Standard 5100-1c
September 1997
Superseding 5100-1b
July 1991

UNITED STATES DEPARTMENT OF AGRICULTURE

FOREST SERVICE

STANDARD FOR

SPARK ARRESTERS FOR INTERNAL COMBUSTION ENGINES

1. SCOPE.

1.1. Scope. This standard establishes the minimum performance and maintenance requirements of spark arresters for single position internal combustion engines used in proximity to grass, brush, timber and similar cellulose materials. This standard provides methods for rating performance, selection of size, and determining the application position. Arresters meeting this standard may not adequately trap hot carbon particles when tilted more than 45 degrees from the qualified position.

Four general spark arrester application positions are considered for a single position engine—vertical, horizontal, inverted, and multi-position. See Figure 1. The application is determined by the attitude at which the inlet pipe enters the body and by a line drawing. The line drawing shall indicate the position of the cleanout plug and position of the main body for proper operation. A spark arresting effectiveness test is required for each application position.

Federal and local laws and administrative requirements indicate when and where arresters are required. During periods of very high or extreme fire danger, arresters meeting this standard will not give complete protection against exhaust spark fires. Additional measures including shutdown of operations may be required during such periods.

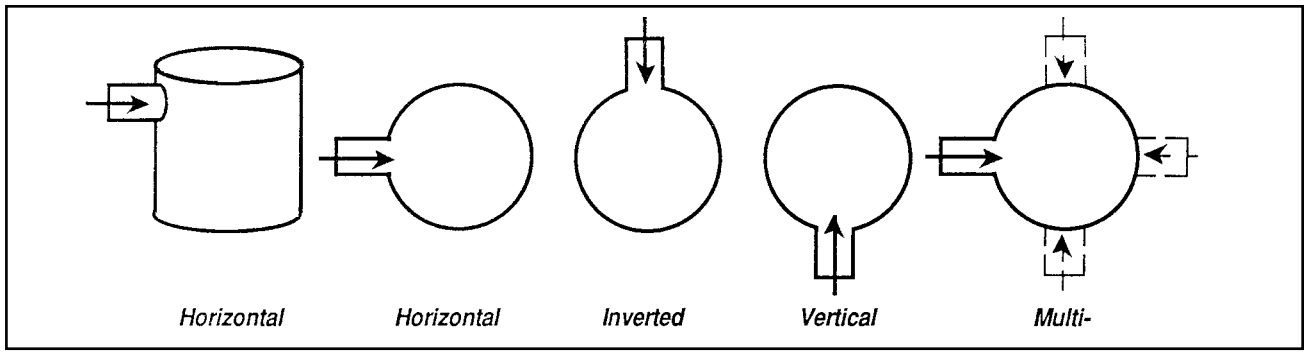

Figure 1. Spark Arrester Positions of Application.

Beneficial comments, recommendations, additions, deletions and any pertinent data that may be used in improving this document should be addressed to: USDA Forest Service, San Dimas Technology and Development Center, 444 East Bonita Avenue, San Dimas, CA 91773-3198 by using the Specification Comment Sheet at the end of this document, or by letter.

2. APPLICABLE DOCUMENTS.

2.1 Non-Government Publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those in effect on the date of the testing.

Society of Automotive Engineers (SAE)

Surface Vehicle Recommended Practice J350 - Spark Arrester Test Procedure for Medium Size Engines

Surface Vehicle Standard J997 - Spark Arrester Test Carbon

Copies of SAE Standard and Recommended Practice are available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

3. REQUIREMENTS.

3.1. Performance.

3.1.1. Arresting Effectiveness. Arresting effectiveness shall be at least 80 percent for all flow points established by 3.2.5.

3.1.2. Arresting Effectiveness Below 80%. If an effectiveness below 80 percent is identified, two additional tests shall be conducted using the same size carbon and at the same back pressure. An effectiveness rating of 80 percent must be achieved for both test runs.

