National Law Enforcement and Corrections Technology Center

A Program of the National Institute of Justice

BULLETIN

February 2001

2000 Evaluation of Replacement Brake Pads for Police Patrol Vehicles

During the past several years, it has become apparent that many law enforcement agencies, when confronted with the need to replace the brake pads on patrol vehicles in their fleets, are more concerned with the cost of the replacement brake pads than with maintaining the optimum level of performance that was designed into the police patrol package vehicle. Similarly, many agencies use private vendors to perform their vehicle maintenance and repair work and do not know or even think about what replacement components are being used. The ability to stop, particularly under the extreme operating conditions typically encountered in police patrol situations, is of critical importance in the law enforcement fleet. Prior to 1997, there was little, if any, information available to law enforcement fleet administrators to guide them in making informed purchasing decisions.

In May 1997, the National Law Enforcement and Corrections Technology Center (NLECTC) of the National Institute of Justice conducted a comprehensive evaluation of replacement brake pads for police patrol vehicles.[1] The evaluation was the first of its type.

In June 2000, the second comparative evaluation of replacement brake pads for police patrol vehicles was performed. It was necessary due to changes in the pad materials and designs available in the automotive aftermarket, and due to changes in the vehicles themselves. It has been found that a brake pad material that works well on one brand and model vehicle does not necessarily work equally as well on a different brand or model vehicle. Clearly, the need for this information within the law enforcement community, however, has not changed. This NLECTC bulletin is a synopsis of the results of that evaluation; a detailed report is also available that contains statistical analyses of the test data. To order a copy of the full report, write or call NLECTC, P.O. Box 1160, Rockville, MD 20849–1160, 800–248–2742; or download it from JUSTNET, www.nlectc.org.

Major manufacturers of replacement brake pads for police vehicles were invited to participate in the evaluation. Twelve companies and two Original Equipment (OE) manufacturing companies (Ford and Chevrolet) were evaluated. Eleven sets of brake pads were tested on the Chevrolet Impala and 13 sets were tested on the Ford Police Interceptor. See table 1 for a list of brand names and edge codes.[2] Brake pads that are supplied with new police-package vehicles were also tested. Several companies, however, did not submit their products for testing. No recommendations can be made about those companies' products.

The Test

Each brand of brake pad was subjected to four tests to measure its performance under various conditions and determine pad and rotor wear characteristics. The brake pads were tested on a 2000 Ford Police

[1] The tests were conducted by Independent Testing and Consulting, Inc.

[2] An edge code contains specific information about a brake lining, including a manufacturer's identification, a numeric code that references the lining type, and alpha characters that indicate the initial friction properties of the lining. These alpha characters describe a range of normal and hot friction values measured when a 1-inch-square piece of friction material is subjected to varying conditions of temperature, pressure, and rubbing speed on a test machine.

Interceptor and a 2000 Chevrolet Impala. These two cars were used as test vehicles because they represent the vast majority of police cars in service use by law enforcement agencies at this time. Both vehicles were equipped with Antilock Braking Systems (ABS).

Once the participating companies were identified and their brake pads acquired, the brake pads and rotors were delivered to Greening Testing Laboratories, Inc. Greening Laboratories coded and marked each brake pad and rotor set so that they stayed together throughout the test process, and then completed the initial burnishing[3] using computer-controlled dynamometers to assure identical break-in.

[3] Brake pads are made of a combination of materials that are held together with resin, which collects on the surface during the manufacturing process. Burnishing is a procedure in which the resin is worn or "polished" off; this gives the brake pads better initial performance and reduces smoking caused by the resin burning off.

