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MELBOURNE, VICTORIA

Propulsion Division Technical Memorandum 469

COMPARATIVE EVALUATION OF ALLISON T56 ENGINE CHIP DETECTORS (U)

by

P.J. Gage

Approved for public release.

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SUMMARY

An experimental investigation was conducted to assess the performance of magnetic chip detectors. Several new detectors were compared with those currently in use in the Allison T56 engine.

Results indicate that the relative performance of two of the new designs was satisfactory.

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1. INTRODUCTION

A request was received from the RAAF for evaluation of several magnetic chip detectors for use in the Allison T56 engine. These chip detectors are magnetic plugs capable of indicating the accretion of particles during engine operation.

The plugs to be assessed were of the quick disconnect type, and their performance was to be compared with that of screw-in types currently in use.

Specific requirements were:

a) Comparison tests for particle capture efficiency

b) Comparison of magnetic field strengths

c) Photographs of individual magnetic plugs and captured samples.

d) Comment on the capture efficiency of the quick disconnect magnetic plugs versus screw-in plugs currently in use.

2. EXPERIMENTAL WORK

2.1 The Plugs

The magnetic chip detectors currently in use in the P-3 Orion are designated CD34E, and those on the Hercules aircraft are designated CD100AC and CD102AC. All of these are screw-in and indicating types. An indicating plug causes a light in the cockpit to shine when captured debris closes an electric circuit, thus indicating that wear particles have been trapped. (see Fig 1).

The four new plugs to be valuated are:

TEDECO B8782
TEDECO B8784
TEDECO B8786
TEDECO B8788 (See Fig 2)

These are quick-disconnect plugs, and all are indicating types.

Figures 1 and 2 show the different geometries of the plugs. Noteworthy variations include collector shape and the depth on insertion into the oil. B8786 and B8788 have oil seals in their retainers, to allow removal for inspection without the oil being drained. These seals cause some restriction to the oil flow past the detector.

2.2. Magnetic Field Strength

Test:

The magnetic field strength of the chip detectors was measured using a Bell 610 gaussmeter with a magnetic probe. The probe was moved through the magnetic field of the chip detector, and the maximum field strength observed was recorded.

Results:

The results of this test are listed in Table 1. Maximum values only are given, and they are accurate to ± 0.1K gauss.

The screw-in chip detectors all had field strengths of 1.2 - 1.4K gauss. The quick disconnect plugs had substantially lower field strengths. TEDECO B8782 was the highest of the replacements, and its strength (0.85K gauss) was only two-thirds of the value for the screw-in types.

2.3 Capture Efficiency

The Test Rig:

A brass cylindrical vessel of height 200mm and internal diameter 87mm was used for the test rig (Fig 3). Magnetic plugs could be located opposite each other near the lower end of the cylinder.

As it was not possible to design the rig to exactly simulate operating conditions, it was designed to have a neutral effect on plug performance. Brass was chosen as the material for the cylinder because it would not effect the magnetic field of the detectors. The plugs were located so that they would be exposed to similar oil flows.

One litre of Mobiljet II synthetic lubricating oil was placed in the vessel, along with 0.5g of simulated wear particles. A motorised stirrer was used to ensure that the plugs were exposed to a rapidly moving, debris-laden oil stream during the tests.

Wear Particles

The particles used in the tests were prepared from mild steel filings. The filings were sieved to produce the following size distribution, similar to that used in previous tests (Ref 1).

SIZE (μm)	% (by weight)
<53	40
53-74	20
75-104	20
105-147	20

0.5g of the filings were used in 1 litre of oil, giving a concentration of 560 ppm (by weight).

Test Procedure:

A direct comparison of the capture efficiency of any two plugs was achieved by placing them in a particle rich environment, so that both were exposed to the same particle concentration. The detector which collected the greater mass of debris was defined as more efficient, by a factor equal to the ratio of the captured particle masses. For these test, CD102AC was chosen as an arbitrary standard. All plugs were tested directly against CD102AC, thus allowing indirect comparison of any two plugs.

Initially all plugs were weighed to determine their mass without deposit.

0.5g of simulated wear particles were placed at the bottom of the test cylinder. Two plugs were inserted, and the oil added.

The stirrer was then switched on for one minute. This time limit was chosen after it had been shown that all plugs continued to collect debris for more than two minutes. This was shown by weighing the plugs after each thirty seconds of stirring. The mass of all plugs continued to increase after two minutes of operation, indicating that debris was still being collected at that time.