3.1.3. Rated Flow of Arrester. The rated flow of the spark arrester shall be the minimum flow rate of the test gas in cubic feet per minute (cfm) or cubic meter per second (cms), at a back pressure of one psi (6.89 kPa), when tested in accordance with this standard.

3.2. Test Method.

3.2.1. Apparatus. The apparatus shall consist of a suitable blower with air directed through the test apparatus, metering instruments, spark arrester and a positive trap for collecting the test carbon particles. The apparatus shall permit mounting of arresters in all positions and shall discharge into the positive trap in a manner similar to that shown in Figure 2.

3.2.2. Test Carbon. Spark arrester fine and coarse test carbon shall be in accordance with SAE Standard J997.

3.2.3. Injecting Mechanism. The test carbon shall be injected by a feeder mechanism that shall not crush or grind the material nor shall it unduly affect, during the process of injection, the normal flow of air through the apparatus. It shall be located approximately as shown in Figure 2.

3.2.4. Back Pressure. Provision shall be made for measuring the differential pressure from intake to discharge of the spark arrester. A device similar to the apparatus illustrated in Figure 2 may be used.

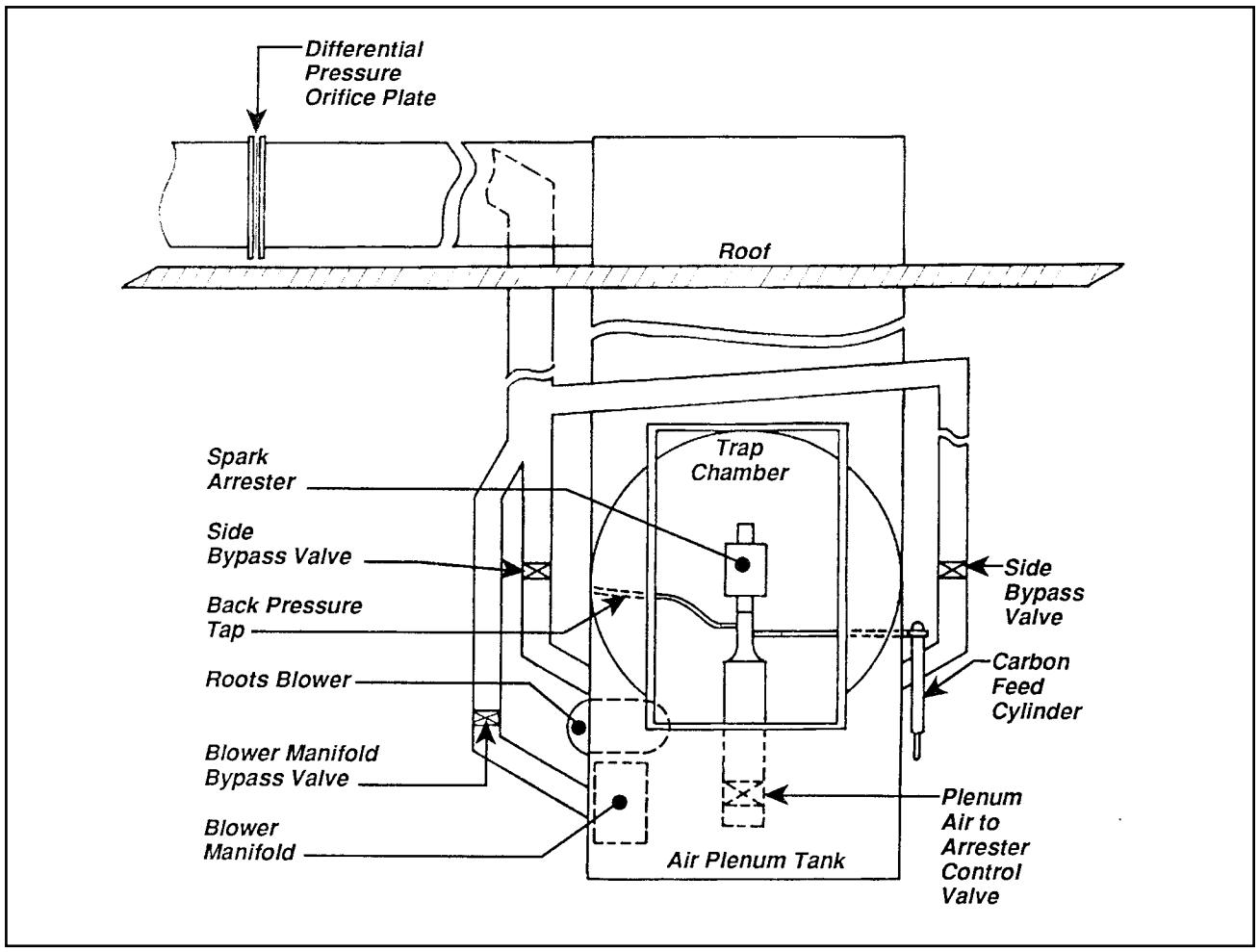

Figure 2. Spark Arrester Test Apparatus Configuration.

3.2.5. Flow Measurements. Any method which measures the gas flow through the spark arrester, with an accuracy of ±5% of the actual value, may be used.

3.2.6. Flow Test Points. The arrester shall be tested for spark arrester effectiveness at not less than six flow rate test points. Two test runs for each flow rate shall be conducted, one run using coarse carbon and the other using fine carbon. The test point at 100 percent of the rated flow at a back pressure of 1 psi (6.89 kPa) is used for establishing the flowrate base line and subsequently, the other flow test points. One flow point will be at 100 percent of the rated flow of the arrester; two points at approximately 10 and 200 percent of the rated flow; and three points approximately evenly spaced between 10 and 100 percent of the rated flow.

