by adding together the number of revolutions for each cut, for revolving the turret, feeding the stock and, in some cases, reversing the spindle; an approximate number of revolutions should also be added for clearance. When the approximate number of seconds to complete one piece has been obtained we make a diagram of the rise and drop on the cam as shown in Fig. 6. To ascertain the exact number of revolutions required for clearance, if the approximate number of revolutions as allowed for

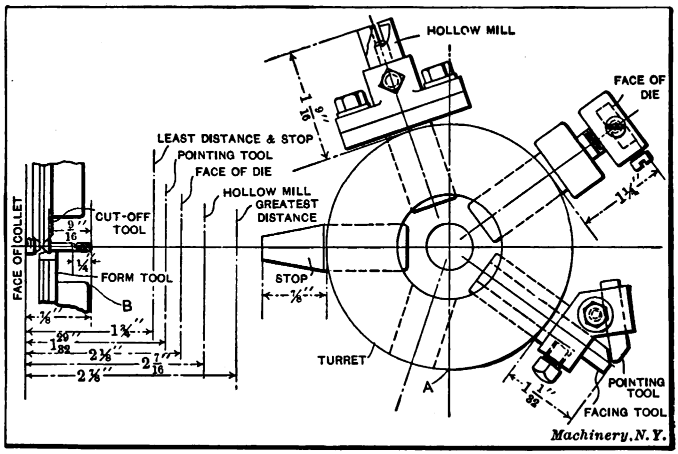


Fig. 7. Position of Tools in Turret, and Forming Tools applied to Work

clearance is not sufficient, the feed on some of the tools is increased, but if the maximum feed that the tools will stand has been used, the number of seconds to make one piece has to be increased. When the actual number of seconds has been obtained, we then convert the revolutions for each operation into hundredths of cam circumference, and proportion the different lobes on the cam to the number of revolutions for each operation. To explain the method adopted in laying out the cams, we will take a practical example.

Assume that it is required to make a screw as shown at *B*, Fig. 7. We first make the diagrams of the circular tools and the tools used in the turret as shown. Then to find the amount that the lead cam is to be cut down below the outer cam circle, measure the distance that the tools project out of the turret and add this amount to the distance that the piece projects from the face of the chuck. Then the least distance between the turret and the face of the chuck subtracted from this amount would give the distance down from the outer circle to where the lobe on the cam starts. For example, take the lobe for the hollow mill.

1 9/16 + 7/8 = 2 7/16 inch.

2 7/16 inch — 1 3/4 inch = 11/16 inch.

In Fig. 8 is given a method of laying out the cams for the screw shown in Fig. 7. This method is commendable, as it can be seen whether the tools will clear one another better than if the cams were drawn separately instead of one on top of the other. If the foregoing suggestions are followed, very little trouble will be encountered in designing a set of cams. The example as given is for making screws, but the same method can be followed in making any other class of work. After the cams have been designed, a tracing should be made and kept for reference. (See Fig. 40, Part I of this treatise, MACHINERY'S Reference Book No. 99.)

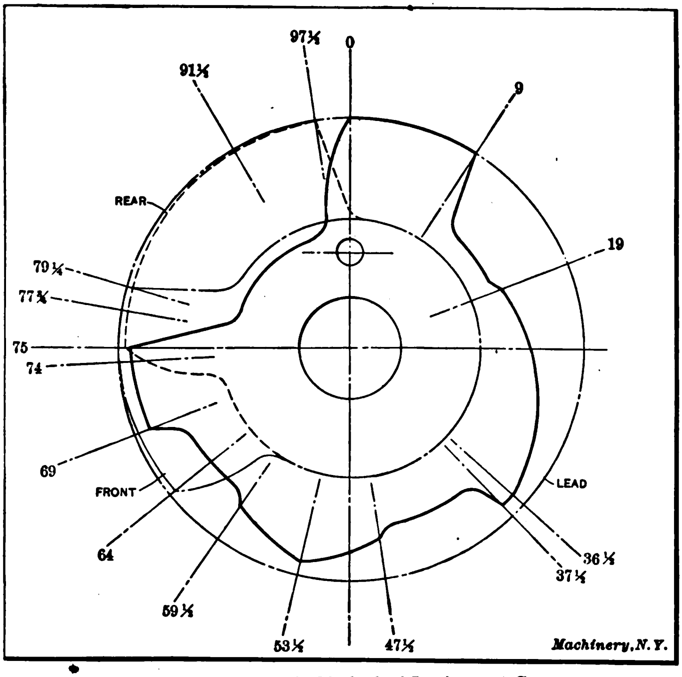


Fig. 8. Commendable Method of Laying out Cams

Practical Points in Designing Cams and Special Tools

1. Use the highest spindle speeds that the various tools will stand.
2. Use the arrangement of circular tools best suited for the class of work. (See Reference Book No. 101.)
3. Decide on the quickest and best method of arranging the operations before designing the cams.
4. Do not use turret tools for forming when the cross-slide tools can be used to better advantage.
5. Do not use a circular cut-off tool without top rake when cutting Norway iron, machine steel, etc.

6. Make the shoulder on the circular cut-off tool large enough so that the clamping screw will grip firmly.

7. When chips clinging to the work are objectionable, the circular form tool should be turned up-side-down and placed on the rear cross-slide.

8. Do not use too narrow a cut-off blade.

9. Allow 0.005 to 0.010 inch for the circular tools to approach the work and 0.003 to 0.005 inch for the cut-off tool to pass the center.

10. When cutting off work large in diameter, the feed on the cut-off tool should be increased until near the end of the cut where the piece breaks off. After it breaks off, the feed should again be increased until the tool has passed the center.

11. When a thread is cut up to a shoulder, the piece should be grooved or necked to make allowance for the lead on the die. This requires an extra projection on the form tool and also an extra amount of rise on the cam.

12. Use circular form and cut-off tools made from high-speed steel when cutting Norway iron, machine steel, etc.

13. Use a fine feed and high spindle speed for all cutting tools.

14. Allow sufficient clearance for tools to pass one another.

15. Always make a diagram of the cross-slide tools in position on the work when difficult operations are to be performed; it is also necessary to make a diagram of the tools held in the turret.

16. Do not drill a hole the depth of which is more than 2½ times the diameter of the drill, but use two or more drills as required. If there are not sufficient holes in the turret, drop the drill back clear of the hole, and advance it into the hole again.

17. Do not run a drill at a slow speed.

18. When the turret tools operate further in than the face of the chuck, see that they will clear the chute when revolving the turret.

19. See that the body of all turret tools will clear the side of the chute when revolving the turret.

20. Do not use a box-tool for a roughing cut. Use a hollow mill.

21. Do not use a box-tool with soft supports. Use solid supports only on cold-drawn or finished stock.

22. The rise on the thread lobe should be reduced so that the spindle will reverse when the die or tap holder is drawn out.

23. When threading Norway iron, machine steel, etc., if the spindle speed used for the other tools is too high for threading, use a special threading attachment. (See MACHINERY's Reference Book No. 104.)

24. When bringing another tool into position after a threading operation, allow clearance before revolving the turret.

25. Make provision to revolve the turret rapidly, especially when pieces are being made in from three to five seconds and when only a few tools are used in the turret. It is sometimes convenient to use two sets of tools.

26. When using a belt-shifting attachment for threading, clearance should be allowed, as it requires extra time to shift the belt.

27. When laying out a set of cams for operating on a piece which requires to be slotted, cross-drilled or burred, allowance should be made on the lead cam so that the transferring arm can descend and ascend to and from the work without coming in contact with any of the turret tools.

28. Always allow a vacant hole in the turret when it is necessary to use the transferring arm.

29. Use standard tools whenever possible.

30. When designing special tools allow as much clearance as possible. Do not make them so that they will just clear, as errors sometimes turn up, causing trouble.

31. When designing special tools having intricate movements, avoid springs as much as possible, and use positive actions.

CHAPTER II

CAMS FOR SCREW-SLOTTING ATTACHMENTS

The Brown & Sharpe Mfg. Co., Providence, R. I., has designed a number of standard and special attachments for its automatic screw machines. These attachments are used for performing various second operations on a piece of work, such as slotting, milling, cross-drilling and burring, at the same time that another piece is being operated on by the cross-slide and turret tools. Thus extra operations are performed without taking additional time.

While the attachments—as such—are widely known, the methods of laying out the cams for operating them are no doubt unfamiliar to a large number of operators and mechanics in general, and, therefore, a description of the methods of laying out the cams for one of these attachments should be of general interest. The best known attachment designed by the Brown & Sharpe Mfg. Co. is its screw-slotting attachment, which is shown in Fig. 9.