Table 1 **Brake pad manufacturers and edge codes of brake pads tested**

Manufacturer	Brand name		Part number	Edge codes
A C Delco	**A C Delco**			
6200 Grand Pointe Drive	Chevrolet	Front:	17D699M	DEL–612–EE
Grand Blanc, MI 48439		Rear:	17D698M	DEL–612–EE
	Ford	Front:	17D748MX	DEL–612–EE
		Rear:	17D674AMX	DEL–612–EE
Advance Auto Parts	**Selectra**			
5673 Airport Road	Chevrolet	Front:	SSD699	FA SD1–EE
Roanoke, VA 24012		Rear:	SSD698	FA SD2–EE
	Ford	Front:	SSD748	FA SD1–EE
		Rear:	SSD674	FA SD1–EE
Carquest Corp.	**Carquest**			
12596 W. Bayaud Avenue	Chevrolet	Front:	GMD699F	CG–832–EE
Suite 400		Rear:	GMD698F	CG–832–EE
Lakewood, CO 80228	Ford	Front:	GMD748F	CG–832–EE
		Rear:	GMD690F	CG–832–EE
DANA Brake and Chassis (Ceramic)*	**Carquest - Gold Ceramic**			
4400 Prime Parkway	Chevrolet	Front:	GCD699	CG–758C–FF
McHenry, IL 60050–7033		Rear:	GCD698	CG–758C–FF
	Ford	Front:	GCD748	CG–758C–FF
		Rear:	GCD690	CG–758C–FF
	NAPA - Ceramix			
	Chevrolet	Front:	CMX7574	CMX–55–FF
		Rear:	CMX7387A	CMX–55–FF
	Ford	Front:	CMX7617	CMX–55–FF
		Rear:	CMX7555A	CMX–55–FF
	Raybestos - Quiet Stop			
	Chevrolet	Front:	PGD699QS	BPI–0508–FF
		Rear:	PGD698QS	BPI–0508–FF
	Ford	Front:	PGD748QS	BPI–0508–FF
		Rear:	PGD674AQS	BPI–0508–FF
DANA Brake and Chassis	**Raybestos**			
4400 Prime Parkway	Chevrolet	Front:	SSD699	BPI–912–EE
McHenry, IL 60050–7033		Rear:	SSD698	BPI–912–EE
	Ford	Front:	SSD748	BPI–912–EE
		Rear:	SSD674A	BPI–912–EE

*The identical ceramic friction material produced by DANA Brake and Chassis is marketed by Carquest, NAPA, and Raybestos, and will be listed throughout the bulletin as DANA B&C (Ceramic).

Following burnishing, a practical evaluation was conducted using two police-package vehicles produced by major American manufacturers, one rear-wheel drive and one front-wheel drive. A detailed report with comparison charts and other analyses were prepared and will be published and distributed to law enforcement and other interested agencies.

Because driving conditions in different parts of the country vary widely, no specific "winners" or "losers" were identified. It is important that your department place the appropriate weights on those portions of the test data most representative of the conditions that you may encounter. A sample distribution of category weights is shown in table 2.

The test results may be used in two ways. First, they may be used to compare the performance of a specific brake pad against the Original Equipment pads to determine which will best meet the needs of your department. In this case, you should emphasize those portions of the evaluation that come closest to reflecting your agency operation,

Table 1 **Brake pad manufacturers and edge codes of brake pads tested (continued)**