3.2.7. Weight of Sample. The test carbon sample for each test run shall be 0.2 grams (3.1 gr) of carbon for each cubic foot of air flow per minute with a minimum of 25 grams (385.8 gr) and a maximum of 200 grams (0.44 lb). This may be expressed by the formula:

Weight of sample(gram) = flow(cfm) at 1 psi (6.89 kPa) back pressure x 0.2 gram (3.1 gr) of carbon.

3.2.8. Duration of Test. Test carbon shall be injected into the air stream at a uniform rate over a period of 15 minutes with a tolerance of plus or minus 5 minutes.

3.2.9. Calculations.

3.2.9.1. Spark Arrester Effectiveness Formula. Spark arrester effectiveness shall be calculated using the following formula:

$$E_f = \frac{(W_S - W_t)}{W_S} \text{ X } 100\%$$

where:

E_f	=	spark arresting effectiveness (%)
W_S	=	weight of carbon sample (grams)
W_t	=	weight of the carbon found in the positive trap chamber that is retained on a United States Standard No. 30 sieve (grams)

3.2.9.2. Spark Arrester Cleanout Effectiveness. In addition, the spark arrester cleanout effectiveness shall be determined by the following formula:

$$Co_{ef} = \frac{(T_{ci})}{T_{co}} \text{ X } 100\%$$

where:

Co_{ef}	=	cleanout effectiveness (%)
T_{ci}	=	Total weight of carbon input for the entire evaluation (grams)
T_{co}	=	Total weight of carbon that passed through for all of the test runs in the entire evaluation (grams)

3.3. Cleaning and Warranty.

3.3.1. Cleaning. The spark arrester shall have provisions for disposal of accumulated particles without the removal of the clamping or mounting devices from the stack, pipe or manifold assembly. Removable items other than fasteners must be indexed to one position to prevent improper assembly.

3.3.2. Warranty. The manufacturer will warrant his product to maintain an acceptable spark arresting effectiveness for a minimum of 1,000 hours, subject to normal use, with maintenance and mounting in accordance with the manufacturer's recommendation.