Screw-slotting Attachment for the No. 00 Machine

The screw-slotting attachment is fastened to a boss, provided for this purpose on the machine, by two cap-screws. An apron, which is also an additional part, carries the arbor *C* to which the transferring arm *F* is attached. The transferring and advancing cam levers *D* and *E* are also fastened to bosses on this apron by cap-screws. These levers are operated by the advancing and transferring cams *J* and *K*. A block *H* is fastened to the arm *F*, and a slotting bushing or carrier for the screw is driven into it. This bushing grips the screw and holds it while the slotting saw, held on an arbor and driven by a pulley through bevel gears, mills the slot in the head.

The design and action of the device is, in detail, as follows: The transferring lever *D* is kept in contact with the cam by means of two

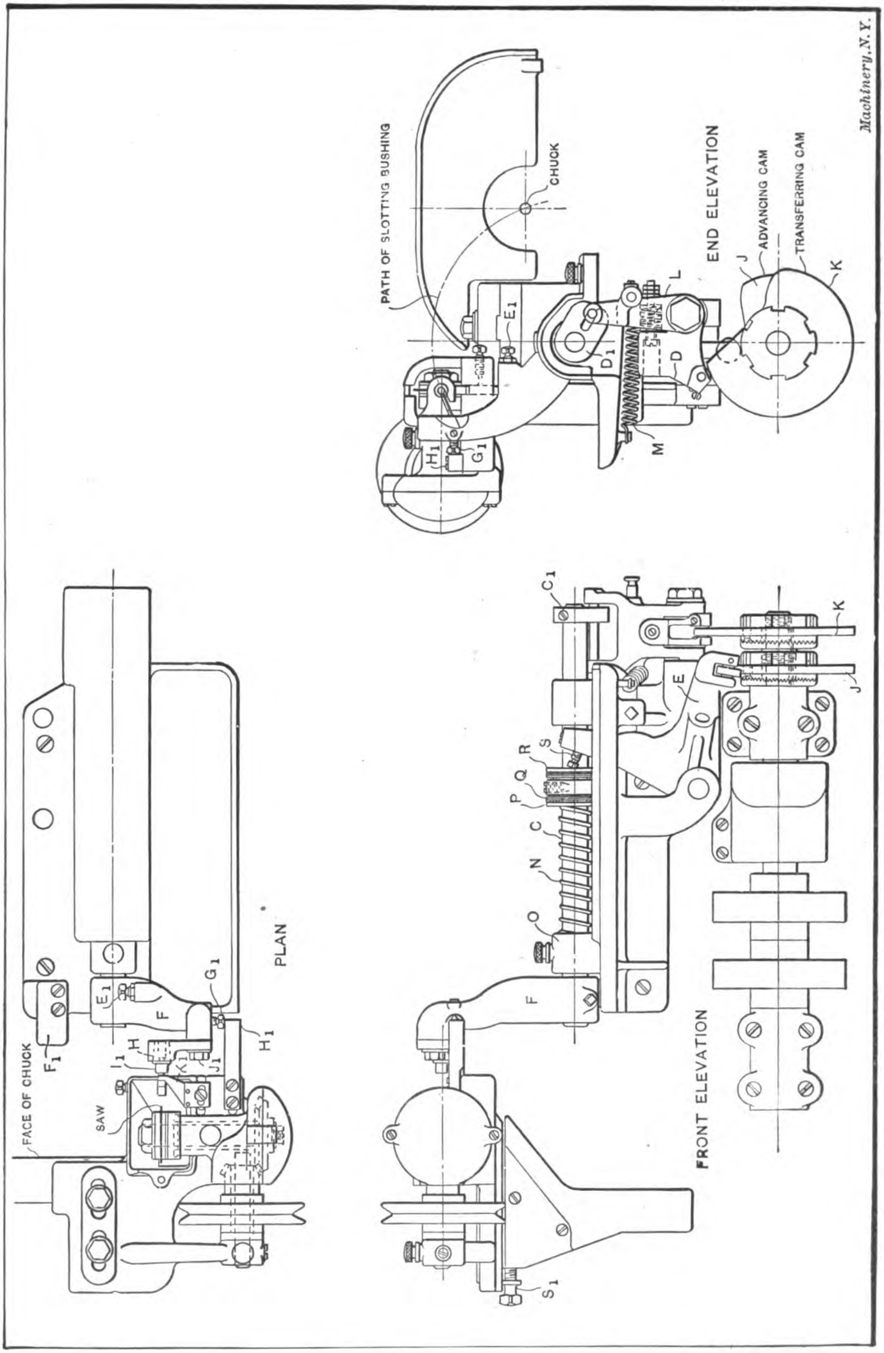


Fig. 9. Assembly Views of Screw-slotting Attachment for the No. 00 Brown & Sharpe Automatic Screw Machine

springs *L* and *M*. The advancing lever *E* is kept in contact with the advancing cam by the spring *N*, located on the transferring-arm rod *C*. This open-wound spring presses against the boss *O* on the attachment and the washer *P*, this latter being held up against a ball retainer *Q* which, in turn, is forced against a washer held to the arbor *C* by a cone-pointed screw. The lever *E* does not bear directly against the thrust-washer *R* to advance the arm, but holds a set-screw *S* which can be adjusted in and out and locked with a headless screw. This screw *S*, in conjunction with the screw S_1, is used for varying the depth of the slot in the head of the screw.

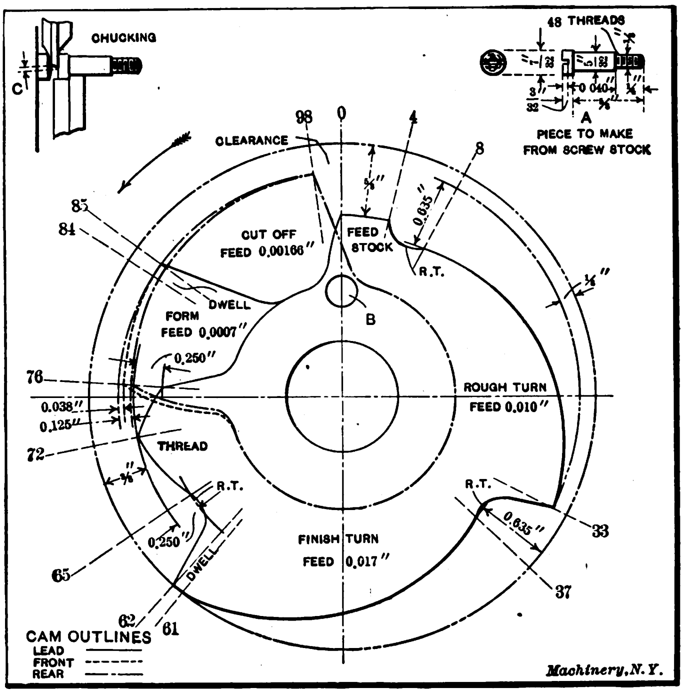


Fig. 10. Turret and Cross-slide Cams for Making a Steel Screw

The transferring lever *D* is connected to a block D_1, which is fastened to the rod *C* by a screw C_1. This block connects arm *F* with lever *D*. The arms of lever *D* and the arm *F* are so proportioned that a small rise of about 1⅛ inch on the cam in this case is sufficient to carry the slotting bushing from the chuck up to the saw through the path indicated in the engraving. When arm *F* drops down into a position in front of the chuck, it is stopped at the desired point by a set-screw E_1, which rests on a block F_1, attached to the machine. When the arm moves up into a position in front of the saw, it is stopped by a set-screw G_1, which bears against a block H_1, fastened to the attachment. The set-screws G_1 and E_1 are used for setting the slotting bushing accurately. The slotting bushing is shown at I_1 in position in block *H*. The shank of this bushing is tapered one-half inch to the foot and is driven into the block. Block *H* is held to the arm by a cap-screw J_1. When the slot in the screw has been cut and arm *F* drops back, the screw is removed from the bushing, which has a slot cut in it, by the ejector K_1, which is simply a piece of sheet steel fastened to the attachment.

