



MATERIAL TECHNOLOGIES & SCIENCES INCORPORATED

March 10, 2000

Mr. Richard A. Steinke
Chairman
American Tire Corporation
705 Yucca Street
Boulder City, Nevada 89005

Dear Mr. Steinke,

The enclosed report contain the physical properties as generated through ASTM test methods and modified ASTM test methods as requested.

The tests were performed by the ASTM methods as outlined, and represent those results that the tests yielded. In the case of the Compressive Strength Tests, modifications to the test were necessary to insure unbiased results.

The test results in this report were developed through static tests from samples that were prepared, ie. cut to size, stacked etc to meet the criteria of the test methods. These samples were furnished by American Tire Corp and were locally purchased.

Every precaution was taken to ensure the accuracy of the tests conducted and the accuracy of this report itself. The information however is provided subject to the condition that Materials Technologies & Sciences Inc. will not be liable for any loss or damage resulting from the use of the data generated.

While the information contained herein is presented in good faith and believed to be accurate it is provided as guidance only. Because many factors affect processing or application/use, it is recommended that these test serve as a guideline.

Vincent F. Panaroni
Vice President
Urethanes



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COMPARATIVE PROPERTIES OF POLYURETHANE MICROCELLULAR BICYCLE TIRES AND RUBBER BICYCLE TIRES

This report has been generated to disclose the comparative physical properties of conventional bicycle tire rubber compounds and microcellular polyurethane (MCP) bicycle tire compounds.

The tests have been requested to determine the physical properties of typical rubber tire compounds and the MCP polyurethane bicycle tire compounds.

The tests selected to be conducted are as follows:

1. Abrasion Test. ASTM D-1044 H-22 Wheel 1000GrWt-1000 Cycles (mg wt loss)
2. Compression Set ASTM- D395 Method B 22 hours @158oF @25% compression
3. Ozone Resistance ASTM-D-1149
4. Tear Resistance (a) Split Tear ASTM D-3574
(b) Die C ASTM D-624
5. Compressive Strength ASTM D-575-91 (Modified)
@ Tires Rated:
50 PSI
55 PSI
60 PSI

The above tests illustrates some of the typical conditions that tires are subjected to in normal usage as they relate to their physical properties. For example;

The abrasion tests illustrates a panic or sudden stop made during the use of the bicycle. It is also an indicator of the wear life of the tire.

The compression set tests illustrates the ability of tires to maintain their required conformation under prolonged storage (Over winter in some regions) for example, nor does the tire, after extended use (Where heat is generated due to frictional force) cause irregularities such as flat spots in the tires.



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Ozone Resistance illustrates the breakdown of compounds due to exposure to elements such as sun, snow, rain etc.

Tear resistance is a generally accepted test as to the strength of compounds. The tearing action utilized in the tests can be illustrated as to irregularities on a road or pavement during normal riding where the tire may slip into a crack or slide off the side of the sidewalk, and the rider turns somewhat violently to avoid falling which could cause ripping or tearing at the tire side walls. The tearing action also is noteworthy in "Off Road" riding where thorns, broken glass, sharp stones, and debris could cause rips in the tire.

Compressive strength for as it applies to these tests indicates the amount of force required to deflect the tire a predetermined distance of 75% of the original height of the tested tire which yields the tire unsafe and unroadworthy. This test will indicate the ability of the tire to hold and maintain certain weights without deflecting the tire into an unusable condition. For example if a 50 psi tire is utilized, the tire should resist 75% of original height deflection by yielding a higher compressive number.

In many instances laboratory testing is frequently not as accurate a guide as to the performance of the product being tested. It has been noted and reported that in many instances laboratory tests showed a particular product to be equal or slightly better and when put into actual field conditions the product proved several times better and in other instances several times worse.