3.4. Marking and Labeling. Each arrester shall be permanently marked with manufacturer's model designation and a trade mark or other identification of manufacturer. The markings shall be readily visible without removal of the arrester from the engine. Where inverted installation is possible, the inlet or outlet shall be marked. In addition to the above markings, screen type arresters must have the words "Screen Type" clearly imprinted in 1/8 inch (3.2 mm) or larger letters on the arrester or on a readily visible exterior surface near the exhaust outlet. A temperature resistant decal is an option to imprinting "Screen Type".

3.5. Additional Requirements for Screen Type Arresters.

3.5.1. Effective Exhaust Area. The effective exhaust area of screen, which is defined as the total area of all screen openings, shall not be less than 200 percent of the exhaust port area measured at the smallest restriction. For system with multiple exhaust port, each exhaust port area will be added to obtain the total exhaust port area.

3.5.2. Screen and Housing Openings. Screen type arresters shall have no screen or housing openings greater than 0.023 inch (0.584 mm).

3.5.3. Endurance Test. Screen type spark arresters on engines 50 hp (37.3 kW) or greater, shall be tested as outlined in Appendix A of this standard.

3.5.4. Screen Material. Screen material shall be heat and corrosion resistant. The screen component shall provide a minimum of 100 hours service life when installed and maintained in accordance with the manufacturers recommendations.

3.5.5. Cleaning and Maintenance. Screen type arresters shall provide for the easy removal of the screen for cleaning or replacement.

4. SPARK ARRESTER SELECTION AND INSTALLATION.

4.1. General. The exhaust flow from the engine should be equal to or less than the Rated Flow of the arrester selected when operated at the manufacturer's recommended maximum speed and power for intermittent operation or maximum governed speed.

4.2. Selection of Arrester. Exhaust flow shall be determined by Table 1 for diesel engines and Tables 2 and 3 for naturally aspirated engines. Engine displacement shall be in cubic inches or cubic centimeters and in accordance with manufacturer's specifications. Speed shall be in revolutions per minute (rpm) and at the manufacturer's recommended maximum speed for intermittent operation or maximum governed rpm, whichever is applicable.

4.3. Installation. Installation shall be in accordance with the manufacturer written recommendations which are submitted with each unit for qualification testing.

4.4. Maintenance. Maintenance shall be in accordance with the manufacturer written recommendations at frequent intervals to ensure proper operation. The spark arrester shall be checked frequently to promptly detect a decline in performance or failure due to leaks, burned out baffles, diffusers, fans, or any other part affecting the effectiveness of the unit.

5. NOTES.

5.1. Preparing Activity. USDA Forest Service, San Dimas Technology and Development Center, 444 East Bonita Avenue, San Dimas, CA 91773-3198.

Table 1. Exhaust Flow in Cubic Feet Per Minute at Maximum Ratings[1] for 4-Cycle Engines[2]

Engine Displacement		Revolutions Per Minute												
cubic cm	cubic inches	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	RPM[3] Differential
16	1	0	1	1	1	1	1	1	1	1	1	2	2	0
33	2	1	1	1	2	2	2	2	2	3	3	3	3	0
49	3	1	2	2	2	3	3	3	4	4	4	5	5	0
66	4	2	2	3	3	4	4	4	5	5	6	6	7	0
82	5	2	3	3	4	4	5	6	6	7	7	8	8	1
94	6	3	3	4	5	5	6	7	7	8	9	9	10	1
115	7	3	4	5	5	6	7	8	9	9	10	11	12	1
131	8	4	4	5	6	7	8	9	10	11	12	13	13	1
148	9	4	5	6	7	8	9	10	11	12	12	14	15	1
164	10	4	6	7	8	9	10	11	12	13	15	16	17	1
328	20	9	11	13	16	18	20	22	25	27	29	31	34	2
492	30	13	17	20	24	27	30	34	37	40	44	47	51	3
656	40	18	22	27	31	36	40	45	49	54	58	63	67	4
820	50	22	28	34	39	45	51	56	62	67	73	79	84	6
984	60	27	34	40	47	54	61	67	74	81	88	94	101	7
1148	70	31	39	47	55	63	71	79	87	94	102	110	118	8
1312	80	36	45	54	63	72	81	90	99	108	117	126	135	9
1475	90	40	51	61	71	81	91	101	111	121	131	142	152	10
1639	100	45	56	67	79	90	101	112	124	135	146	157	169	11
3279	200	90	112	135	157	180	202	225	247	270	292	314	337	22
4918	300	135	168	202	236	270	303	337	371	404	438	472	506	34
6557	400	180	225	270	315	360	404	449	494	539	584	629	674	45
8194	500	224	281	337	393	449	505	562	618	674	732	786	843	56
9836	600	269	337	405	472	539	606	674	742	809	876	944	1011	67
11475	700	314	393	472	550	629	708	786	865	944	1023	1101	1180	79
13115	800	359	449	540	629	719	809	899	989	1079	1169	1258	1348	90
14754	900	404	506	607	708	809	910	1011	1113	1213	1315	1415	1517	101
16393	1000	449	562	674	786	899	1011	1124	1236	1348	1461	1573	1685	112