At the completion of the test run, the oil was drained and the plugs removed. The plugs, with the deposit still attached, were carefully washed in n-hexane to remove the oil, and then allowed to dry for 15 minutes. They were then weighed a second time, to determine the mass of collected particles.

After each test the particle concentration was restored by adding debris of mass equal to the amount just collected.

Repeatability of results was checked by placing two CD102AC chip detectors in the cylinder, and testing them three times. To determine the influence of sampling position on plug capture efficiency, the position of the plugs was reversed, and a further three tests completed. The results, shown in Table 2, indicate that relative capture efficiency was consistent, with plug 1 (S/NQM011) consistently 0.9 times as effective as plug 2 (S/N QL23).

The results in Table 3 show that position of the plugs did not significantly alter their effectiveness, as the captured mass was the same (within 1%) for individual plugs in different locations.

Two series of comparative tests were conducted:

In the first series, all plugs were mounted so that their magnets lay flush with the cylinder wall, so that flow near each plug was known to be similar.

In the second series, the quick disconnect plugs were tested in their retainers. Figure 2 shows that detectors B8784 and B8788 have been designed so that the magnetic heads are mounted some distance from the wall. The different depth of insertion was expected to alter the flow conditions because the flow velocity and particle concentration may vary at different distances from the wall. B8786 and B8788 were expected to experience flow restrictions due to the presence of an oil seal, which partly shrouded the collecting surface (See Fig 2).

3. RESULTS OF PARTICLE CAPTURE EFFICIENCY TESTS

The results of the first series of tests, are listed in Tables 4 - 9. Three tests were completed with all plugs, each plug being compared with CD102AC. The average values of the three tests are included in each table, along with an indication of the experimental scatter about the mean.

Tables 10 - 13 show the results for the new plugs tested in their own retainers. Again three tests were completed with all plugs.

The capture efficiency of each plug, expressed relative to the efficiency of CD102AC, is presented in Figure 4.

Photographs of captured sample debris on all plugs are presented in Figure 5.

4. DISCUSSION

Under the conditions of this series of tests, the quick release chip detector B8782 had an efficiency about 1.5 times that of the screw-in types (CD34E, CD100AC, CD102AC), both when it was flush mounted and when mounted in its retainer.

The quick release plug B8784 matched the efficiency of CD102AC when it was mounted in its retainer. It was less effective when flush mounted.

Plugs B8786 and B8788 are not as effective as the screw-in types.

It appears that the following factors effect capture efficiency:

i) magnetic field strength - the plugs with greater field strength tend to be more effective.

ii) magnet geometry - the broad flat capture surface of B8782 was very efficient.

iii) depth of insertion into the reservoir - B8784 performed markedly better when mounted in its retainer (capture surface 22 mm from the wall).

iv) presence of an oil seal - B8786 performance worsened when it was mounted in its retainer, with the oil seal shrouding its magnet. Performance of B8788 was little changed, but this may be because the improvement due to increased depth of insertion was cancelled by the degradation due to presence of an oil seal.

According to these test, the plugs may be ranked in the following order (best performance to worst performance)

B8782
CD346
CD100AC
CD102AC, B8784
B8786, B8788

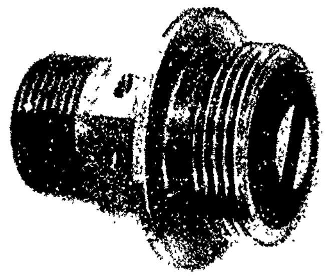
B8782 is a suitable replacement for the screw-in plugs.

B8784 may be used to replace CD102AC.

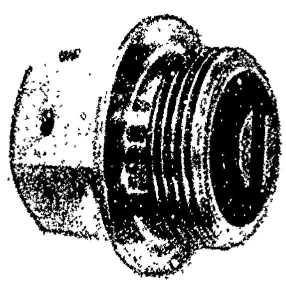
B8786 and B8788 have lower performance than detectors currently in use.

REFERENCES

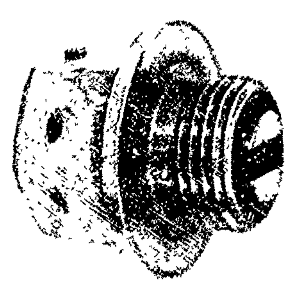
1. ATKINS, M.L.
Evaluation of Allison T56 Engine Magnetic Plug Efficiency. Letter Report. Aeronautical Research Laboratory, File C2/03.