Manufacturer	Brand name		Part number	Edge codes
Federal-Mogul Corporation	**Wagner Severe Duty Disc Pads**			
26555 Northwestern Highway	Ford	Front:	SX748	WAG–SX1–EE
Southfield, MI 48034		Rear:	SX674A	WAG–SX5–EE
Hawkhead Automotive, Inc.	**Force 4**			
200 Industrial Loop	Chevrolet	Front:	M–7574–Z–D699	FTC–134–EE
Orange Park, FL 32073		Rear:	M–7387–Z–D814	FTC–134–EE
	Ford	Front:	M–7617–Z–748	FTC–134–EE
		Rear:	M–7610–Z–D674	FTC–134–EE
Honeywell Friction Materials	**Bendix - Premium Grade (Chevrolet) and Fleet Metlock (Ford)**			
105 Pawtucket Avenue	Chevrolet	Front:	MKD699	BX TMA–FF
Rumford, RI 02916–2422		Rear:	MKD698	BX ZA–FF
	Ford	Front:	MKD748FM	BX FM2–FF
		Rear:	MKD674CFM	BX FM–EE
NAPA Raylock	**SD (Severe Duty) and AE (Application Engineered) Disc Brake Pads**			
600 Raylock Drive, S.W.	Chevrolet	Front:	SD7574M	SD 66–EE
Atlanta, GA 30336–1633		Rear:	AE7387AM	AE 49–EE
	Ford	Front:	SD7617M	SD 66–EE
		Rear:	AE7555A	AE 46–EE
Performance Friction Corp.	**Carbon Metallic**			
P.O. Box 819	Ford	Front:	0748.20	PFC 08–FF
Clover, SC 29710–0819		Rear:	0690.20	PFC 08–FF
Satisfied Brake Products	**Satisfied**			
805 Education Road	Chevrolet	Front:	FL699	SAT SV30–EE
Cornwall, Ont. K6H 6C7		Rear:	PR814	SAT NA10–GG
	Ford	Front:	FL748	SAT SV30–EE
		Rear:	PR674	SAT NA10–GG
TMD Friction, Inc.	**TMD Friction**			
3994 Pepperell Way	Chevrolet	Front:	7574–2014T	BBA–2015 TA–FF
Dublin, VA 24084		Rear:	7387–2014T	BBA–2015 TA–FF
	Ford	Front:	7617–2004T	BBA–2015 TB–FF
		Rear:	7610–2016T	BBA–2016 TB–FF
Original Equipment	**OEM**			
Ford and Chevrolet Dealers	Chevrolet	Front:	18029828	AK NS166H–FF
		Rear:	18042417	AK NS166H–FF
	Ford	Front:	YW7Z–2001–AA	BBA 2004TA–FF
		Rear:	F8AZ–2200–AA	BX ZC–FF

Table 2 **Tests and sample category weights**

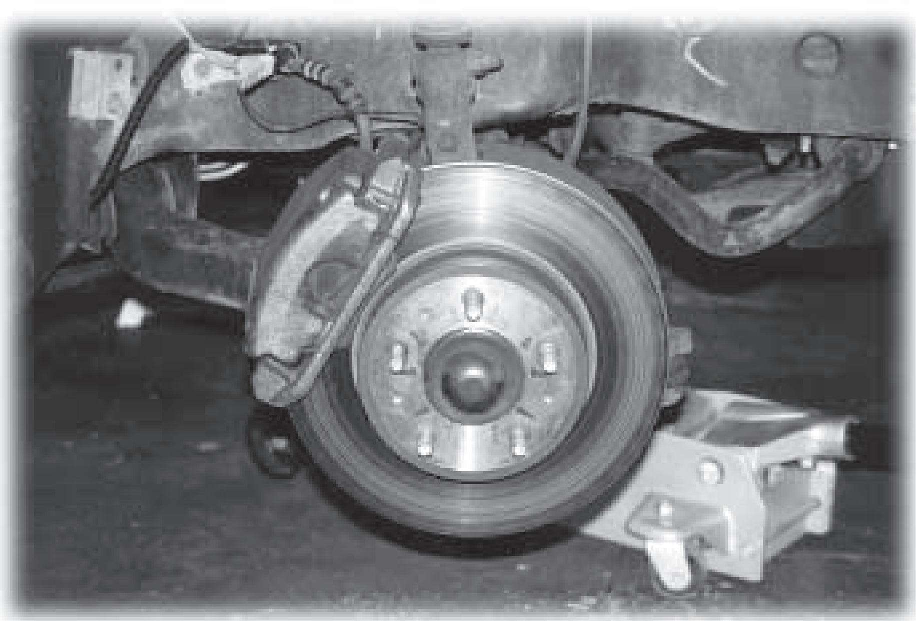
Test	Sample category weight*
Ambient-temperature (cold) breaking performance	10
Normal-operating-temperature breaking performance	25
High-operating-temperature breaking performance and fade resistance	45
Panic stop (antilock brake mode)	20
Total	**100**

*This table presents an example only. It is important that you assign weights to these categories according to your agency's needs.

and thus the needs of your department. Second, the overall test results may be used to adjust the manufacturer's bid or local vendor's price for these brake pad brands. In each test category, the absolute difference between a given brake pad and the Original Equipment brake pad is divided by the OE brake pad's score, resulting in a "deviation factor." This factor is then multiplied by a category weight, such as those listed in table 2, to produce a weighted category score. The total of these weighted scores for a particular brake pad is then used to adjust the brake pad's bid or local retail price for comparison with the bid or price of the Original Equipment pads.