[1]Volumetric efficiency 80%; exhaust temperature 900 ◦F (482.2 °C

[2]For 2-cycle engines, multiply value by 2; for 2-cycle supercharged engines, multiply value by 3.25; for 4-cycle supercharged engines, multiply value by 1.25.

[3]The “RPM Differential” column gives the difference between “RPM” columns for interpolation purposes. Entries are to the nearest whole number.

GENERAL- All chart values are proportional, so a flow can be calculated for a 1000-cubic-inch engine by doubling the flow figure for an identical engine but with 500 cubic-inch displacement. The same rule applies to revolutions per minute. Therefore, a flow can be calculated for a 3000 maximum rpm engine by doubling the flow value of an identical engine but with 1500 maximum rpm.

This chart may also be used like an interest table. If an engine has a cubic inch displacement of 438 at 2600 rpm, select readings for 400, 30, and 8 at 2600 rpm. The sum is the flow rate. When rpm fall between columns, ie.,1600 to 1800 rpm, 1800 to 2000 rpm, etc., take the next highest rpm column. To be more exact, use the “RPM Differential” value.

Example: A 4-cycle diesel engine has a total displacement of 633 cubic inches. If the maximum rpm is 2600, what is the maximum exhaust flow?

> **Solution:** 600 cu. in. displacement @ 2600 rpm = 876; 30 cu. in. = 44, and 3 cu. in.= 4; Sum = 924 cfm.

Table 2. Exhaust Flow in Cubic Feet Per Minute at Ratings[1] for 4-Cycle Gasoline or Propane Naturally Aspirated Engines[2]

Engine Displacement		Revolutions Per Minute											
cubic cm	cubic inches	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	RPM[3] Differential
16	1	1	1	1	2	2	2	2	2	2	2	2	0
33	2	2	2	3	3	3	4	4	4	4	5	5	0
49	3	3	4	4	5	5	5	6	6	7	7	7	0
66	4	4	5	5	6	7	7	8	8	9	10	11	1
82	5	5	6	7	8	8	9	10	10	11	12	12	1
94	6	7	7	8	9	10	11	12	12	13	14	15	1
115	7	8	9	10	11	12	12	13	14	15	16	17	1
131	8	9	10	11	12	13	14	15	16	18	19	20	1
148	9	10	11	12	14	15	16	17	18	20	21	22	1
164	10	11	12	14	15	16	18	19	21	22	23	25	1
328	20	22	25	28	30	33	36	38	41	44	47	49	3
492	30	33	37	41	45	49	54	58	62	66	70	74	4
656	40	44	49	55	60	66	71	77	82	88	93	99	6
820	50	55	62	69	75	82	89	96	103	110	117	123	7
984	60	66	74	82	90	99	107	115	123	132	140	148	8
1148	70	77	86	96	106	115	125	134	144	153	163	173	10
1312	80	88	99	110	121	132	143	153	164	175	186	197	11
1475	90	99	111	123	136	148	160	173	185	197	210	222	12
1639	100	110	123	137	151	164	178	192	206	219	233	247	14
3279	200	219	247	275	301	329	356	383	411	438	466	493	27
4918	300	329	370	411	452	493	536	575	617	658	699	740	41
6557	400	438	493	548	603	658	712	767	822	877	931	986	55
8187	500	548	617	685	754	822	891	959	1028	1096	1165	1233	69
9836	600	658	740	822	904	986	1068	1151	1233	1315	1397	1479	82
11475	700	767	863	959	1055	1151	1247	1343	1439	1534	1630	1726	96
13115	800	877	986	1096	1205	1315	1425	1534	1644	1753	1863	1973	110
14754	900	986	1110	1233	1356	1480	1603	1726	1850	1973	2096	2219	123
16393	1000	1096	1233	1370	1507	1644	1781	1918	2055	2192	2329	2466	137