Laying out a Set of Cams for a Screw-slotting Operation

Undoubtedly the method of setting and operating this screw-slotting attachment can best be described by taking a practical example. Suppose it is necessary to make the shouldered steel screw shown at *A* in Fig. 10 on a No. 00 Brown & Sharpe automatic screw machine. To pro-

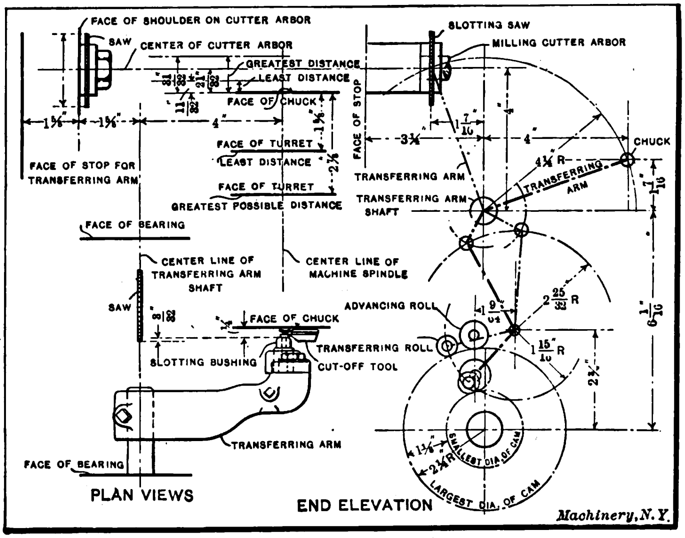


Fig. 11. Diagram used in determining the Rises on the Transferring and Advancing Cams

ceed: First design the cross-slide and turret cams, making allowance for one empty hole in the turret, thus enabling the transferring arm to drop down and pick up the screw while it is being cut off. It will not be necessary to describe the method of laying out the turret and cross-slide cams, as this has been described in the previous chapter, so we will confine our attention to the calculations necessary in laying out the transferring and advancing cams for removing and slotting the screw.

Before proceeding with the laying out of these cams, it is necessary to make a diagram such as is shown in Fig. 11. Here a diagrammatical view of the necessary movement of the transferring and advancing levers is shown. To the right of the illustration is a diagram of the movement of the transferring arm and lever. For the slotting attachment, the transferring arm does not have to dwell at any intermediate point between the chuck and the slotting saw, so that no calculation is necessary to find the rise on the cam—the full rise or 1⅛ inch being sufficient to lift the slotting bushing from the chuck to the slotting saw. To the left of the illustration is a diagram in which is indicated the least and greatest possible distances between the face of the turret and the chuck, and also the position of the screw-slotting arbor relative to the chuck. Below this, the transferring arm is shown in position on the screw. Here it can be seen that the lobes for placing the bushing on the work and advancing it to the saw will be of the same height, as the distance 3/32 inch is considerably less than the adjustment provided for the screw-slotting attachment; this adjustment is equal to 5/16 inch on each side of the center line.

When the rises or the heights of the various lobes on the cams have been determined, the next problem is to determine their relative positions, or, in other words, the starting and finishing points of the lobes on the transferring and advancing cams, respectively.

Laying out the Transferring and Advancing Cams

The location hole *B* in the cam shown in Fig. 10 is not used in the transferring and advancing cams, so that these cams, when made, can be shifted around to the desired position. However, it is best to start from some predetermined point when laying out the cams. The least confusion will result if the point at which the piece breaks off is used for the point at which the bushing is located on the work. This point, of course, cannot be determined exactly, but it is easy to locate it approximately.

The method of determining this is as follows: Taking the screw shown at *A*, in Fig. 10, as an example, we will assume that it will break off when the teat is 0.010 inch in diameter. (This screw is made in 9 seconds and requires 360 revolutions of the work spindle, which in this case is rotated at 2400 R. P. M.) Then assuming that the length of the bevel on the cut-off tool, or distance *C*, Fig. 3, equals 0.010 inch, and that the amount to pass the center of the work equals 0.005 inch, we find that the distance the point of the cut-off tool will have to travel after the piece breaks off equals $0.010 + 0.005 + 0.005 = 0.020$ inch. To find the hundredth line on the cam circle where the screw is supposed to break off, divide the travel (in inches) of the cut-off tool, still to be completed after the piece is cut-off, by the feed of the cut-off tool per revolution of the work. (See cut-off cam, Fig. 10.) Thus,

$$\frac{0.020}{0.00166} = 12.05 \text{ revolutions.}$$

In other words, it requires 12 revolutions of the spindle after the piece is cut off before the cut-off tool reaches the end of its travel. The hundredths of cam surface equivalent to 12 revolutions of the spindle are $\frac{12 \times 100}{360} = 3\frac{1}{2}$ hundredths, approximately. Therefore we assume that the screw will break off when the center of the cross-slide roll is at 94½ hundredths. As this is where the screw will break off, it is necessary to have the bushing on the work a moment previous to this. In this case we will allow 1/2 hundredth, but it is usually best to allow one hundredth of the cam surface to give the arm time to steady itself after forcing the bushing onto the work.

Having determined the point where the slotting bushing should be located on the work we can proceed to lay out the transferring and advancing cams. The method of laying out these cams is shown in Fig. 12. As previously determined, the advancing cam is not cut down below the outer circumference except for the rise for feeding the screw to the saw and dropping back, so a circle is drawn with a 2¼-inch radius as shown, which represents the largest diameter of the cams. A circle *A*, representing the path of the center of the transferring lever, is next drawn. Then a vertical line *B*, representing the path of the center of the advancing cam, is drawn. When this line and circle have been drawn, we have the relative positions of the transferring and advancing rolls. The transferring roll is ½ inch in diameter, while the advancing roll is ¾ inch, on the No. 00 machine only.

To find the starting and finishing points on the cams, proceed as follows: Draw a circle *C* representing the advancing roll on the hundredth line marked 94; then draw a quick-rise on the cam with a 1½-inch radius. As the screw will be severed from the bar at 97¼ hundredths, this is the finishing point of the lobe for placing the screw in the slotting bushing. Next construct the quick-drop on the cam and draw another circle *D*, 1/16 inch below the largest diameter of the cam, so that the arm will drop back from the chuck before it begins to rise.

Now, to determine the position of the transferring roll, draw two circles *E* and *F* of such diameters that the distance *G* equals the relative distance between the center of the transferring arm lever and the path of the center of the advancing lever; these levers swing through arcs in planes at right angles to each other.

To obtain the center of the transferring lever, relative to the path of the advancing lever, draw a line through the center of the circle *D* and tangent to the circle *F*. Then draw another line tangent to the circle *E* and parallel to the line which is tangent to the circle *F* and passes through the center of the circle *D*. The point where the last drawn line cuts the circle *A* will be the center of the transferring lever. With this point as center and the compasses set to the radius of the transferring lever, strike an arc, and with its center on this arc draw the transferring roll circle *H*, touching the smallest diameter of the cam. The quick-rise on the transferring cam is then constructed, and the finishing point of this rise is made with a ¼-inch radius, so that the speed at which the arm is traveling will be decreased as it approaches the top of its travel. If this is not done, the arm will hit the stop and rebound, which will have a tendency to knock the screw out of the slotting bushing. When the transferring roll is on the highest point of the cam, the advancing roll should be at the bottom. A clearance of

1/100 is allowed between the point when the transferring roll is on the top of the cam, and the point when the advancing roll begins to advance the screw to the saw. The starting and finishing points of the lobes on the advancing cam for advancing the screw to the saw are constructed in a manner similar to that just described.

Nothing will be gained by dropping the arm down to pick up another screw before the teat has been reduced sufficiently so that the screw can be removed; hence as much of the cam surface as possible is used for slotting, thus preventing forcing the feed too much. To find the

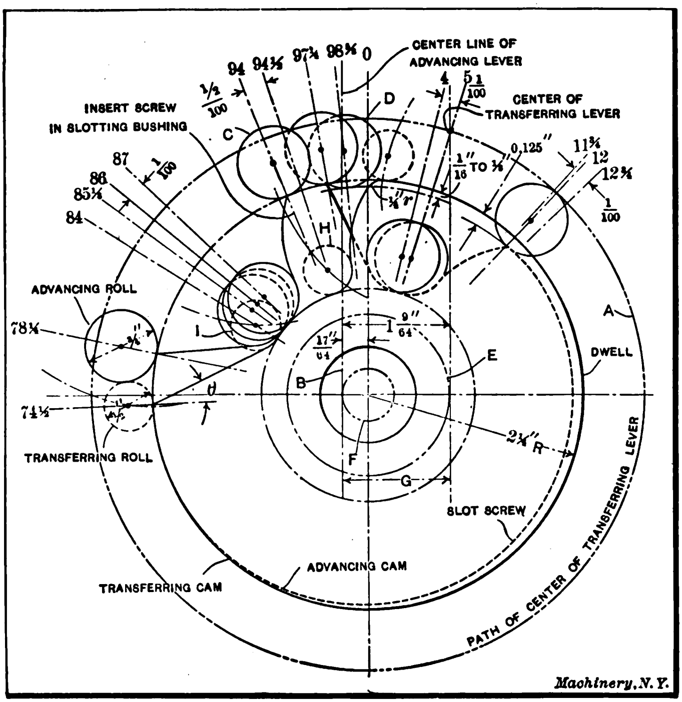


Fig. 12. Illustration showing Method of laying out Transferring and Advancing Cams

finishing point, we work backward, as it were, and locate the transferring roll at the base of the cam, as shown at *I*; then draw the quick-rise at an angle *θ*, which should be from 15 to 20 degrees for the No. 00 automatic screw machine. When this angle is drawn, we then have the finishing point on the transferring cam. The finishing point of the advancing cam is found by laying out the rolls in their respective positions, in the same manner as before, care being taken to retain the correct relations between the center of the transferring lever and the path of the advancing lever. This problem may seem to be rather complicated at first, but after some practice it will be found to be simple enough. A rise of 0.125 inch is generally allowed on the advancing