Readers familiar with the first replacement brake pad evaluation report, published in April 1998, will notice several significant changes in both the test methodologies employed and the primary focus of several of the tests, as well as the removal of the brake pad and rotor wear tests. These changes were a direct result of a meeting held in March 1998 after the draft of the first report was completed. At this meeting, representatives from the participating brake pad manufacturers, brake specialists from the vehicle manufacturers, and other companies that supported the testing program provided feedback on the first round of tests.

While all participants agreed that this first attempt to evaluate replacement brake pads for police vehicles was a positive "first step," it was noted that several modifications to the methodology would further enhance the value of the information presented. It was generally agreed that while the deceleration rate attainable and stopping distances achieved in a panic stop are important to law enforcement, far more decelerations are made under normal driving and traffic conditions. Consequently, the group's recommendation was for future brake pad test programs to focus more on comparing pedal effort required to maintain a targeted deceleration rate, with particular attention paid to pedal force as it relates to brake pad temperature. (***Note****: When braking to a targeted deceleration rate, where the speed of the vehicle at brake application is the same, the stopping distance should also theoretically be the same, making any measurement of stopping distances irrelevant.*)
The brake pad and rotor wear tests were also recommended to be discontinued, as they resulted from extremely severe operating conditions performed over



Closeup of a typical disc brake system.

Photo courtesy of Ed Sanow.

a relatively short period of time. As such, these tests may not be an accurate predictor of achievable brake pad and rotor life when used in normal police patrol service.

When reviewing the test data summaries contained in this bulletin, the reader should consider the following points:

1. Generally speaking, when ***lower pedal force*** is required to maintain a given deceleration rate, the brake pad is working more efficiently. Low pedal force can reduce driver fatigue, particularly in "stop and go" (heavy traffic) situations, or any time that frequent brake applications are required. It is also beneficial for drivers who may be less able to apply higher levels of pressure to the brake pedal.

2. ***Low pedal force*** indicates that the friction material used in a given brake pad is more effective than those materials that require more pedal force. The more effective friction material could, in certain cases, translate into somewhat faster brake pad or rotor wear.

3. While a certain temperature level is necessary for proper functioning, ***excessive heat*** is generally the enemy of any type of mechanical device or system. In terms of brake system performance, excessively high temperatures can contribute to premature breakdown of rubber components, such as hoses and seals, as well as certain electronic components, such as ABS sensors. In addition, as brake fluid absorbs moisture from the atmosphere, high operating temperatures can raise the temperature of the brake fluid/water mixture in the cylinders and calipers to the point where the moisture turns to steam, or vaporizes. This produces a condition known as "vapor lock," resulting in reduced braking capability (evidenced by a "spongy" feeling when the brake pedal is depressed), or, in severe cases, the total loss of braking ability.

Table 3 **Ambient-temperature (cold) braking performance (overall comparisons)**

Brake pad	Average initial speed (mph)	Average pedal force (lbf ft)	Average ambient temperature (°F)
Chevrolet Impala			
Original Equipment (Chevrolet)	45.4	12.6	65.3
AC Delco	45.5	10.0	74.1
Advance Auto	45.5	11.3	72.3
Carquest	46.1	8.8	75.1
DANA B&C (Ceramic)	45.7	13.4	66.5
Hawkhead	45.3	6.9	65.5
Honeywell-Bendix	45.7	10.7	73.0
NAPA	45.7	9.1	61.5
Raybestos	45.4	9.3	72.0
Satisfied Brake	45.6	9.9	72.5
TMD Friction	45.2	10.6	61.3
Ford Police Interceptor			
Original Equipment (Ford)	45.7	12.9	69.5
AC Delco	45.7	7.6	67.6
Advance Auto	45.6	12.5	76.0
Carquest	45.5	10.8	75.6
DANA B&C (Ceramic)	46.2	12.9	69.7
Hawkhead	45.9	6.9	72.7
Honeywell-Bendix	45.6	11.0	72.8
NAPA	45.4	13.7	71.4
Performance Friction	45.8	13.0	74.3
Raybestos	45.6	10.5	69.7
Satisfied Brake	46.1	12.9	59.7
TMD Friction	46.0	11.2	70.6
Wagner	46.1	12.7	68.2

Ambient-Temperature (Cold) Braking Performance Test

Law enforcement officers regularly begin their patrol shifts and respond to emergency situations in a patrol vehicle that has been parked for several hours and before normal or optimal operating temperatures have been reached. The general stopping characteristics and the pedal force required when the brake components are essentially cold are of significant importance.

