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**SUMMARY OF  
WEAR METALS DATA  
FMC CORP./DRY VALLEY MINE**

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## I. INTRODUCTION

In June of 1993, FMC Corporations Dry Valley Mine began a field trial of FPC-1 Fuel Performance Catalyst. The trial was designed to determine the effect of the catalyst upon fuel consumption, smoke emissions, oil soot levels and subsequent wear metals reduction.

Fuel consumption testing was conducted first using the Carbon Mass Balance Technique with the equipment operating under steady-state engine conditions. Fuel consumption for the fleet tested was reduced on average by 10.7%. The following table shows the equipment tested and the percentage fuel consumption reduction for each individual piece of equipment:

<u>Unit</u>	<u>Type</u>	<u>Engine</u>	<u>RPM</u>	<u>%Change Fuel Consumption</u>
204	CAT785 Haul Truck	3512	1800	-9.93
202	CAT785 Haul Truck	3512	1800	-7.98
201	CAT785 Haul Truck	3512	1800	-14.15

Smoke density was also measured during the fuel consumption test using the Bacharach Smoke Spot Method. Again, under steady-state engine conditions, smoke density was reduced 16.3% after FPC-1 fuel treatment. This was consistent with the observations of technicians and operators who indicated that smoke was less dense and lighter colored after treatment with FPC-1.

## II. Oil Analysis Study

The oil analysis required a much longer period of time, and is still underway. However, data compiled between the mid-summer or late fall of 1992 and December of 1994 indicates a definite overall reduction in wear metals and therefore engine wear.

The oil analysis was extended to include the following pieces of equipment:

<u>Unit#</u>	<u>Unit Type/Engine</u>
101	P&H 2250 Shovel/CAT 3516
201	CAT 785 Haul Truck/3512
202	CAT 785 Haul Truck/3512
203	CAT 785 Haul Truck/3512
204	CAT 785 Haul Truck/3512
301	Cummins TD25G
303	CAT D10N
351	Dresser 970 RTD/VTA28C 1710 Cummins

The oil sample data provided begins in July 1992 and the analysis is being performed by Western States Caterpillar on samples drawn approximately every 250 hours of operation. The baseline oil sample data (untreated fuel) covers approximately 1,500 – 2,000 hours of equipment operation (7/92 – 6/93). The treated data covers a period of approximately 4,000 hours of equipment operation (7/93 – 12/94).

Prior oil analysis studies indicate soot and wear metals increase for a short period of time after initial FPC-1 treatment. Wear metals did appear to increase briefly in some equipment immediately after treatment but then began to trend lower and in most cases continued to trend lower (See Table 1).

Of particular note is the effect of FPC-1 upon the rate of engine wear. The rate of engine wear can be calculated from the relationship between total iron in the oil sample (parts per million iron) and the number of hours the engine operated on the oil change when the oil sample was taken. The simple calculation reveals a parts per million iron per hour of engine operation (Fe ppm/hr). Table 1 below summarizes the wear rate data in terms of iron wear per hour of operation, and calculates a percent change over the base fuel:

**Table 1: Average rate of Iron Wear/Hour  
(Fe ppm/hr)**

<u>Unit No.</u>	<u>Base Fuel</u>	<u>Treated Fuel 1</u>	<u>%Change</u>	<u>Treated Fuel 2</u>	<u>%Change</u>
101	.074	.058	-21.6	.057	-23.0
201	.107	.099	-7.5	.096	-10.3
202	.144	.100	-30.6	.094	-34.7
203	.105	.090	-14.3	.091	-13.3
204	.152	.097	-36.2	.095	-37.5
301	.082	.046	-43.9	.045	-45.1
303	.115	.101	-12.2	.101	-12.2
351	.076	.081	-6.6	.083	-9.2
<b>AVG.</b>	<b>.107</b>	<b>.084</b>	<b>-21.5%</b>	<b>.083</b>	<b>-22.4%</b>

- Notes:
- (1) Average of all data collected after FPC-1 treatment occurred in 6/93.
  - (2) Same as (1) except first approximately 500 hours of operation after treatment excluded as this is considered carbon cleanup period.