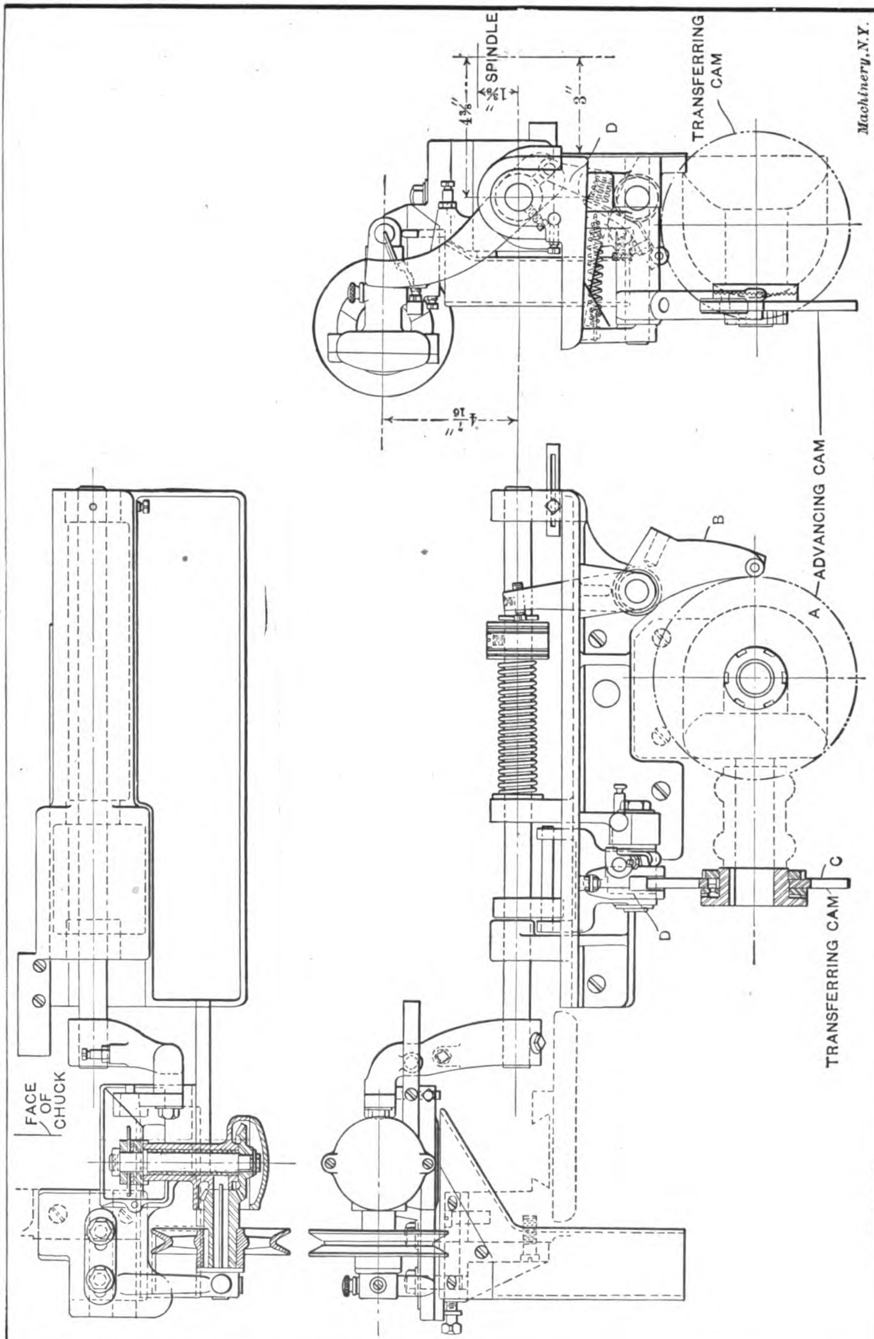


Fig. 13. Screw-slotting Attachment for the No. O Brown & Sharpe Automatic Screw Machine

cam, so that all sizes of screws within the range of the machine can be slotted with this same set of cams.

Screw-slotting Attachment for the No. 0 and No. 2 Machines

The principle on which the screw-slotting attachment for the No. 0 and No. 2 machines works does not vary from that used on the No. 00

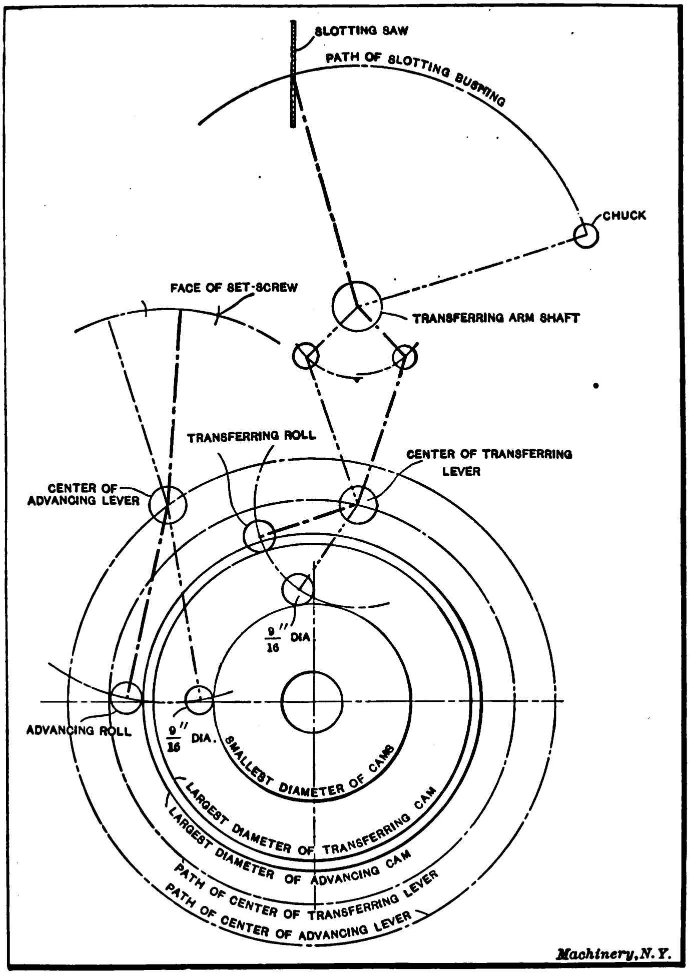


Fig. 14. Diagram used in laying out Transferring and Advancing Cams for the No. 0 Brown & Sharpe Automatic Screw Machine

machine, but the advancing and transferring cams are located differently. On the No. 00 machine, these cams are held side by side on the front cam-shaft, while in the No. 0 and No. 2 machines, the advancing cam is held on the stud which holds the lead cam, while the transferring cam is held on the front cam-shaft. The movement of the levers, of course, in this case differs from that on the No. 00 machine. Referring to the illustration Fig. 13, which shows the attachment used on the No. 0 machine, *A* is the advancing cam and *B* the advancing cam lever; *C* is the transferring cam, and *D* the transferring lever. The method of carrying the screw to the saw is similar to that on the No. 00 machine, as are also the other movements, so that this will not need further description. It is, however, necessary to describe the method of laying out the transferring and advancing cams.

The method of laying out the transferring and advancing cams is illustrated diagrammatically in Fig. 14 where the advancing and transferring levers, as well as the cams, are shown in the same plane. The method of finding the starting and finishing points of the lobes on the transferring and advancing cams is the same as that used for the ordinary cross-slide and lead cams. The only point to remember is to retain the proper distances between the centers of the levers, and to swing them into their proper positions. A templet could be made for these cams, which would simplify the problem of laying out the starting and finishing points. When a templet is not available, the method previously described for the No. 00 machine can be used; that is, keeping the center distances in the same relation, in their respective paths, and swinging the rolls into the desired position.