[1]Volumetric efficiency 80%; exhaust temperature 1200 ˚F (648.9 °C)

[2]For 2-cycle engines, multiply value by 2; for 4-cycle supercharged engines, multiply value by 1.25.

[3]The “RPM Differential” column gives the difference between “RPM” columns for interpolation purposes. Entries are to the nearest whole number.

GENERAL-All chart values are proportional, so a flow can be calculated for a 1000 cubic-inch engine by doubling the flow figure for an identical engine but with 500 cubic-inch displacement. The same rule applies to revolutions per minute. Therefore, a flow can be calculated for a 3600 maximum rpm engine by doubling the flow value of an identical engine but with 1800 maximum rpm.

This chart may also be used like an interest table. If an engine has a cubic inch displacement of 438 at 2600 rpm, select readings for 400, 30, and 8 at 2600 rpm. The sum is the flow rate. When rpm fall between columns, ie.,1600 to 1800, 1800 to 2000, etc., take the next highest rpm column. To be more exact, use the “RPM Differential” value.

Example: A 4-cycle diesel engine has a total displacement of 133 cubic inches. If the maximum rpm is 3200, what is the maximum exhaust flow?

> **Solution:** 100 cubic inches displacement @ 3200 rpm = 219; 30 cubic inches = 66, and 3 cubic inches 7; Sum = 292 cfm.

Table 3. Exhaust Flow in Cubic Feet Per Minute at Maximum Ratings[1] for 4-Cycle Gasoline or Propane Naturally Aspirated Engine Displacement in Cubic Centimeters[2]; Revolutions Per Minute 3400 to 14000 Included.

Engine Displacement		Revolutions Per Minute											
cubic cm	cubic inches	3400	3600	3800	4000	5000	6000	7000	8000	9000	10000	12000	14000
1	0.061	0	0	0	0	0	0	0	0	0	0	1	1
2	0.122	0	0	0	0	0	1	1	1	1	1	1	1
3	0.183	0	0	0	1	1	1	1	1	1	1	2	2
4	0.244	1	1	1	1	1	1	1	1	2	2	2	2
5	0.305	1	1	1	1	1	1	1	2	2	2	2	3
6	0.366	1	1	1	1	1	2	2	2	2	2	3	4
7	0.427	1	1	1	1	1	2	2	2	3	3	4	4
8	0.488	1	1	1	1	2	2	2	3	3	3	4	5
9	0.549	1	1	1	2	2	2	3	3	3	4	5	5
10	0.610	1	2	2	2	2	3	3	3	4	4	5	6
16	1.00	2	2	3	3	3	4	5	5	6	7	8	9
20	1.22	3	3	3	3	4	5	6	7	8	8	10	12
30	1.83	4	5	5	5	6	8	9	10	11	13	15	18
40	2.44	6	6	6	7	8	10	12	13	15	17	20	23
50	3.05	7	8	8	8	11	13	15	17	19	21	25	30
60	3.66	9	9	10	10	13	15	18	20	23	25	30	35
70	4.27	10	11	11	12	15	18	20	24	26	29	35	41
80	4.88	11	12	13	13	17	20	23	27	30	34	40	47
90	5.49	13	14	14	15	19	23	26	30	34	38	45	53
100	6.10	14	15	16	17	21	25	29	33	38	42	50	59
164	10.00	23	25	26	27	34	41	48	54	61	68	82	95
200	12.20	29	30	32	33	42	50	59	67	75	84	101	117
300	18.31	43	45	48	50	63	75	89	100	113	126	151	176
400	24.41	57	61	64	67	84	101	117	134	150	168	201	234
500	30.51	71	76	80	84	105	126	146	167	188	210	251	293
600	36.61	86	91	96	100	126	151	176	201	225	252	302	351
700	42.71	100	106	112	117	147	176	205	234	263	294	352	410
800	48.82	114	121	128	134	168	201	234	267	301	336	402	469
900	54.92	128	136	144	150	189	226	264	301	339	378	453	527
1000	61.02	143	151	161	167	210	251	293	334	376	420	503	596
1639	100.00	232	247	261	272	342	410	477	545	612	685	820	955