CD 34E
SCREW IN
FLUSH MOUNTING
NO OIL SEAL
MAGNETIC FIELD 1.2K GAUSS

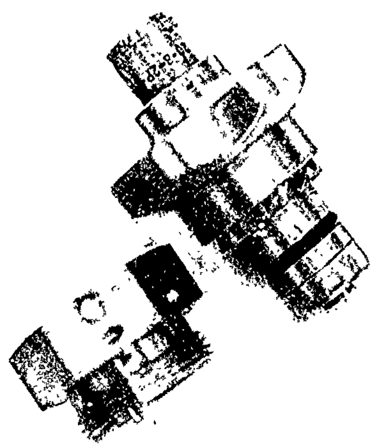


CD 100AC
SCREW IN
FLUSH MOUNTING
NO OIL SEAL
MAGNETIC FIELD 1.4K GAUSS

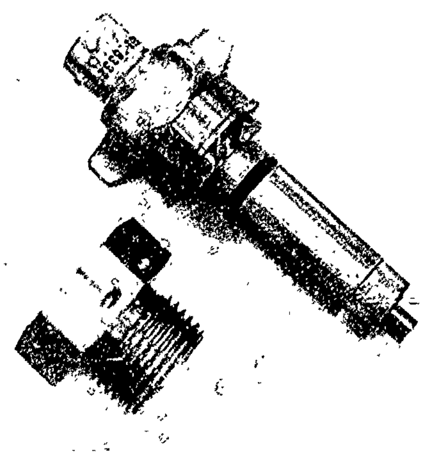


CD 102AC
SCREW IN
FLUSH MOUNTING
NO OIL SEAL
MAGNETIC FIELD 1.3K GAUSS

FIGURE 1

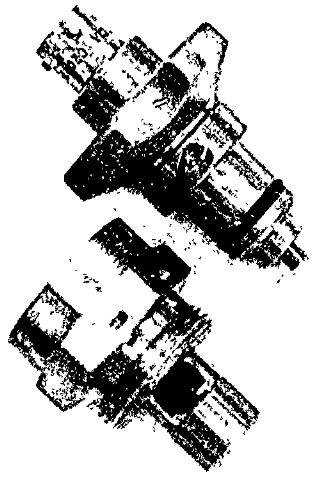


B8782
QUICK RELEASE
FLUSH MOUNTING
NO OIL SEAL
MAGNETIC FIELD 0.85K GAUSS

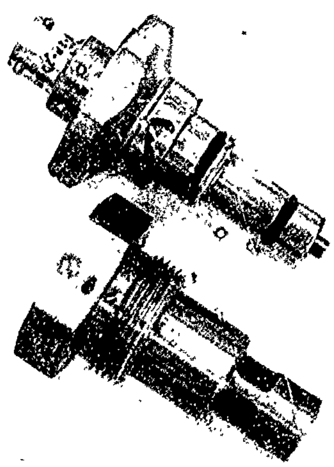


B8784
QUICK RELEASE
DEPTH OF INSERTION: 22mm
NO OIL SEAL
MAGNETIC FIELD 0.2K GAUSS

FIGURE 2



B8786
QUICK RELEASE
FLUSH MOUNTING
OIL SEAL
MAGNETIC FIELD 0.25K GAUSS



B8788
QUICK RELEASE
DEPTH OF INSERTION: 17mm