The screw-slotting attachment for the No. 2 Brown & Sharpe automatic screw machine does not differ from that for the No. 0 machine. The transferring cams in both these machines are made in two pieces, as it would be impossible otherwise to assemble them on the front camshaft. As there are no intermediate points at which the transferring arm is to dwell between the chuck and slotting saw, there are no calculations necessary for determining different heights on the transferring cam, the rise from the lowest to the highest point of the cam being sufficient to lift the screw from the chuck to the slotting saw.

The diagram shown in Fig. 11 should be laid out so that all the dimensions required for laying out the height of the lobes on the cams can be found. It is always advisable to allow at least one-hundredth of the cam surface for clearance, between the starting or finishing points of the lobes on the transferring or advancing cams. This allows the transferring arm to stop for a brief interval before the direction of its motion is changed.

APPENDIX

MILLING SCREW MACHINE CAMS

There are several methods used for finishing plate cams. Most methods require that the outline be accurately laid out, after which the stock is removed, generally by drilling a series of holes around the outline and breaking away the outer part. The cam is then finished to the scribed lines by milling and filing. This method, however, is slow, and the highest accuracy is not obtainable in this way.

Another method which is applicable to all cams with a constant rise is illustrated and described in the following: A diagrammatical view of the relative positions of the compound vertical milling attachment and the index head used in this method, is shown in Fig. 15. By this method constant-rise cams may be milled, so to speak, automatically, by placing the cam blank on the index head spindle, and gearing the head for spiral milling. An end-mill is held in the compound vertical milling attachment, which is adjustable to any angle in the vertical plane, as indicated. The milling attachment and the spiral head are set at a certain angle with the table surface, this angle being determined by the rise of the cam and the forward feed of the milling machine table for one turn of the index head spindle; this forward feed is usually called the spiral lead for which the machine is geared. It will be clear even to persons unfamiliar with this method, that when the table is feeding forward, the slowly revolving cam blank is fed against the cutting edge of the end-mill, and as this latter is stationary, the radius of the cam will be constantly decreased. It is the object of this article to describe a method for finding the angle to which the spiral head is to be set, and the lead for which the spiral head is to be geared, so as to obtain very accurate results when milling constant-rise cams. The formulas given below and the accompanying tables of leads obtainable on the Brown & Sharpe milling machines, and their logarithms, are used for facilitating the necessary calculations. In order to carry out the calculations by the method outlined, a table of logarithms of numbers (MACHINERY'S Reference Book No. 53) and a table of logarithms of angular functions (MACHINERY'S Reference Book No. 55) are required. In order to find the gears to be used for any spiral lead obtainable on the machine, a book entitled "Tables of Leads for Use with Universal Milling Machines," published by the Brown & Sharpe Mfg. Co., Providence, R. I., should be used.

General Formulas for the Calculations

In the following formulas let

l = lead of the cam lobe to be milled; the lead of the cam lobe is the rise of the cam if the given rate of rise were continued for one whole revolution or 360 degrees

R = rise of the cam in a given part N of the circumference,

N = the part of the circumference in which a given rise takes place; N is expressed as a decimal in hundredth of the cam circumference,

L = spiral lead for which the milling machine is geared,

a = angle to which the index head and milling attachment are to be set.

The finding of the angle a to which the index head is to be set for any specific case is most easily explained by reference to Fig. 16. In the right-angle triangle shown, the hypotenuse L represents the distance that the milling machine table will be fed forward while the

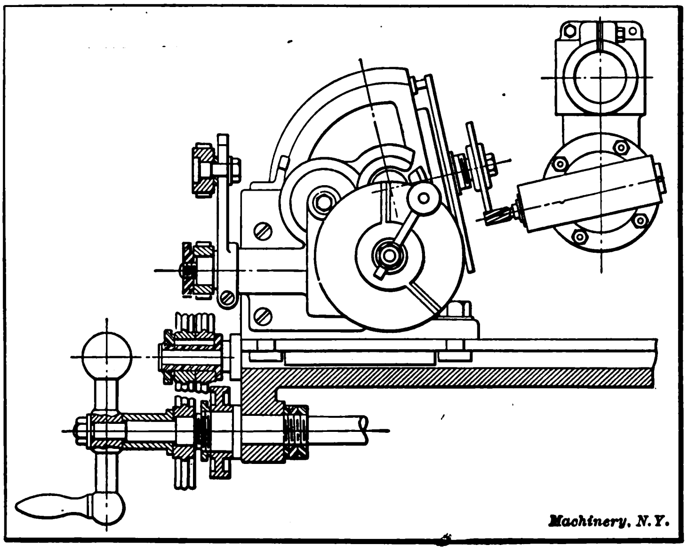


Fig. 15. Diagrammatical View showing Method of Milling Cams on the Milling Machine

index head spindle makes one complete revolution, or, in other words, L is the spiral lead for which the machine is geared. The side l in the triangle represents the rise that the cam to be milled would have in 360 degrees, or in one complete revolution; hence, this side represents the lead of the cam. It is then clear that

$$\sin = \frac{l}{L} \qquad (1)$$

$$\text{But } l = \frac{R}{N}\text{, hence: } \sin a = \frac{R}{N \times L} \qquad (2)$$

It is apparent from Formula (2) that when R, N and L are known angle a can be determined. As it is not practicable, however, to set either the index head or the vertical milling attachment closer than to whole or half degrees, the lead L must be so selected that the angle

a will be within 5 minutes either way of a whole or a half degree. Hence trial calculations must be made, and it is for the purpose of facilitating these calculations that the tables on pages 36 to 38 have been prepared.

Practical Use of Tables and Formulas

The practical use of the formulas given and of the tables can be best explained by means of an example. Assume that a set of cams is designed and drawn as shown in Fig. 17, and that the toolmaker is to be given the necessary data for milling the lobes on these cams. The milling is to be done according to the method illustrated in Fig. 15. The calculations should be made by the draftsman or whoever designs the cams, and it is recommended that the results of the calculations

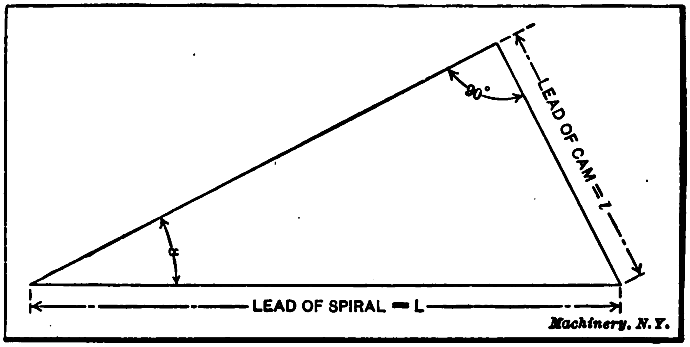


Fig. 16. Relation between Setting Angle of Index Head, Spiral Lead and Lead of Cam Lobe

be tabulated as shown in the table. Referring to the cam drawings in Fig. 17, let us first take the first lobe on the front-slide cam. Here the rise $R = 0.155$ inch and this rise takes place in 0.24 of the whole cam circumference. Hence $N = 0.24$. We have further:

$$l = \frac{R}{N} = \frac{0.155}{0.24} = 0.6458$$

and, from Formula (1):

$$\sin a = \frac{l}{L} = \frac{0.6458}{L} \qquad (3)$$

As already mentioned we must now find a lead L so selected that angle a will be within 5 minutes either way of a whole or half degree. In order to accomplish this result proceed as follows:

First find the logarithm of 0.6458:

$$\log 0.6458 = \bar{1}.81010$$

Now turn to the accompanying tables on pages 36 to 38 (Tables XI to XII). Beginning with any lead L that is *larger* than the numerator 0.6458, subtract the logarithms of the leads, as found in the tables, from the logarithm of the numerator 0.6458 until, by repeated trials,