Oil analysis studies conducted earlier reveal FPC-1 generally reduces soot mass in the motor oil over the same oil change interval, and also soot particle size. The reduced mass and particle size would reduce abrasion and slow viscosity change. Although soot levels generally did not decrease in this case, soot particle size evidently did as evidenced by the significant reduction in iron wear metal levels. The fact that soot levels did not materially change may be due to the fact that this equipment, in most cases, was a new fleet (approx. 2000 hours of equipment operation) at the commencement of this test. Soot levels in 5 of the 8 pieces of equipment appeared to be trending upward at the beginning of the test and may well have reached higher levels still without treatment with FPC-1.

A similar comparison was made on copper (Cu) wear metal levels. The data appears to be less consistent than the iron wear metals and there were several major “spikes” that occurred in several pieces of equipment both before and after treatment with FPC-1 (See data summary tables in Appendices). These spikes were removed from the averages for a more valid comparison. The data in Table 2 below makes this comparison:

**Table 2: Average Rate of Copper Wear/Hour  
(CU ppm/hr)\**

<u>Unit No.</u>	<u>Base Fuel</u>	<u>Treated Fuel(1)</u>	<u>%Change</u>	<u>Treated Fuel(2)</u>	<u>%Change</u>
101	.031	.018	-41.9	.017	-45.2
201	.130	.065	-50.0	.063	-51.5
202	.027	.018	-33.3	.017	-37.0
203	.063	.047	-25.4	.047	-25.4
204	(3)	.039	(3)	.039	(3)
301	.009	.005	-44.4	.005	-44.4
303	.007	.012	71.4	.012	71.4
351	.024	.022	-8.3	.020	-16.7
<b>Avg.</b>	<b>.042</b>	<b>.028</b>	<b>-40.5%</b>	<b>.028</b>	<b>-40.5%</b>

- Notes:
- (1) Average of all data collected after FPC-1 treatment occurred in 6/93.
  - (2) Same as (1) except first 500 hours of operation after treatment excluded as this is normal carbon cleanup period.
  - (3) Too few data points for baseline so valid comparison could not be made.

### **III. CONCLUSION**

The FMC Corporation Dry Valley Mine data generated to-date demonstrates a significant reduction in engine wear as evidenced by reductions in both iron (Fe) and copper (Cu) wear metal levels. Iron levels have been reduced up to 22.4% and copper levels have been reduced up to 40.5% (See attached data).

Unit #101 - FMC Dry Valley								
Oil Analysis Data								
CAT 3516 (P&H 2250)								
Engine Hours:								
7/30/92	203							
11/7/94	5691							
Sample	Hours on	Soot	Soot	Iron	Iron	Copper	Copper	
Date	Oil	% Allow	%/hour	ppm	ppm/hr	ppm	ppm/hr	Oil Report Comments
7/30/92	203	27	0.133	19	0.094	26	0.128	
8/27/92	115	23	0.200	8	0.070	5	0.043	
9/25/92	295	79	0.268	23	0.078	17	0.058	
12/10/92	248	54	0.218	16	0.065	6	0.024	
1/21/93	241	53	0.220	15	0.062	6	0.025	
3/11/93	263	52	0.198	21	0.080	4	0.015	
6/21/93	228	58	0.254	15	0.066	5	0.022	
<b>Baseline Ave.</b>			<b>0.213</b>	<b>17</b>	<b>0.074</b>	<b>10</b>	<b>0.031</b>	
8/19/93	273			17	0.062	7	0.026	
9/15/93	224			14	0.063	5	0.022	
10/21/93	276	83	0.301	14	0.051	4	0.014	
11/11/93	202	80	0.396	13	0.064	4	0.020	
12/3/93	281	58	0.206	12	0.043	3	0.011	
1/3/94	236	72	0.305	14	0.059	4	0.017	
1/25/94	293	65	0.222	12	0.041	4	0.014	
2/22/94	248	68	0.274	14	0.056	4	0.016	
3/17/94	251	66	0.263	12	0.048	4	0.016	
4/8/94	164	32	0.195	9	0.055	3	0.018	
5/2/94	259	69	0.266	13	0.050	5	0.019	
7/7/94	318	99	0.311	21	0.066	5	0.016	
8/15/94	232	87	0.375	19	0.082	5	0.022	
11/7/94	257	80	0.311	17	0.066	4	0.016	