OIL SEAL
MAGNETIC FIELD 0.3K GAUSS

FIGURE 2 CONTINUED

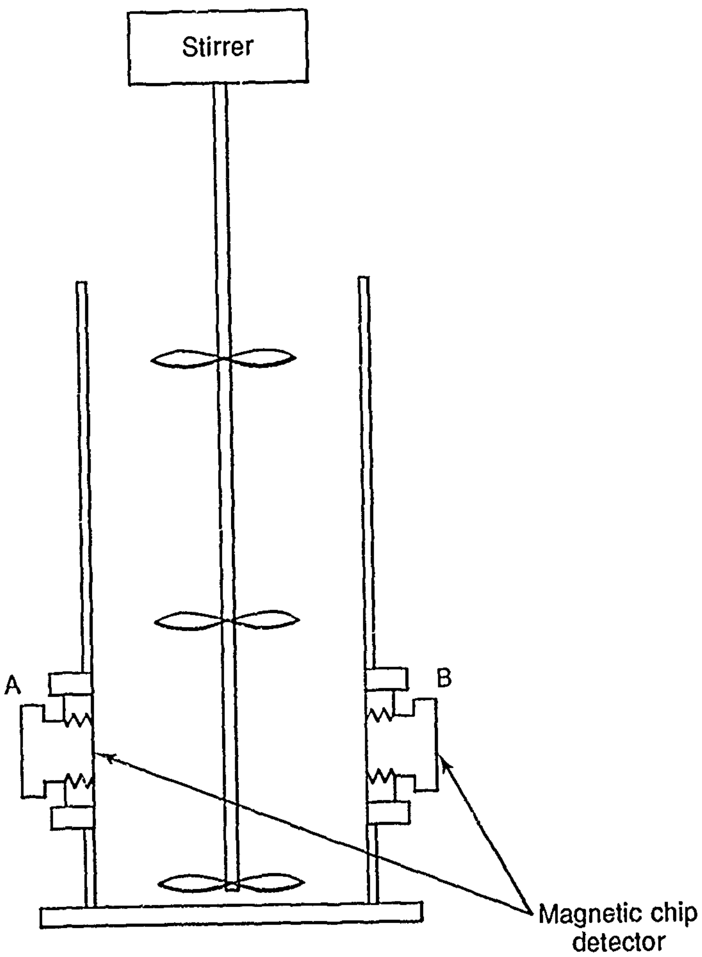


FIGURE 3 TEST RIG FOR COMPARING CHIP DETECTORS

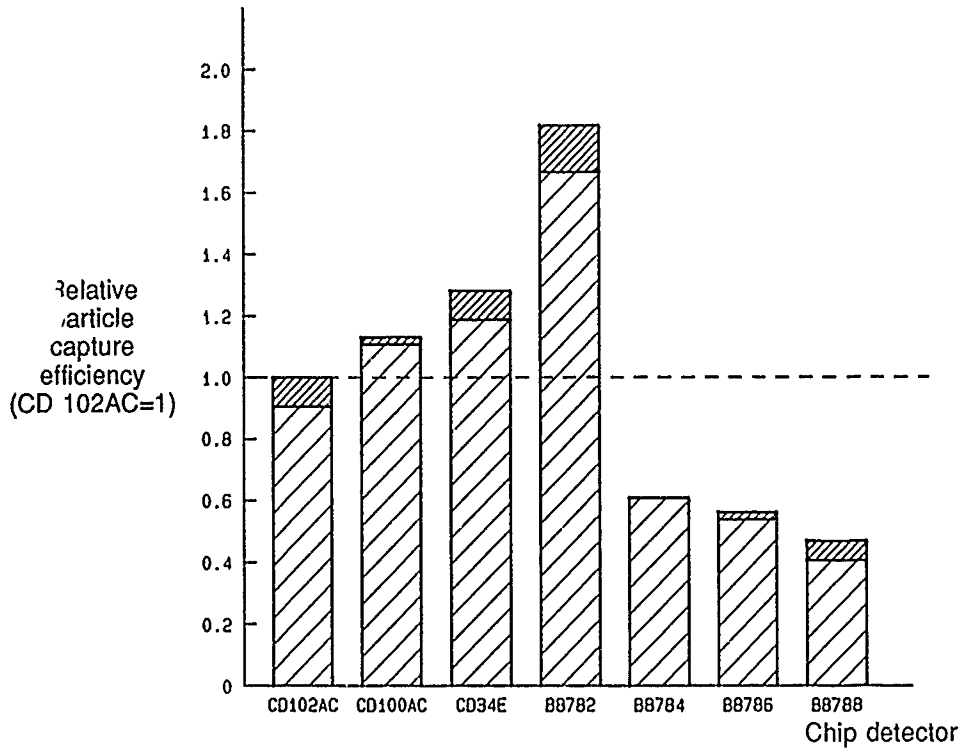


FIGURE 4(a) ALL DETECTORS FLUSH MOUNTED

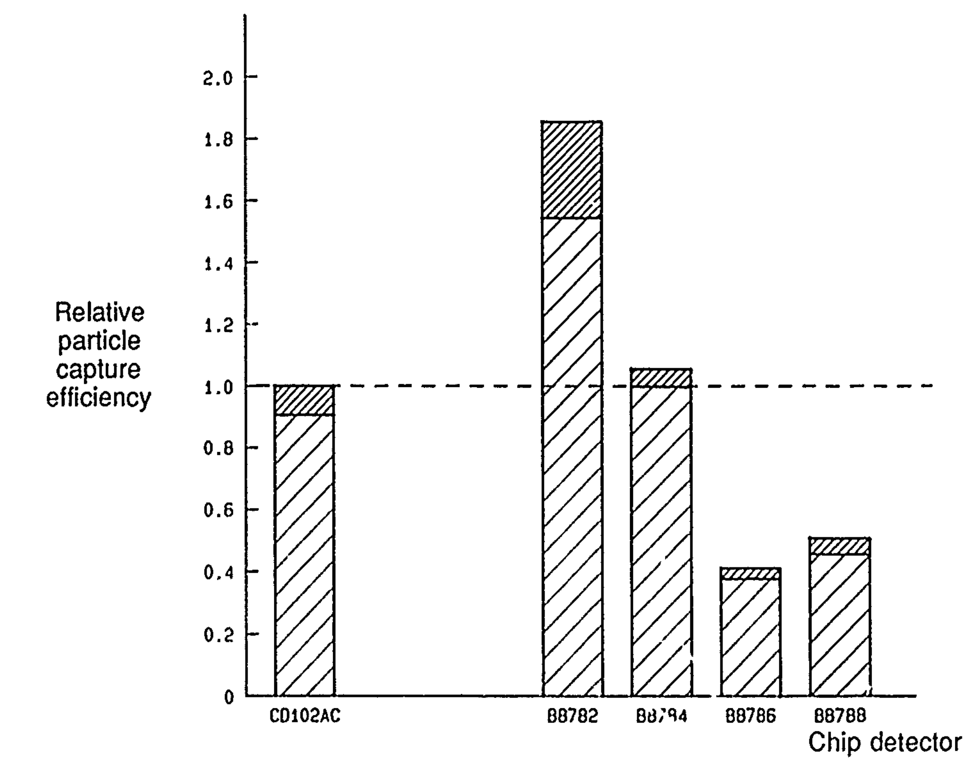
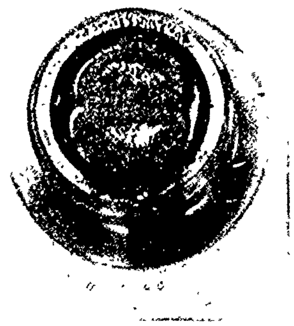
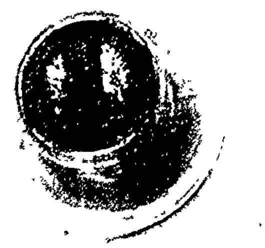


FIGURE 4(b) QUICK DISCONNECT DETECTORS MOUNTED IN THEIR RETAINERS

CD 34E



CD 100AC



CS 102AC

FIGURE 5 TYPICAL PARTICLE CAPTURES

B8782

B8784

FIGURE 5 CONTINUED

B8786

B8788

FIGURE 5 CONTINUED

TABLE 1

MAGNETIC FIELD STRENGTH

PLUG	FIELD STRENGTH
CD102 AC (S/N QM011)	1.3K
CD102 AC (S/N QL23)	1.23K
CD100 AC	1.4K
CD34E	1.2K
B8782	0.85K
B8784	0.2K
B8786	0.25K
B8788	0.30K

TABLE 2

Plug 1 CD102AC S/N QM011 Capture Mass (g)	Plug 2 CD203AC S/N QL23 Capture Mass (g)	Relative Efficiency Mass QM011 / Mass QL23
0.1147	0.1277	0.90
0.1286	0.1418	0.91
0.1172	0.1350	0.87
0.1251	0.1382	0.91
0.1153	0.1320	0.87
0.1164	0.1311	0.89
0.1196 ± 7.5%	0.1343 ± 5%	0.90

Plug 1 is consistently 0.9 times as effective as Plug 2

TABLE 3

a) Plug 1CD102AC (S/N QM011)

Capture Mass (g) Position A	Capture Mass (g) Position B
0.1147	0.1251
0.1286	0.1153
0.1172	0.1164
Av = 0.1202 ± 7%	Av = 0.1189 ± 5%

Relative efficiency $\frac{\text{Position A}}{\text{Position B}} = \frac{0.1202}{0.1189} = 1.01$

b) Plug 2CD102AC (S/N QL23)