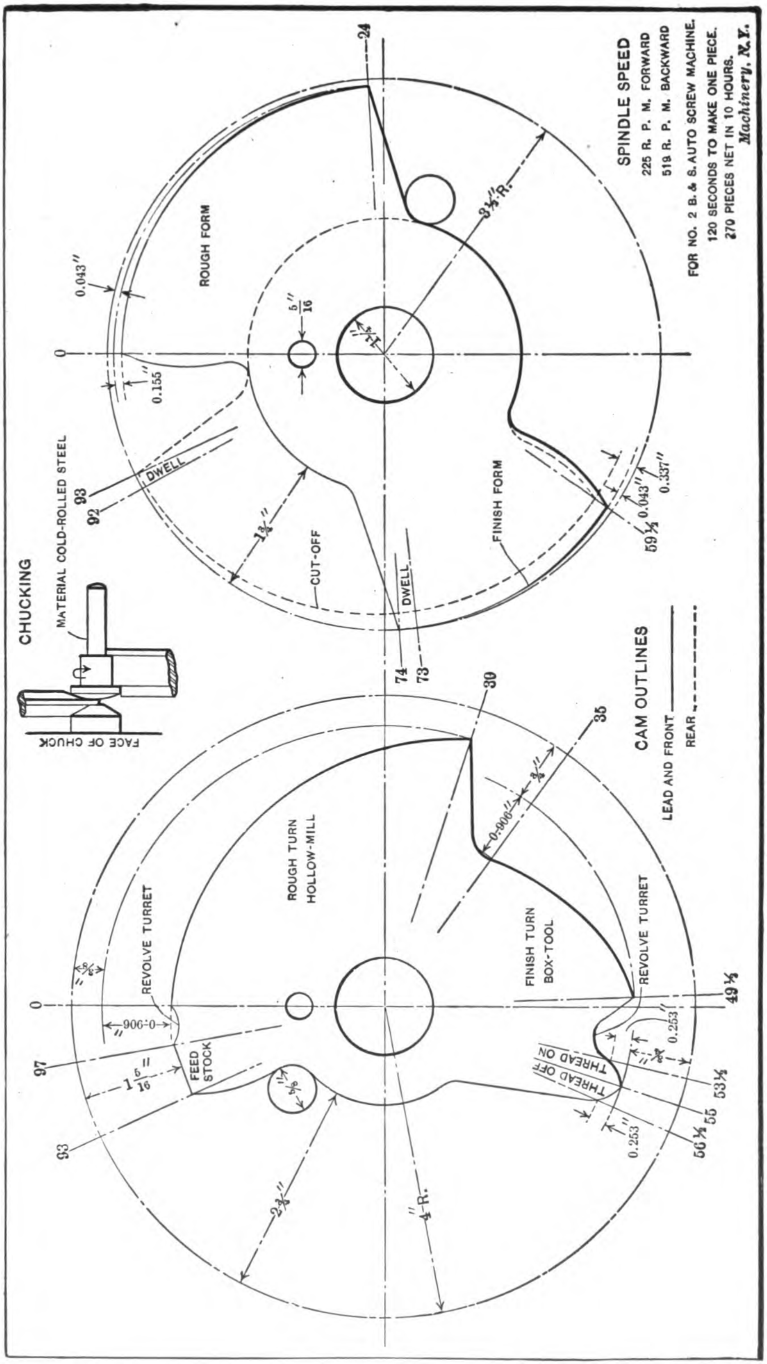


Fig. 17. Cams used as Examples in the Calculations

TABLE XI. DATA FOR MILLING SCREW MACHINE CAMS

Spiral Lead	Logarithm	Spiral Lead	Logarithm	Spiral Lead	Logarithm	Spiral Lead	Logarithm	Spiral Lead	Logarithm
0.900	$\bar{1}$.95424	1.776	0.24944	2.333	0.36791	2.894	0.46150	3.429	0.53517
0.930	$\bar{1}$.96848	1.778	0.24993	2.338	0.36884	2.909	0.46374	3.438	0.53631
0.933	$\bar{1}$.96988	1.786	0.25188	2.344	0.36996	2.917	0.46494	3.488	0.54258
1.029	0.01242	1.800	0.25527	2.368	0.37438	2.924	0.46598	3.491	0.54295
1.042	0.01787	1.809	0.25744	2.381	0.37676	2.933	0.46731	3.492	0.54307
1.047	0.01995	1.818	0.25959	2.386	0.37767	2.934	0.46746	3.500	0.54407
1.050	0.02119	1.823	0.26079	2.392	0.37876	2.946	0.46923	3.520	0.54654
1.067	0.02816	1.860	0.26951	2.400	0.38021	2.950	0.46982	3.535	0.54839
1.085	0.03543	1.861	0.26975	2.424	0.38453	2.977	0.47378	3.552	0.55047
1.116	0.04766	1.867	0.27114	2.431	0.38578	2.984	0.47480	3.556	0.55096
1.196	0.07773	1.875	0.27300	2.442	0.38775	3.000	0.47712	3.564	0.55194
1.200	0.07918	1.886	0.27554	2.445	0.38828	3.030	0.48144	3.565	0.55206
1.221	0.08672	1.905	0.27989	2.450	0.38917	3.044	0.48344	3.571	0.55279
1.228	0.08920	1.919	0.28307	2.456	0.39023	3.055	0.48501	3.572	0.55291
1.240	0.09342	1.920	0.28330	2.481	0.39463	3.056	0.48515	3.582	0.55413
1.244	0.09482	1.925	0.28443	2.489	0.39602	3.070	0.48714	3.588	0.55485
1.250	0.09691	1.944	0.28870	2.500	0.39794	3.080	0.48855	3.600	0.55630
1.302	0.11461	1.954	0.29092	2.514	0.40037	3.086	0.48940	3.618	0.55847
1.309	0.11694	1.956	0.29137	2.532	0.40346	3.101	0.49150	3.636	0.56062
1.333	0.12483	1.990	0.29885	2.537	0.40432	3.111	0.49290	3.637	0.56074
1.340	0.12710	1.993	0.29950	2.546	0.40586	3.117	0.49374	3.646	0.56182
1.371	0.13704	2.000	0.30103	2.558	0.40790	3.125	0.49485	3.655	0.56289
1.395	0.14457	2.009	0.30298	2.567	0.40943	3.126	0.49499	3.657	0.56312
1.400	0.14613	2.030	0.30750	2.571	0.41010	3.140	0.49693	3.663	0.56384
1.429	0.15503	2.035	0.30856	2.593	0.41380	3.143	0.49734	3.667	0.56431
1.433	0.15625	2.036	0.30878	2.605	0.41581	3.150	0.49831	3.673	0.56502
1.440	0.15836	2.045	0.31069	2.618	0.41797	3.175	0.50174	3.684	0.56632
1.447	0.16047	2.047	0.31112	2.619	0.41814	3.182	0.50270	3.686	0.56656
1.458	0.16376	2.057	0.31323	2.625	0.41913	3.189	0.50365	3.704	0.56867
1.467	0.16643	2.067	0.31534	2.640	0.42160	3.190	0.50379	3.721	0.57066
1.488	0.17260	2.083	0.31869	2.658	0.42455	3.198	0.50488	3.733	0.57206
1.500	0.17609	2.084	0.31890	2.667	0.42602	3.200	0.50515	3.750	0.57403
1.522	0.18241	2.098	0.32077	2.674	0.42716	3.214	0.50705	3.763	0.57553
1.527	0.18384	2.100	0.32222	2.678	0.42781	3.225	0.50853	3.771	0.57646
1.550	0.19033	2.121	0.32654	2.679	0.42797	3.241	0.51068	3.772	0.57657
1.556	0.19201	2.133	0.32899	2.700	0.43136	3.256	0.51268	3.799	0.57967
1.563	0.19396	2.143	0.33102	2.713	0.43345	3.267	0.51415	3.809	0.58081
1.595	0.20276	2.171	0.33666	2.727	0.43569	3.273	0.51495	3.810	0.58092
1.600	0.20412	2.178	0.33806	2.743	0.43823	3.275	0.51521	3.818	0.58184
1.607	0.20602	2.182	0.33885	2.750	0.43933	3.281	0.51601	3.819	0.58195
1.628	0.21165	2.188	0.34005	2.778	0.44373	3.300	0.51851	3.822	0.58229
1.637	0.21405	2.193	0.34104	2.791	0.44576	3.308	0.51957	3.837	0.58399
1.650	0.21748	2.200	0.34242	2.800	0.44716	3.333	0.52284	3.840	0.58433
1.667	0.22194	2.222	0.34674	2.812	0.44902	3.345	0.52440	3.850	0.58546
1.674	0.22376	2.233	0.34889	2.828	0.45148	3.349	0.52492	3.876	0.58838
1.680	0.22531	2.238	0.34986	2.843	0.45378	3.360	0.52634	3.889	0.58984
1.706	0.23198	2.240	0.35025	2.845	0.45408	3.383	0.52930	3.896	0.59062
1.711	0.23325	2.250	0.35218	2.849	0.45469	3.403	0.53186	3.907	0.59184
1.714	0.23401	2.274	0.35679	2.857	0.45591	3.409	0.53263	3.911	0.59229
1.744	0.24155	2.286	0.35908	2.865	0.45712	3.411	0.53288	3.920	0.59329
1.745	0.24180	2.292	0.36021	2.867	0.45743	3.422	0.53428	3.927	0.59406
1.750	0.24304	2.326	0.36661	2.880	0.45939	3.428	0.53504	3.929	0.59428