Unit #201 - FMC Dry Valley								
Oil Analysis Data								
CAT 785 Haul Truck								
Engine Hours:								
7/30/9	216							
9/8/94	5584							
Sample	Hours on	Soot	Soot	Iron	Iron	Copper	Copper	
Date	Oil	% Allow	%/hour	ppm	ppm/hr	ppm	ppm/hr	Oil Report Comments
7/30/92	216	90	0.417	28	0.130	185	0.856	High Copper
9/29/92	310	93	0.300	35	0.113	48	0.155	
11/18/92	219			26	0.119	13	0.059	
1/11/93	245	87	0.355	23	0.094	39	0.159	
3/15/93	227	102	0.449	22	0.097	114	0.502	High Copper
5/4/93	266	108	0.406	26	0.098	55	0.207	
6/21/93	261	126	0.483	26	0.100	18	0.069	
Baseline Ave.			0.402		0.107		0.130	
8/10/93	282			38	0.135	22	0.078	Trace of water or condensation
9/8/93	250			28	0.112	23	0.092	
10/3/93	235	107	0.455	20	0.085	11	0.047	
11/2/93	251	111	0.442	27	0.108	27	0.108	
12/3/93	238	97	0.408	34	0.143	77	0.324	High Copper
12/21/93	224	90	0.402	19	0.085	29	0.129	
1/20/94	286	96	0.336	21	0.073	13	0.045	
2/14/94	251	85	0.339	26	0.104	8	0.032	
3/11/94	240	102	0.425	19	0.079	7	0.029	
3/31/94	209	75	0.359	21	0.100	6	0.029	
4/25/94	210	114	0.543	17	0.081	5	0.024	
5/12/94	250	103	0.412	25	0.100	9	0.036	
6/6/94	246	120	0.488	24	0.098	10	0.041	
7/6/94	222	97	0.437	23	0.104	7	0.032	
8/3/94	237	114	0.481	22	0.093	4	0.017	High sodium, water, and glycol
8/15/94	50	19	0.380	8	0.160	10	0.500	Very low hours on oil sample

9/8/94	258	109	0.422	27	0.105	16	0.062		
10/14/94	296	101	0.341	22	0.074	6	0.020		
11/18/94	289	101	0.349	29	0.100	6	0.021		
<b>FPC-1 Treated Ave.</b>			<b>0.415</b>		<b>0.099</b>		<b>0.065</b>		
<b>Percent Change</b>			<b>3.2%</b>		<b>-7.5%</b>		<b>-50.0%</b>		
<b>*Percent Change</b>					<b>-10.3%</b>		<b>-51.5%</b>		
<b>* Change if first two samples after FPC-1 treatment are removed.</b>									
<i>Data deleted due to abnormalities!</i>									

Unit #202 - FMC Dry Valley								
Oil Analysis Data								
CAT 785 Haul Truck								
Engine Hours:								
8/19/92	250							
11/8/94	6206							
Sample	Hours on	Soot	Soot	Iron	Iron	Copper	Copper	
Date	Oil	% Allow	%/hour	ppm	ppm/hr	ppm	ppm/hr	Oil Report Comments
8/19/92	250	134	0.536	35	0.140	163	0.652	High Copper
10/14/92	249	129	0.518	34	0.137	44	0.177	High Copper
11/30/92	245	118	0.482	26	0.106	8	0.033	
1/28/93	247	132	0.534	29	0.117	6	0.024	
3/24/93	249	133	0.534	32	0.128	4	0.016	
5/24/93	265			39	0.147	5	0.019	
6/7/93	73	80	1.096	17	0.233	3	0.041	
Baseline Ave.			0.617		0.144		0.027	
7/6/93	221	150	0.679	33	0.149	6	0.027	
8/19/93	264			33	0.125	5	0.019	
9/13/93	250			33	0.132	7	0.028	
10/9/93	271			24	0.089	5	0.018	
11/29/93	248	142	0.573	26	0.105	3	0.012	
12/27/93	252	137	0.544	28	0.111	5	0.020	
1/24/94	270	129	0.478	23	0.085	4	0.015	
2/16/94	255	136	0.533	27	0.106	4	0.016	
3/10/94	219	129	0.589	20	0.091	4	0.018	
4/5/94	234			25	0.107	4	0.017	
5/17/94	262	140	0.534	22	0.084	4	0.015	
6/6/94	208	133	0.639	19	0.091	5	0.024	
8/3/94	239	143	0.598	20	0.084	3	0.013	
8/25/94	234	149	0.637	17	0.073	3	0.013	
10/2/94	226	132	0.584	20	0.088	3	0.013	