Objective: Determine the stopping performance characteristics of the test brake pads when the entire brake system is at ambient rather than normal or optimal operating temperature.

Methodology: Each of the test brake pad/rotor sets was evaluated to determine its cold temperature braking characteristics. This was accomplished by performing 10 decelerations (at a specific predetermined location on the test track) from 45 mph to 15 mph at a deceleration rate of 10 ft/s^2. After each deceleration, the test vehicle was accelerated back to 45 mph and driven for approximately 2 miles (back to the predetermined deceleration point) to allow the brake components to cool before the next deceleration in the series. Temperature increase during each deceleration and brake pedal force necessary to maintain the target deceleration rate were recorded. Table 3 shows the results from this test. Table 3a graphically shows the pedal force comparisons.

Normal-Operating-Temperature Braking Performance Test

Most of a law enforcement officer's day is spent on normal patrol, driving at normal speeds. Heat produced in the braking system, and the resulting changes in the pedal force required to make normal stops can be of great importance, particularly for

Table 3a **Ambient-temperature (cold) braking performance (average pedal force data only)**

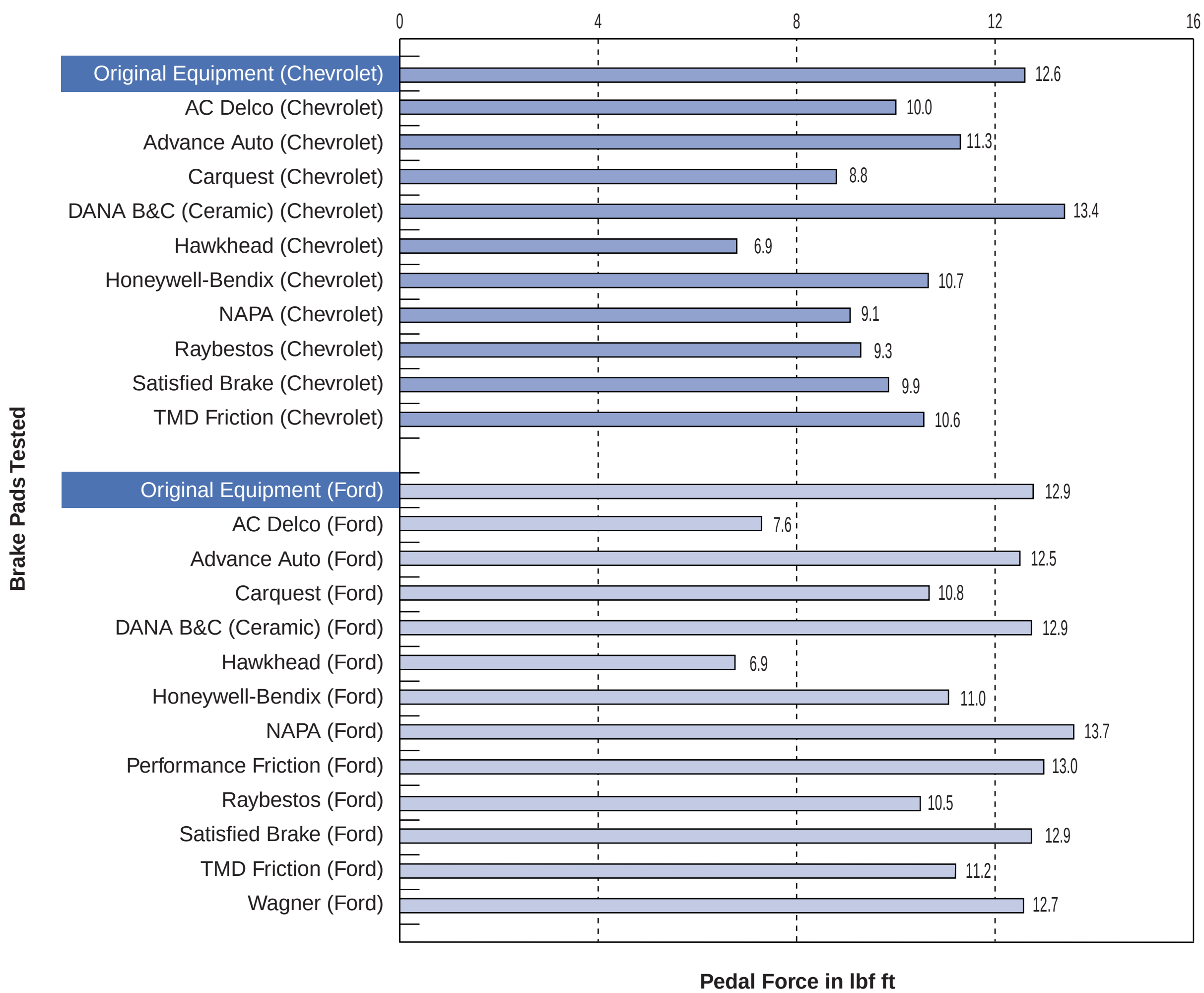


Table 4 **Normal-operating-temperature braking performance (overall comparisons)**

Brake pad	Average initial speed (mph)	Average pedal force (lbf ft)	Average ambient temperature (°F)
	Chevrolet Impala		
Original Equipment (Chevrolet)	60.6	16.3	65.4
AC Delco	60.9	9.5	75.0
Advance Auto	60.4	13.4	72.7
Carquest	60.3	9.1	72.5
DANA B&C (Ceramic)	60.9	16.2	68.5
Hawkhead	60.2	10.5	67.1
Honeywell-Bendix	60.3	11.5	73.3
NAPA	60.7	10.0	62.2
Raybestos	60.2	9.1	73.0
Satisfied Brake	60.2	10.4	72.4
TMD Friction	60.0	11.0	64.6
	Ford Police Interceptor		
Original Equipment (Ford)	60.5	16.3	70.9
AC Delco	60.5	8.2	66.2
Advance Auto	60.4	13.7	75.3
Carquest	60.4	10.9	75.2
DANA B&C (Ceramic)	60.2	14.8	67.9
Hawkhead	60.0	9.8	72.4
Honeywell-Bendix	59.9	13.6	73.5
NAPA	60.5	14.9	72.0
Performance Friction	60.5	13.7	74.5
Raybestos	60.6	9.9	71.2
Satisfied Brake	59.8	12.3	61.4
TMD Friction	61.0	13.2	71.5
Wagner	59.9	16.3	70.3

Closeup of rotor and brake pad set. A thermocouple device (shown at right) was attached to each set of brake pads to monitor brake temperatures during testing.

Thermocouple device

Photo courtesy of Ed Sanow.

officers whose size, weight, or strength make them less able to produce the higher pedal efforts required by some brake pad materials.