The tests have been conducted utilizing the following products submitted:

1. MCP tire rated 50 psi 26 inch
2. MCP tire rated 55 psi 26 inch
3. MCP tire rated 60 psi 26 inch
4. Rubber #1 air tire and tube 26 inch inflated @
 - a. 50 psi
 - b. 55 psi
 - c. 60 psi
5. Rubber #2 air tire and tube 26 inch inflated @
 - a. 50 psi
 - b. 55 psi
 - c. 60 psi



TEST RESULTS

ABRASION RESISTANCE

ASTM D-1044

H-22 WHEEL

1,000 GRAM WEIGHT, 1,000 CYCLES

MILLIGRAMS WEIGHT LOSS

| | | | | | | | | | | | | |
|----------------|--------|----|----|----|----|----|----|-----|----|-----|----|------|
| Rubber Tire #1 | Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | avg |
| Mg. Wt. Loss | | 78 | 75 | 75 | 79 | 83 | 88 | 79 | 81 | 83 | 85 | 80.6 |
| Rubber Tire #2 | Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | avg |
| Mg. Wt. Loss | | 93 | 97 | 97 | 93 | 99 | 91 | 105 | 95 | 101 | 97 | 96.8 |
| MCP 50 | Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | avg |
| Mg. Wt. Loss | | 22 | 24 | 28 | 20 | 21 | 25 | 23 | 23 | 25 | 24 | 21.4 |
| MCP 55 | Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | avg |
| Mg. Wt. Loss | | 25 | 23 | 24 | 26 | 29 | 25 | 26 | 24 | 27 | 22 | 25.1 |
| MCP 60 | Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | avg |
| Mg. Wt. Loss | | 25 | 27 | 22 | 23 | 28 | 27 | 25 | 23 | 29 | 29 | 25.8 |

The abrasion tests conclude that the average of the three (3) MCP compound tires as furnished show abrasion resistance superior to the locally purchased Rubber compound tires by a factor of 3.86 : 1.



TEST RESULTS

COMPRESSION SET
ASTM D-395
METHOD B
22 HOURS @158oF
@ 25% DEFLECTION

| | | | | | | | | | | | | |
|----------------|--------|----|----|----|----|----|----|----|----|----|----|------|
| Rubber Tire #1 | Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | avg |
| Deflection % | | 60 | 68 | 66 | 69 | 59 | 65 | 68 | 73 | 66 | 67 | 66.1 |
| Rubber Tire #2 | Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | avg |
| Deflection % | | 66 | 67 | 73 | 69 | 63 | 66 | 68 | 71 | 62 | 67 | 67.2 |
| MCP 50 | Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | avg |
| Deflection % | | 17 | 20 | 17 | 22 | 23 | 23 | 24 | 23 | 26 | 20 | 21.5 |
| MCP 55 | Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | avg |
| Deflection % | | 19 | 21 | 17 | 23 | 23 | 21 | 26 | 28 | 21 | 23 | 22.2 |
| MCP 60 | Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | avg |
| Deflection % | | 25 | 21 | 23 | 22 | 22 | 27 | 19 | 24 | 23 | 24 | 23.0 |

The Compression Set test conclude that the average of the three (3) MCP compound tires as furnished show Compression Set resistance superior to the locally purchased Rubber compound tires by a factor of 2.99 : 1.

The recovery from a compression mode as tested can be related to long term storage, excessive temperature variations while in a stagnant position such as a storage shed or garage in the sun belt.

The Rubber tire compounds although higher in compression set values are consistent with each other even though manufactured by different bicycle tire companies.



TEST RESULTS
ASTM D-3574
TEAR SPLIT (PLI)
(POUNDS PER LINEAR FOOT)

| | | | | | | | | | | | | |
|----------------|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------|
| Rubber Tire #1 | Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | avg |
| (PLI) | | 180 | 177 | 168 | 172 | 178 | 181 | 169 | 172 | 173 | 170 | 174 |
| Rubber Tire#2 | Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | avg |
| (PLI) | | 153 | 165 | 152 | 159 | 163 | 162 | 155 | 161 | 158 | 160 | 158.8 |
| MCP 50 | Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | avg |
| (PLI) | | 179 | 185 | 188 | 179 | 180 | 182 | 188 | 185 | 189 | 188 | 184.3 |
| MCP 55 | Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | avg |
| (PLI) | | 185 | 188 | 195 | 192 | 189 | 187 | 191 | 190 | 186 | 197 | 190.0 |
| MCP 60 | Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | avg |
| (PLI) | | 195 | 192 | 190 | 201 | 198 | 195 | 189 | 187 | 198 | 195 | 194.0 |

The Split Tear test results indicate that the average of the three (3) MCP compound tires as furnished show a slightly higher resistance to tearing via the split tear route than the locally purchased Rubber compound tires by a factor of 1.15 : 1.