TABLE XII. DATA FOR MILLING SCREW MACHINE CAMS

Spiral Lead	Logarithm	Spiral Lead	Logarithm	Spiral Lead	Logarithm	Spiral Lead	Logarithm	Spiral Lead	Logarithm
3.977	0.59956	4.572	0.66011	5.160	0.71265	5.848	0.76701	6.548	0.81611
3.979	0.59977	4.582	0.66106	5.168	0.71332	5.861	0.76797	6.563	0.81710
3.987	0.60065	4.583	0.66115	5.185	0.71475	5.867	0.76842	6.578	0.81809
4.000	0.60206	4.584	0.66124	5.186	0.71483	5.893	0.77034	6.600	0.81954
4.011	0.60325	4.651	0.66755	5.195	0.71559	5.912	0.77173	6.645	0.82249
4.019	0.60412	4.655	0.66792	5.209	0.71675	5.920	0.77232	6.667	0.82393
4.040	0.60638	4.667	0.66904	5.210	0.71684	5.926	0.77276	6.689	0.82536
4.059	0.60842	4.675	0.66978	5.226	0.71817	5.952	0.77466	6.697	0.82588
4.060	0.60853	4.687	0.67089	5.233	0.71875	5.954	0.77481	6.698	0.82595
4.070	0.60959	4.688	0.67099	5.236	0.71900	5.969	0.77590	6.719	0.82730
4.073	0.60991	4.691	0.67127	5.238	0.71917	5.972	0.77612	6.720	0.82737
4.074	0.61002	4.714	0.67339	5.250	0.72016	5.980	0.77670	6.735	0.82834
4.091	0.61183	4.736	0.67541	5.256	0.72066	6.000	0.77815	6.750	0.82930
4.093	0.61204	4.762	0.67779	5.280	0.72263	6.016	0.77931	6.757	0.82975
4.114	0.61426	4.773	0.67879	5.303	0.72452	6.020	0.77960	6.766	0.83033
4.125	0.61542	4.778	0.67925	5.316	0.72558	6.061	0.78254	6.784	0.83149
4.135	0.61648	4.784	0.67979	5.328	0.72656	6.077	0.78369	6.806	0.83289
4.144	0.61742	4.785	0.67988	5.333	0.72697	6.089	0.78455	6.818	0.83366
4.167	0.61982	4.800	0.68124	5.347	0.72811	6.109	0.78597	6.822	0.83391
4.186	0.62180	4.813	0.68242	5.348	0.72819	6.112	0.78618	6.825	0.83410
4.200	0.62325	4.821	0.68314	5.357	0.72892	6.122	0.78689	6.857	0.83613
4.242	0.62757	4.849	0.68565	5.358	0.72900	6.125	0.78711	6.875	0.83727
4.253	0.62870	4.861	0.68673	5.375	0.73038	6.137	0.78796	6.880	0.83759
4.264	0.62982	4.884	0.68878	5.400	0.73239	6.140	0.78817	6.944	0.84161
4.267	0.63012	4.889	0.68922	5.418	0.73384	6.143	0.78838	6.945	0.84167
4.278	0.63124	4.898	0.69002	5.426	0.73448	6.160	0.78958	6.968	0.84311
4.286	0.63205	4.900	0.69020	5.427	0.73456	6.171	0.79036	6.977	0.84367
4.300	0.63347	4.911	0.69117	5.444	0.73592	6.173	0.79048	6.982	0.84398
4.320	0.63548	4.914	0.69144	5.455	0.73679	6.202	0.79253	6.984	0.84410
4.341	0.63759	4.950	0.69461	5.469	0.73791	6.222	0.79393	7.000	0.84510
4.342	0.63769	4.961	0.69557	5.473	0.73823	6.234	0.79477	7.018	0.84590
4.361	0.63959	4.978	0.69705	5.486	0.73926	6.250	0.79588	7.040	0.84757
4.363	0.63979	4.984	0.69758	5.500	0.74036	6.255	0.79623	7.071	0.84948
4.364	0.63988	5.000	0.69897	5.556	0.74476	6.279	0.79789	7.104	0.85150
4.365	0.63998	5.017	0.70044	5.568	0.74570	6.286	0.79837	7.106	0.85163
4.375	0.64098	5.023	0.70096	5.581	0.74671	6.300	0.79934	7.111	0.85193
4.386	0.64207	5.029	0.70148	5.582	0.74679	6.343	0.80229	7.130	0.85309
4.400	0.64345	5.040	0.70243	5.600	0.74819	6.350	0.80277	7.143	0.85388
4.444	0.64777	5.074	0.70535	5.625	0.75012	6.364	0.80373	7.159	0.85485
4.465	0.64982	5.080	0.70586	5.657	0.75259	6.379	0.80475	7.163	0.85509
4.466	0.64992	5.088	0.70655	5.698	0.75572	6.396	0.80591	7.167	0.85534
4.477	0.65099	5.091	0.70680	5.714	0.75694	6.400	0.80618	7.176	0.85588
4.479	0.65118	5.093	0.70697	5.730	0.75815	6.417	0.80733	7.200	0.85733
4.480	0.65128	5.105	0.70800	5.733	0.75838	6.429	0.80814	7.268	0.86141
4.500	0.65321	5.116	0.70893	5.756	0.76012	6.450	0.80956	7.272	0.86165
4.522	0.65533	5.119	0.70919	5.759	0.76035	6.460	0.81023	7.273	0.86171
4.537	0.65677	5.120	0.70927	5.760	0.76042	6.465	0.81057	7.292	0.86285
4.545	0.65753	5.133	0.71037	5.788	0.76253	6.482	0.81171	7.310	0.86392
4.546	0.65763	5.134	0.71046	5.814	0.76448	6.512	0.81371	7.314	0.86415
4.548	0.65782	5.142	0.71113	5.818	0.76477	6.515	0.81391	7.326	0.86487
4.558	0.65877	5.143	0.71122	5.833	0.76589	6.534	0.81518	7.330	0.86510
4.567	0.65963	5.156	0.71231	5.847	0.76693	6.545	0.81591	7.333	0.86528