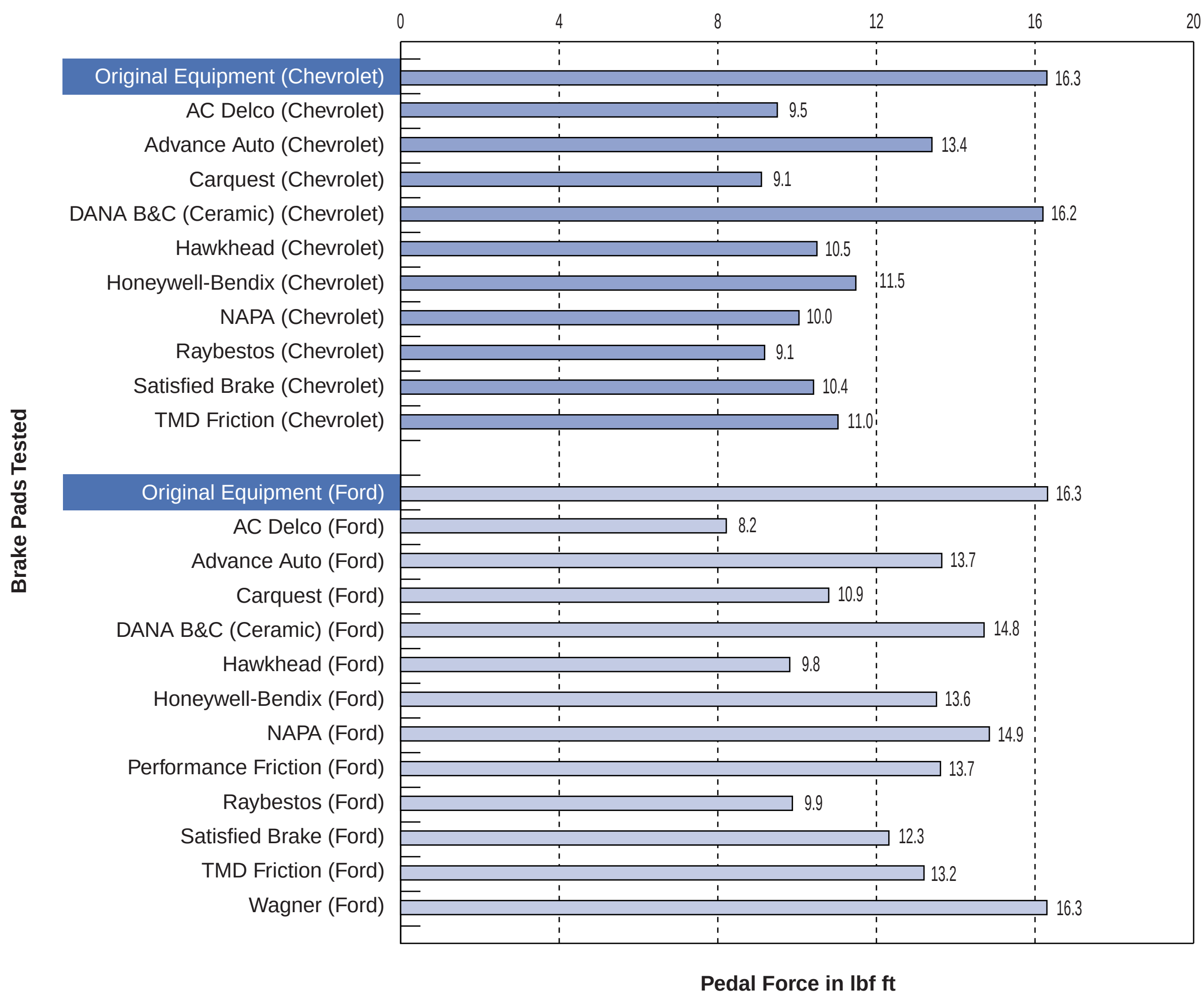
Objective: Determine the stopping performance characteristics of the test brake pads under normal or optimal operating temperature conditions.

Methodology: Each of the test brake pad/rotor sets was evaluated to determine its normal operating temperature braking characteristics. This was accomplished by performing 15 decelerations (at a specific location on the test track) from 60 mph to 20 mph at a deceleration rate of 15 ft/s². After each deceleration, the test vehicle was accelerated back to 60 mph and driven for approximately 1 mile (to another predetermined deceleration location) to allow the brake components to cool before the next deceleration in the series. Temperature increases during each deceleration and throughout the entire test process, as well as brake pedal force necessary to maintain the target deceleration rate, were recorded. Table 4 shows the results from this test. Table 4a graphically shows the pedal force comparisons.

Hot Pursuit (Fade Resistance) Braking Performance Test

Law enforcement officers regularly respond to emergency or pursuit situations that require emergency driving, including frequent hard brake applications from high speeds. The ability of the brakes to provide high deceleration rates without significant brake fade and without unacceptable increases in pedal effort during these extreme conditions is of critical importance to the success of the law enforcement mission and to the safety of the officers and general public.