[1]Volumetric efficiency 80%; exhaust temperature 1200˚F (648.9 °C)

[2]For 2-cycle engines, multiply value by 2.

GENERAL-All chart values are proportional, so a flow can be calculated for a 1000 cubic-centimeter engine by doubling the flow figure for an identical engine but with 500 cubic-centimeter displacement. The same rule applies to revolutions per minute. Therefore, a flow can be calculated for a 8000 maximum rpm engine by doubling the flow value of an identical engine but with 4000 maximum rpm.

Example: A 2-cycle motorcycle with a displacement of 125 cc @ 7500 RPM, select readings for 100, 20, and 5 in the 8000 RPM column. The sum of these is the flow for a 4-cycle engine. When revolution fall between columns, ie.,7000 & 8000, take the next highest column. To be more exact, interpolate. For the 2-cycle engine, multiply the chart value by 2.

Appendix A

ENDURANCE TEST FOR SCREEN TYPE SPARK ARRESTER

The following test shall be conducted at an independent laboratory, or at the manufacturer test facility, at no cost to the United States Government. Choice of the independent laboratory or manufacturer test facility shall be at the discretion of the applicant but must be acceptable to the USDA Forest Service.

1 The arrester must be properly mounted on an engine of the type and maximum size for which the arrester is to be used. Engine size shall be determined by the maximum calculated rated flow and the manufacturer rated horse-power. If the arrester is intended for both two and four stroke cycle applications, separate tests shall be conducted for each type of engine.

2. The test shall be conducted for a minimum of 100 hours, which need not be continuous. One hour cycling periods, representative of actual operating conditions, including idle at no load through maximum operating engine speed at full load, shall be conducted throughout the entire 100 hour period.

3. The engine manufacturer recommended oil to fuel ratio shall be observed for all two stroke cycle tests.

4. During the 100 hour test the following data shall be recorded at increments of not more than two hours:

a. Operating time
b. Engine speed
c. Temperature in screen area
d. Engine load or output horsepower
e. Exhaust back pressure
f. Time and circumstance of any part failure or malfunction. In addition, complete information on the engine, including make, model, serial number, fuel used, etc., shall be provided. Also, there shall be a description of the test setup, including photographs.

5. If it is necessary to clean the spark arrester screen, the time of such cleaning shall be recorded as described in 4f, above. It is imperative that the screen and other components not be cleaned during or after the 75th hour of the 100 hour endurance test period.

6. Upon completion of the test, the spark arrester and any parts that may have failed shall be returned along with a full test report to the San Dimas Technology & Development Center, San Dimas, CA, for the purpose of a qualification examination.

United States Department of Agriculture, Forest Service
Standardization Document Improvement Proposal

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Standard Number and Title: **Specification 5100-1c, Spark Arresters for Internal Combustion Engines**

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USDA Forest Service
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