11/8/94	339	145	0.428	25	0.074	4	0.012		
<b>FPC-1 Treated Ave.</b>			<b>0.558</b>		<b>0.100</b>		<b>0.018</b>		
<b>Percent Change</b>			<b>-9.6%</b>		<b>-30.6%</b>		<b>-33.3%</b>		
<b>* Percent Change</b>					<b>-34.7%</b>		<b>-37.0%</b>		
<b>* Change if first two samples after FPC-1 treatment are removed.</b>									
<i>Data deleted due to abnormalities!</i>									

Unit #203 - FMC Dry Valley								
Oil Analysis Data								
CAT 785 Haul Truck								
Engine Hours:								
11/4/92	583							
8/18/94	5286							
Sample	Hours on	Soot	Soot	Iron	Iron	Copper	Copper	
Date	Oil	% Allow	%/hour	ppm	ppm/hr	ppm	ppm/hr	Oil Report Comments
11/4/92	333			26	0.078	52	0.156	
12/17/92	219	60	0.274	28	0.128	18	0.082	
2/11/93	274	86	0.314	25	0.091	9	0.033	
3/25/93	214	77	0.360	19	0.089	5	0.023	
5/31/93	248	149	0.601	44	0.177	556	2.242	High Copper Only
6/1/93	250			16	0.064	5	0.020	
Baseline Ave.			0.387		0.105		0.063	
7/6/93	235	84	0.357	26	0.111	12	0.051	
8/26/93	329			20	0.061	12	0.036	Water dilution
9/16/93	200			2	0.010	1	0.005	
10/21/93	258	118	0.457	32	0.124	260	1.008	High Copper Only
11/11/93	200	105	0.525	44	0.220	77	0.385	Water Dilution
12/13/93	294	78	0.265	25	0.085	17	0.058	
1/4/94	254	91	0.358	24	0.094	9	0.035	
1/27/94	242	75	0.310	20	0.083	5	0.021	
2/19/94	250	95	0.380	22	0.088	7	0.028	
3/14/94	239	103	0.431	21	0.088	7	0.029	
4/6/94	214			22	0.103	8	0.037	
5/2/94	275	108	0.393	24	0.087	14	0.051	
5/25/94	248	110	0.444	17	0.069	56	0.226	High Copper
6/21/94	244	118	0.484	26	0.107	266	1.090	High Copper
7/28/94	266	110	0.414	20	0.075	149	0.560	High Copper
8/18/94	234	100	0.427	12	0.051	39	0.167	