TABLE XIII. DATA FOR MILLING SCREW MACHINE CAMS

Spiral Lead	Logarithm	Spiral Lead	Logarithm	Spiral Lead	Logarithm	Spiral Lead	Logarithm	Spiral Lead	Logarithm
7.334	0.86534	8.081	0.90747	8.953	0.95197	9.828	0.99247	10.800	1.03342
7.347	0.86611	8.103	0.90859	8.959	0.95226	9.844	0.99317	10.853	1.03555
7.371	0.86753	8.119	0.90950	8.960	0.95231	9.900	0.99564	10.859	1.03579
7.372	0.86759	8.140	0.91062	8.980	0.95328	9.921	0.99656	10.909	1.03778
7.400	0.86923	8.145	0.91089	9.000	0.95424	9.923	0.99664	10.913	1.03794
7.408	0.86970	8.148	0.91105	9.044	0.95636	9.943	0.99752	10.937	1.03890
7.424	0.87064	8.149	0.91110	9.074	0.95780	9.954	0.99800	10.945	1.03922
7.442	0.87169	8.163	0.91185	9.091	0.95861	9.967	0.99856	10.949	1.03937
7.465	0.87303	8.167	0.91206	9.115	0.95976	9.968	0.99861	10.972	1.04029
7.467	0.87315	8.182	0.91286	9.134	0.96066	10.000	1.00000	11.000	1.04139
7.500	0.87506	8.186	0.91307	9.137	0.96080	10.033	1.00143	11.021	1.04222
7.525	0.87651	8.212	0.91445	9.143	0.96109	10.046	1.00199	11.057	1.04364
7.543	0.87754	8.229	0.91535	9.164	0.96209	10.057	1.00247	11.111	1.04575
7.576	0.87944	8.250	0.91645	9.167	0.96223	10.078	1.00337	11.137	1.04677
7.597	0.88064	8.306	0.91939	9.210	0.96426	10.080	1.00346	11.160	1.04766
7.601	0.88087	8.312	0.91971	9.214	0.96445	10.101	1.00436	11.163	1.04778
7.611	0.88144	8.333	0.92080	9.260	0.96661	10.159	1.00685	11.169	1.04801
7.619	0.88190	8.334	0.92085	9.302	0.96858	10.175	1.00753	11.198	1.04914
7.620	0.88195	8.361	0.92226	9.303	0.96862	10.182	1.00783	11.200	1.04922
7.636	0.88287	8.372	0.92283	9.333	0.97002	10.186	1.00800	11.225	1.05019
7.639	0.88304	8.377	0.92309	9.334	0.97007	10.209	1.00898	11.250	1.05115
7.644	0.88332	8.400	0.92428	9.351	0.97086	10.228	1.00979	11.313	1.05358
7.657	0.88406	8.437	0.92619	9.375	0.97197	10.233	1.01000	11.314	1.05362
7.674	0.88502	8.457	0.92722	9.382	0.97230	10.238	1.01022	11.363	1.05549
7.675	0.88508	8.484	0.92860	9.385	0.97243	10.267	1.01144	11.401	1.05694
7.679	0.88530	8.485	0.92865	9.406	0.97340	10.286	1.01225	11.429	1.05801
7.680	0.88536	8.506	0.92978	9.428	0.97442	10.312	1.01334	11.454	1.05896
7.700	0.88649	8.523	0.93059	9.429	0.97447	10.313	1.01338	11.459	1.05915
7.714	0.88728	8.527	0.93080	9.460	0.97589	10.320	1.01368	11.467	1.05945
7.752	0.88941	8.532	0.93105	9.472	0.97644	10.336	1.01435	11.512	1.06115
7.778	0.89087	8.534	0.93115	9.524	0.97882	10.370	1.01578	11.518	1.06138
7.792	0.89165	8.552	0.93207	9.545	0.97978	10.371	1.01582	11.520	1.06145
7.813	0.89282	8.556	0.93227	9.546	0.97982	10.390	1.01662	11.574	1.06348
7.815	0.89293	8.572	0.93308	9.547	0.97987	10.417	1.01774	11.629	1.06554
7.818	0.89310	8.594	0.93420	9.549	0.97996	10.419	1.01783	11.638	1.06588
7.833	0.89421	8.600	0.93450	9.556	0.98028	10.451	1.01916	11.667	1.06696
7.855	0.89515	8.640	0.93651	9.569	0.98087	10.467	1.01982	11.688	1.06774
7.857	0.89526	8.681	0.93857	9.598	0.98218	10.473	1.02007	11.695	1.06800
7.872	0.89609	8.682	0.93862	9.600	0.98227	10.476	1.02020	11.719	1.06889
7.875	0.89625	8.687	0.93887	9.625	0.98340	10.477	1.02024	11.721	1.06896
7.883	0.89669	8.721	0.94057	9.643	0.98421	10.500	1.02119	11.728	1.06922
7.920	0.89873	8.727	0.94086	9.675	0.98565	10.558	1.02358	11.733	1.06941
7.936	0.89960	8.730	0.94101	9.690	0.98632	10.571	1.02412	11.757	1.07030
7.954	0.90059	8.750	0.94201	9.697	0.98664	10.606	1.02555	11.785	1.07133
7.955	0.90064	8.772	0.94310	9.723	0.98780	10.631	1.02657	11.786	1.07137
7.963	0.90108	8.800	0.94448	9.741	0.98860	10.655	1.02755	11.825	1.07280
7.974	0.90163	8.833	0.94635	9.768	0.98981	10.659	1.02772	11.852	1.07379
7.994	0.90276	8.839	0.94640	9.773	0.99003	10.667	1.02804	11.905	1.07573
8.000	0.90309	8.889	0.94885	9.778	0.99025	10.694	1.02914	11.938	1.07693
8.021	0.90423	8.909	0.94983	9.796	0.99105	10.713	1.02991	11.944	1.07715
8.035	0.90499	8.929	0.95080	9.818	0.99202	10.714	1.02995	11.960	1.07778
8.063	0.90650	8.930	0.95085	9.822	0.99220	10.750	1.03141	12.000	1.07918

a remainder is obtained which is the logarithm of the sine of an angle which is within 5 minutes of a whole or a half degree. The angle thus found is the setting angle for the index head and the lead giving this angle is the one for which the head is to be geared. Proceeding according to the directions given above we have:

$$\begin{array}{rl} & \log 0.6458 = \bar{1}.81010 \\ \text{(Subtract)} & \log 0.900 = \bar{1}.95424 \\ \hline & \log \sin \alpha = \bar{1}.85586 \end{array}$$

From a table of logarithms of sines we find that α = 45 degrees 51 minutes. As this angle is not within 5 minutes of a whole or a half degree, try the next lead in Table XI, as follows:

$$\begin{array}{rl} & \log 0.6458 = \bar{1}.81010 \\ \text{(Subtract)} & \log 0.930 = \bar{1}.96848 \\ \hline & \log \sin \alpha = \bar{1}.84162 \end{array}$$

Hence α = 43 degrees 59 minutes.

This angle fills the requirements. No more trials are, therefore, required, and the index head and the compound vertical milling attachment are to be set to 44 degrees; the gears to use for gearing the spiral head for 0.930 inch lead are found from Brown & Sharpe Mfg. Co.'s book "Table of Leads for Use with Universal Miling Machines," as aready mentioned.

In using this method, the following conditions must be taken into consideration:

If a spiral lead can be found in the accompanying tables which is exactly equal to the numerator l in the fraction giving sin α in Formula (1), then this lead is the lead for which the spiral head is to be geared. It will be seen that sin α in this case becomes equal to 1, which is the sine of 90 degrees. This indicates that the compound vertical milling attachment and the index head are to be set in a vertical position. The calculations required for this case then become very simple, as no further trials are necessary.

Especial attention should be given to the fact that the spiral leads L used in the trial calculations must be larger than the numerator l in the fraction giving sin α in Equation (1). If the number expressing the lead were not greater than the numerator, the value of the fraction would be greater than 1, but as the sines of all angles are smaller than 1, this would be an impossible condition.

In finding the lead corresponding to a suitable angle, a simple way is to write the logarithm of the lead L on the upper edge of a second sheet of paper and to hold this under the originally written value of the logarithm of the numerator l in Formula (1), putting the difference on the second sheet of paper until a logarithm of sin α is found, giving a suitable angle, as explained above. This saves repeating the writing down of the logarithm of the numerator l for each trial subtraction.

As another example illustrating what has been said, we may calculate the first lobe on the lead cam. Here $L = 0.906$, $N = 0.30$. Hence

$$l = \frac{0.906}{0.30} = 3.02.$$

It is found by repeated trials, starting with $L = 3.03$, that no lead gives an angle α even approximately within the given requirements, before we come to the lead 3.111:

$$\begin{array}{rl} & \log 3.02 = 0.48001 \\ \text{(Subtract)} & \log 3.111 = 0.49290 \\ \hline & \log \sin \alpha = \bar{1}.98711 \end{array}$$

Hence $\alpha = 76$ degrees 6 minutes.

TABLE XIV. RESULTS OBTAINED BY THE CALCULATIONS FOR ANGLE AND LEAD

Piece No. 4-817
Computed by H. W. E.
Checked by W. W. J.
Date: Nov. 17, 1910

Name of Cam	Rise on Cam in Inches	Number of Hundredths	Angle α in Degrees	Lead in Inches	Gear on Worm	First Gear on Stud	Second Gear on Stud	Gear on Screw
Lead cam	0.906	30	76	3.111	40	72	56	100
Lead cam	0.906	14½	80	6.343	100	44	24	86
Front cam	0.155	24	44	0.930	24	72	24	86
Front cam	0.043	13½	20	0.930	24	72	24	86
Rear cam	0.337	32½	82	1.047	24	64	24	86

While the angle 76 degrees 6 minutes is not quite within the limits that we have specified, it is so nearly so that it is safe enough to assume the setting angle to be 76 degrees, the corresponding lead being 3.111. We can calculate the actual rise of the cam with this lead and angle and compute the error resulting in the rise. From Formula (2) we have:

$$R = \sin \alpha \times N \times L \qquad (4)$$

Inserting $\alpha = 76$ degrees, $N = 0.30$, and $L = 3.111$, we obtain $R = 0.9056$ inch.

The error in the rise thus is 0.0004 inch, which for all practical purposes can be disregarded. The same method is employed for the other lobes. With a little practice, the work can be carried on rapidly, and the method is very simple to remember.

While it is the best practice always to use a spiral lead which corresponds to an angle within 5 minutes of a whole or half degree, as stated, yet a considerable amount of time may be saved in milling cam lobes with several leads, when the greatest accuracy may not be required, by gearing the machine for the greatest lead of lobe and changing the setting angle of the head for the other leads.