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TEST RESULTS ASTM D-624 DIE C TEAR (PLI) (POUNDS PER LINEAR INCH)

| | | | | | | | | | | | | |
|---------------|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------|
| Rubber Tire#1 | Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | avg |
| (PLI) | | 557 | 560 | 554 | 556 | 563 | 551 | 556 | 551 | 553 | 556 | 555.7 |

| | | | | | | | | | | | | |
|---------------|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------|
| Rubber Tire#2 | Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | avg |
| (PLI) | | 553 | 556 | 570 | 571 | 565 | 551 | 550 | 567 | 555 | 561 | 559.9 |

| | | | | | | | | | | | | |
|--------|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------|
| MCP 50 | Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | avg |
| (PLI) | | 610 | 590 | 601 | 593 | 595 | 608 | 599 | 598 | 597 | 609 | 600.0 |

| | | | | | | | | | | | | |
|--------|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------|
| MCP 55 | Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | avg |
| (PLI) | | 612 | 615 | 601 | 599 | 595 | 608 | 605 | 611 | 599 | 599 | 604.4 |

| | | | | | | | | | | | | |
|--------|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------|
| MCP 60 | Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | avg |
| (PLI) | | 601 | 606 | 621 | 595 | 617 | 612 | 618 | 603 | 601 | 611 | 608.5 |

The Die C Tear Test results indicate that the average of the three (3) MCP compound tires as furnished show a slightly higher resistance to tearing via the Die C route than the locally purchased Rubber compounds by a factor of 1.083 : 1.



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TEST RESULTS ASTM D-1149 OZONE RESISTANCE

| | | | | | | |
|----------------------------------|--------|------|------|------|------|------|
| Rubber Tire #1 | Sample | 1 | 2 | 3 | 4 | 5 |
| Initial Cracking, Exposure Hours | | 3 | 2 | 7 | 5 | 2 |
| General Cracking, Exposure Hours | | 5 | 5 | 9 | 7 | 5 |
| Total Exposure, Hours | | 5 | 5 | 9 | 7 | 5 |
| Rubber Tire #2 | Sample | 1 | 2 | 3 | 4 | 5 |
| Initial Cracking, Exposure Hours | | 17 | 15 | 19 | 16 | 15 |
| General Cracking, Exposure Hours | | 88 | 85 | 91 | 87 | 85 |
| Total Exposure, Hours | | 88 | 85 | 91 | 87 | 85 |
| MCP 50 | Sample | 1 | 2 | 3 | 4 | 5 |
| Initial Cracking, Exposure Hours | | NONE | NONE | NONE | NONE | NONE |
| General Cracking, Exposure Hours | | NONE | NONE | NONE | NONE | NONE |
| Total Exposure, Hours | | 144 | 144 | 144 | 144 | 144 |
| MCP 55 | Sample | 1 | 2 | 3 | 4 | 5 |
| Initial Cracking, Exposure Hours | | NONE | NONE | NONE | NONE | NONE |
| General Cracking, Exposure Hours | | NONE | NONE | NONE | NONE | NONE |
| Total Exposure, Hours | | 144 | 144 | 144 | 144 | 144 |
| MCP 60 | Sample | 1 | 2 | 3 | 4 | 5 |
| Initial Cracking, Exposure Hours | | NONE | NONE | NONE | NONE | NONE |
| General Cracking, Exposure Hours | | NONE | NONE | NONE | NONE | NONE |
| Total Exposure, Hours | | 144 | 144 | 144 | 144 | 144 |

The Ozone Test results indicate that the MCP compound completed the required 144 hours of exposure and the Rubber compounds failed at much lower hours of exposure.