Unit #204 - FMC Dry Valley								
Oil Analysis Data								
CAT 785 Haul Truck								
Engine Hours:								
8/5/92	236							
11/28/94	6110							
Sample	Hours on	Soot	Soot	Iron	Iron	Copper	Copper	
Date	Oil	% Allow	%/hour	ppm	ppm/hr	ppm	ppm/hr	Oil Report Comments
8/5/92	236	46	0.195	41	0.174	165	0.699	Normal for engine break-in
10/4/92	244	131	0.537	36	0.148	54	0.221	Normal for engine break-in
11/18/92	228			46	0.202	252	1.105	High Copper
1/26/93	254	108	0.425	32	0.126	130	0.512	High Copper
6/26/93	250	144	0.576	27	0.108	10	0.040	
<b>Baseline Ave.</b>			<b>0.433</b>		<b>0.152</b>		<b>??</b>	
8/30/93	300			29	0.097	12	0.040	
9/13/93	206			25	0.121	7	0.034	
10/21/93	249	136	0.546	24	0.096	5	0.020	
11/11/93	220	121	0.550	24	0.109	19	0.086	
12/9/93	310	118	0.381	30	0.097	12	0.039	
1/5/94	225	114	0.507	22	0.098	7	0.031	
1/26/94	250	96	0.384	18	0.072	5	0.020	
2/23/94	302	102	0.338	16	0.053	5	0.017	
4/12/94	150	96	0.640	133	0.887	218	1.453	High Copper, Iron, Silicon
4/20/94	106	81	0.764	33	0.311	53	0.500	Sodium, Copper elevated
5/5/94	154	117	0.760	24	0.156	19	0.123	Traces of sodium, glycol
5/12/94	83	82	0.988	14	0.169	9	0.108	
5/31/94	215	133	0.619	31	0.144	29	0.135	Traces of glycol, sodium, copper
6/23/94	209	126	0.603	24	0.115	95	0.455	Sodium, copper elevated
8/3/94	179	63	0.352	11	0.061	27	0.151	
8/9/94	66	101	1.530	19	0.288	37	0.561	
9/6/94	204	114	0.559	18	0.088	8	0.039	

9/27/94	250	116	0.464	20	0.080	6	0.024			
10/25/94	272	114	0.419	25	0.092	5	0.018			
11/28/94	280	107	0.382	19	0.068	4	0.014			
<b>FPC-1 Treated Ave.</b>			<b>0.490</b>		<b>0.097</b>		<b>0.039</b>			
<b>Percent Change</b>			<b>13.2%</b>		<b>-36.2%</b>					
<b>* Percent Change</b>					<b>-37.5%</b>					
<b>* Change if first two samples after FPC-1 treatment are removed.</b>										
<i>Data deleted due to abnormalities!</i>										



Unit #301 - FMC Dry Valley								
Oil Analysis Data								
Cummins TD25G								
Engine Hours:								
10/21/92	372							
11/21/94	4010							
Sample Date	Hours on Oil	Soot % Allow	Soot %/hour	Iron ppm	Iron ppm/hr	Copper ppm	Copper ppm/hr	Oil Report Comments
10/21/92	184	75	0.408	22	0.120	1	0.005	
3/2/93	232	19	0.082	17	0.073	3	0.013	
5/4/93	258	46	0.178	14	0.054	2	0.008	
<b>Baseline Ave.</b>			<b>0.223</b>		<b>0.082</b>		<b>0.009</b>	
7/22/93	260			19	0.073	2	0.008	
8/25/93	222			8	0.036	1	0.004	
10/7/93	276	65	0.236	14	0.051	1	0.004	
11/1/93	227	29	0.128	8	0.035	1	0.004	
12/13/93	256	42	0.164	17	0.066	1	0.004	
1/4/94	233	34	0.146	10	0.043	1	0.004	
2/1/94	256	37	0.145	12	0.047	1	0.004	
3/11/94	197	9	0.046	7	0.036	1	0.005	
4/5/94	232			10	0.043	1	0.004	
4/25/94	127	26	0.205	6	0.047	1	0.008	
5/23/94	225	39	0.173	6	0.027	1	0.004	
7/6/94	240	33	0.138	13	0.054	1	0.004	
8/4/94	236	37	0.157	9	0.038	1	0.004	
10/10/94	249	50	0.201	14	0.056	2	0.008	
11/21/94	236	24	0.102	9	0.038	1	0.004	
<b>FPC-1 Treated Ave.</b>			<b>0.153</b>		<b>0.046</b>		<b>0.005</b>	
<b>Percent Change</b>			<b>-31.4%</b>		<b>-43.9%</b>		<b>-44.4%</b>	

					-45.1%			-44.4%	
	* Percent Change								
	* Change if first two samples after FPC-1 treatment are removed.								