Capture Mass (g) Position A	Capture Mass (g) Position B
0.1277	0.1382
0.1418	0.1320
0.1350	0.1311
0.1348 ± 5%	0.1338 ± 3.3%

Relative Efficiency $\frac{\text{Position A}}{\text{Position B}} = \frac{0.1348}{0.1338} = 1.01$

RELATIVE EFFICIENCIES (ALL PLUGS FLUSH MOUNTED)

TABLE 4

CD100AC vs CD102AC (S/N QL23)

Capture Mass (g) CD100AC	Capture Mass (g) CD102AC	Relative Efficiency Mass 100AC / Mass 102AC
0.1398	0.1231	1.14
0.1414	0.1310	1.08
0.1407	0.1286	1.01
0.1406 ± 1%	0.1276 ± 3%	1.10

TABLE 5

CD34E vs CD102AC (S/N QL23)

Capture Mass (g) CD34E	Capture Mass (g) CD102AC	Relative Efficiency Mass CD34E / Mass 102AC
0.1569	0.1260	1.25
0.1668	0.1438	1.16
0.1616	0.1336	1.21
0.1617 + 3%	0.1345 + 7%	1.21

TABLE 6

B8782 vs CD102AC (S/N QL23)

Capture Mass (g) B8782	Capture Mass (g) CD102AC	Relative Efficiency Mass B8782 / Mass 102AC
0.1803	0.1101	1.64
0.2093	0.1154	1.81
0.2060	0.1158	1.78
0.1985 ± 9%	0.1138 ± 3%	1.74

TABLE 7

B884 vs CD102AC (S/N QL23)

Capture Mass (g) B8784	Capture Mass (g) CD102AC	Relative Efficiency $\frac{\text{Mass B8784}}{\text{Mass CD102AC}}$
0.0815	0.1339	0.61
0.0854	0.1390	0.61
0.0840	0.1375	0.61
0.0836 ± 2.5%	0.1368 ± 2.5%	0.61

TABLE 8

B8786 vs CD102AC (S/N QL23)

Capture Mass (g) B8786	Capture Mass (g) CD102AC	Relative Efficiency $\frac{\text{Mass B8786}}{\text{Mass CD102AC}}$
0.0803	0.1460	0.55
0.0783	0.1483	0.53
0.0813	0.1504	0.54
0.0800 ± 2%	0.1482 ± 1.5%	0.54

TABLE 9

B8788 vs CD102AC (S/N QL23)

Capture Mass (g) B8788	Capture Mass (g) CD102AC	Relative Efficiency $\frac{\text{Mass B8788}}{\text{Mass CD102AC}}$
0.0592	0.1369	0.43
0.0529	0.1330	0.40
0.0626	0.1370	0.46
0.0582 ± 9%	0.1356 ± 2%	0.43

TABLE 10

Plug: B8782 Depth of Insertion: 0mm Flow Restriction: None	Capture Mass (g) B8782	Capture Mass (g) QL23	Efficiency Mass B8783 / Mass QL23
	0.1621	0.1045	1.55
	0.1774	0.0961	1.85
	0.1797	0.0983	1.83
	0.1731 ± 6%	0.0996 ± 5%	1.74

TABLE 11

Plug: B8784 Depth of Insertion: 22mm Flow Restriction: None	Capture Mass (g) B8784	Capture Mass (g) QL23	Efficiency Mass 8782 / Mass QL23
	0.1285	0.1285	1.0
	0.1327	0.1262	1.05
	0.1033	0.099	1.04
	0.1215 ± 15%	0.1179 ± 16%	1.03

TABLE 12

Plug: B8786 Depth of Insertion: 0mm Flow Restriction: Oil Seal	Capture Mass (g) B8786	Capture Mass (g) QL23	Efficiency Mass 87[illegible]6 / Mass QL23
	0.0409	0.0981	0.42
	0.0643	0.1661	0.39
	0.0512	0.1318	0.39
	0.0521 ± 20%	0.132 ± 25%	0.40

TABLE 13

Plug: B8788 Depth of Insertion: 17mm Flow Restriction: Oil Seal	Capture Mass (g) B8788	Capture Mass (g) QL23	Efficiency Mass 8788 / Mass QL23
	0.0646	0.1242	0.52
	0.0732	0.1645	0.44
	0.0552	0.1205	0.46
	0.0643 ± 15%	0.1364 ± 20%	0.47

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