TEST RESULTS

ASTM D-575-91 (MODIFIED)

STANDARD TEST METHODS

FOR RUBBER PROPERTIES IN COMPRESSION

(INCH POUNDS TO DEFLECT 75% ORIGINAL HEIGHT)

| Rubber Tire #1 | Sample | 1 | 2 | 3 | 4 | 5 | avg |
|----------------------|--------|------|------|------|------|------|--------|
| 50 psi (Inch Pounds) | | (25) | (27) | (27) | (25) | (25) | (25.8) |
| 55 psi (Inch Pounds) | | (37) | (35) | (35) | (35) | (36) | (35.6) |
| 60 psi (Inch Pounds) | | (44) | (45) | (43) | (47) | (48) | (45.4) |

| Rubber Tire #2 | Sample | 1 | 2 | 3 | 4 | 5 | avg |
|----------------------|--------|------|------|------|------|------|--------|
| 50 psi (Inch Pounds) | | (23) | (25) | (25) | (26) | (23) | (24.4) |
| 55 psi (Inch Pounds) | | (39) | (37) | (37) | (36) | (35) | (36.8) |
| 60 psi (Inch Pounds) | | (43) | (47) | (48) | (48) | (47) | (46.6) |

Average Inch Pounds Rubber Tires #1 & #2

50 psi (25.1 Inch Pounds)
55 psi (36.2 Inch Pounds)
60 psi (46.0 Inch Pounds)

| MCP 50 | Sample | 1 | 2 | 3 | 4 | 5 | avg |
|---------------|--------|-------|------|------|-------|------|---------|
| (Inch Pounds) | | (103) | (97) | (99) | (104) | (98) | (100.2) |

| MCP 55 | Sample | 1 | 2 | 3 | 4 | 5 | avg |
|---------------|--------|-------|-------|-------|-------|-------|---------|
| (Inch Pounds) | | (128) | (125) | (128) | (127) | (127) | (127.0) |

| MCP 60 | Sample | 1 | 2 | 3 | 4 | 5 | avg |
|---------------|--------|-------|-------|-------|-------|-------|---------|
| (Inch Pounds) | | (155) | (156) | (153) | (155) | (155) | (154.8) |

The Compressive Strength test results show conclusively that the MCP tires as furnished require more Inch Pounds of force to deflect the tested tires 75% of their original height by a factor of:

3.992 : 1 @ 50psi
3.508 : 1 @ 55 psi
3.365 : 1 @ 60 psi



CONCLUSIONS

The results of the static testing conducted on the Rubber Tire Compound and the MCP Polyurethane Tire Compound show the MCP Polyurethane Tire Compound to have superior overall physical properties when tested.

The abrasion resistance tests results concluded that the MCP Polyurethane Tire Compound exceeded the abrasion resistance qualities of the Rubber Tire Compound by a factor of 3.86 : 1.

The compression set results conclude that the MCP Polyurethane Tire Compound had superior properties in compression set as tested against the Rubber Tire Compound.

The tear tests although marginal did show the MCP Polyurethane Tire Compound to have slightly higher results as compared to the Rubber Tire Compound by factors of :

- (a) Split Tear 1.150 : 1
- (b) Die C Tear 1.083 : 1

The modified compressive strength tests showed superior deflection results of the MCP Polyurethane Tire Compound when tested against the Rubber Tire Compound. The results show a factor of :

- (a) 3.992 : 1 @ 50psi
- (b) 3.508 : 1 @ 55psi
- (c) 3.365 : 1 @ 60psi

The results of the ozone tests are the most dramatic. All of the Rubber Tire Compound samples failed to attain the required 144 hour duration time whereas all of the MCP Polyurethane Tire Compound failed to exhibit any of the failure characteristics such as initial cracking and general cracking and attained the full 144 hours of the test.

In conclusion, it can be reported that the MCP Polyurethane Tire Compound as submitted is superior and is a viable alternative to the Rubber Tire Compound purchased locally.

The overall static physical properties tests rate the MCP Polyurethane Tire Compound superior to the Rubber Tire Compound.