Unit #303 - FMC Dry Valley								
Oil Analysis Data								
CAT D10N								
Engine Hours:								
10/8/92	3760							
10/24/94	9396							
Sample Date	Hours on Oil	Soot % Allow	Soot %/hour	Iron ppm	Iron ppm/hr	Copper ppm	Copper ppm/hr	Oil Report Comments
10/8/92	297	70	0.236	45	0.152	3	0.010	
12/3/92	298	60	0.201	39	0.131	2	0.007	
1/18/93	181	71	0.392	21	0.116	1	0.006	
3/8/93	256	38	0.148	26	0.102	2	0.008	
4/26/93	230	43	0.187	22	0.096	1	0.004	
6/9/93	245	51	0.208	22	0.090	2	0.008	
Baseline Ave.			0.229		0.115		0.007	
7/26/93	290			34	0.117	4	0.014	
9/1/93	231			20	0.087	2	0.009	
10/11/93	357			25	0.070	3	0.008	
10/25/93	268	73	0.272	22	0.082	3	0.011	
11/17/93	254	28	0.110	18	0.071	2	0.008	
12/16/93	230	56	0.243	27	0.117	3	0.013	
1/31/94	248	43	0.173	16	0.065	2	0.008	
2/28/94	186	33	0.177	24	0.129	2	0.011	
3/30/94	223	45	0.202	24	0.108	3	0.013	
4/25/94	249	63	0.253	24	0.096	4	0.016	
5/13/94	237	54	0.228	29	0.122	5	0.021	
5/31/94	222	50	0.225	20	0.090	4	0.018	
6/30/94	247	73	0.296	36	0.146	7	0.028	
8/30/94	277	58	0.209	25	0.090	5	0.018	
9/26/94	260	64	0.246	33	0.127	4	0.015	
10/24/94	266	51	0.192	28	0.105	4	0.015	

<b>FPC-1 Treated Ave.</b>		<b>0.217</b>		<b>0.101</b>		<b>0.012</b>			
<b>Percent Change</b>		<b>-5.2%</b>		<b>-12.2%</b>		<b>71.4%</b>			
<b>* Percent Change</b>				<b>-10.1%</b>		<b>71.4%</b>			
<b>* Change if first two samples after FPC-1 treatment are removed.</b>									

Unit #351 - FMC Dry Valley								
Oil Analysis Data								
Dresser 970								
Engine Hours:								
9/18/92	536							
11/9/94	5023							
Sample Date	Hours on Oil	Soot % Allow	Soot %/hour	Iron ppm	Iron ppm/hr	Copper ppm	Copper ppm/hr	Oil Report Comments
9/18/92	??	183		36		50		
10/7/92	105	131	1.248	18	0.171	17	0.162	
11/24/92	147			11	0.075	5	0.034	
1/19/93	219	167	0.763	18	0.082	6	0.027	
3/22/93	229	129	0.563	19	0.083	4	0.017	
6/16/93	268	158	0.590	17	0.063	5	0.019	
Baseline Ave.			0.639		0.076		0.024	
8/9/93	215			10	0.047	8	0.037	
9/13/93	251			23	0.092	9	0.036	
10/21/93	200	133	0.665	15	0.075	4	0.020	
11/11/93	240	151	0.629	16	0.067	4	0.017	
12/13/93	230	163	0.709	23	0.100	5	0.022	
1/14/94	300	180	0.600	23	0.077	4	0.013	
2/18/94	248	155	0.625	16	0.065	3	0.012	
3/24/94	185	175	0.946	21	0.114	4	0.022	
4/14/94	164	113	0.689	12	0.073	3	0.018	
5/6/94	190	145	0.763	21	0.111	4	0.021	
6/2/94	250	147	0.588	20	0.080	4	0.016	
6/27/94	239	148	0.619	15	0.063	5	0.021	
8/5/94	232	138	0.595	16	0.069	5	0.022	
8/30/94	242	165	0.682	21	0.087	7	0.029	
9/29/94	250	151	0.604	20	0.080	6	0.024	
11/9/94	284	167	0.588	27	0.095	7	0.025	

<b>FPC-1 Treated Ave.</b>		<b>0.664</b>		<b>0.081</b>		<b>0.022</b>			
<b>Percent Change</b>		<b>3.9%</b>		<b>6.6%</b>		<b>-8.3%</b>			
<b>* Percent Change</b>				<b>9.2%</b>		<b>-16.7%</b>			
<b>* Change if first two samples after FPC-1 treatment are removed.</b>									
<i>Data deleted due to abnormalities or missing information!</i>									