Table 4a **Normal-operating-temperature braking performance (average pedal force data only)**



Objective: Determine the stopping performance characteristics and the resistance to fade of the test brake pads under severe high-operating-temperature conditions.

Methodology: Each of the test brake pad/rotor sets was evaluated to determine its performance characteristics in a simulated "hot pursuit" mode. This was accomplished by performing two decelerations in rapid succession from 90 mph to 0 mph at 22 ft/s^2 to heat up the brake pads and rotors. These two "heat up" stops were followed immediately by three decelerations, from 70 mph to 30 mph at a deceleration rate of 22 ft/s^2, performed in rapid succession (approximately 1/4-mile intervals). After this five-deceleration series, the test vehicle remained stationary in a 3-minute heat soak. Following the heat soak, the entire series of five decelerations was repeated 4 additional times for a total of 25 decelerations. Temperature increases during each individual deceleration, each deceleration series, and throughout the entire test process, as well as brake pedal force necessary to maintain the target deceleration rate, were recorded. Table 5 shows the results from this test. Table 5a graphically shows the pedal force comparison.

"Panic" Stop (Antilock Braking Mode) Performance Test

Police patrol vehicles are subject to rigorous use. This includes frequent maximum (panic stop) brake applications from high speeds. The ability of the brake system to resist fade and allow the antilock

Table 5 **Hot pursuit (fade resistance) braking performance (overall comparisons)**

Brake pad	Average initial speed* (mph)	Average pedal force (lbf ft)	Average ambient temperature (°F)
	Chevrolet Impala		
Original Equipment (Chevrolet)	78.1	26.2	67.6
AC Delco	78.8	22.6	75.1
Advance Auto	78.8	26.2	75.7
Carquest	78.1	28.4	72.8
DANA B&C (Ceramic)	78.2	27.6	71.7
Hawkhead	78.4	27.9	70.4
Honeywell-Bendix	77.8	21.6	74.2
NAPA	77.8	29.0	65.2
Raybestos	78.3	29.0	73.9
Satisfied Brake	77.9	21.9	72.3
TMD Friction	78.5	17.7	67.4
	Ford Police Interceptor		
Original Equipment (Ford)	77.9	26.6	72.2
AC Delco	78.4	21.5	68.6
Advance Auto	78.2	36.6	76.3
Carquest	78.1	25.1	76.6
DANA B&C (Ceramic)	78.7	32.7	65.9
Hawkhead	78.0	25.7	73.4
Honeywell-Bendix	78.5	23.9	75.1
NAPA	79.0	32.1	72.7
Performance Friction	78.3	28.6	74.7
Raybestos	77.7	21.2	73.6
Satisfied Brake	78.4	22.9	63.5
TMD Friction	78.1	24.2	72.8
Wagner	77.8	30.7	71.4

*Average initial speed calculations included the 10 decelerations from a 90 mph target speed and 15 decelerations from a 70 mph target speed that make up this test sequence.

system to function so that the officer can maintain vehicle control is of critical importance.

Objective: Evaluate the performance characteristics of each brake pad set when subjected to a series of sudden "panic" stops from 70 mph.

Methodology: Each of the test brake pad/rotor sets was evaluated to determine performance characteristics in a series of "panic" stops. This was accomplished immediately after the "hot pursuit" portion of the evaluation was completed. This was accomplished by performing two decelerations in rapid succession from 90 mph to 0 mph at 22 ft/s^2 to heat up the brake pads and rotors. These two "heat up" stops were followed immediately by three decelerations at the maximum deceleration rate attainable (activating ABS if possible) and were performed in rapid succession (approximately 1/4-mile intervals). After this five deceleration series, the test vehicle remained stationary in a 4-minute heat soak. Following the heat soak, the entire series of 5 decelerations was repeated 3 additional times for a total of 20 decelerations. Temperature increases during each individual deceleration, each deceleration series, and throughout the entire test process, as well as the average deceleration rate attainable on each stop, were recorded. Brake pedal force necessary to maintain the target deceleration rate was recorded. Table 6 shows the results from this test. Table 6a graphically shows projected stopping distance.

Table 5a **Hot pursuit (fade resistance) braking performance (average pedal force data only)**

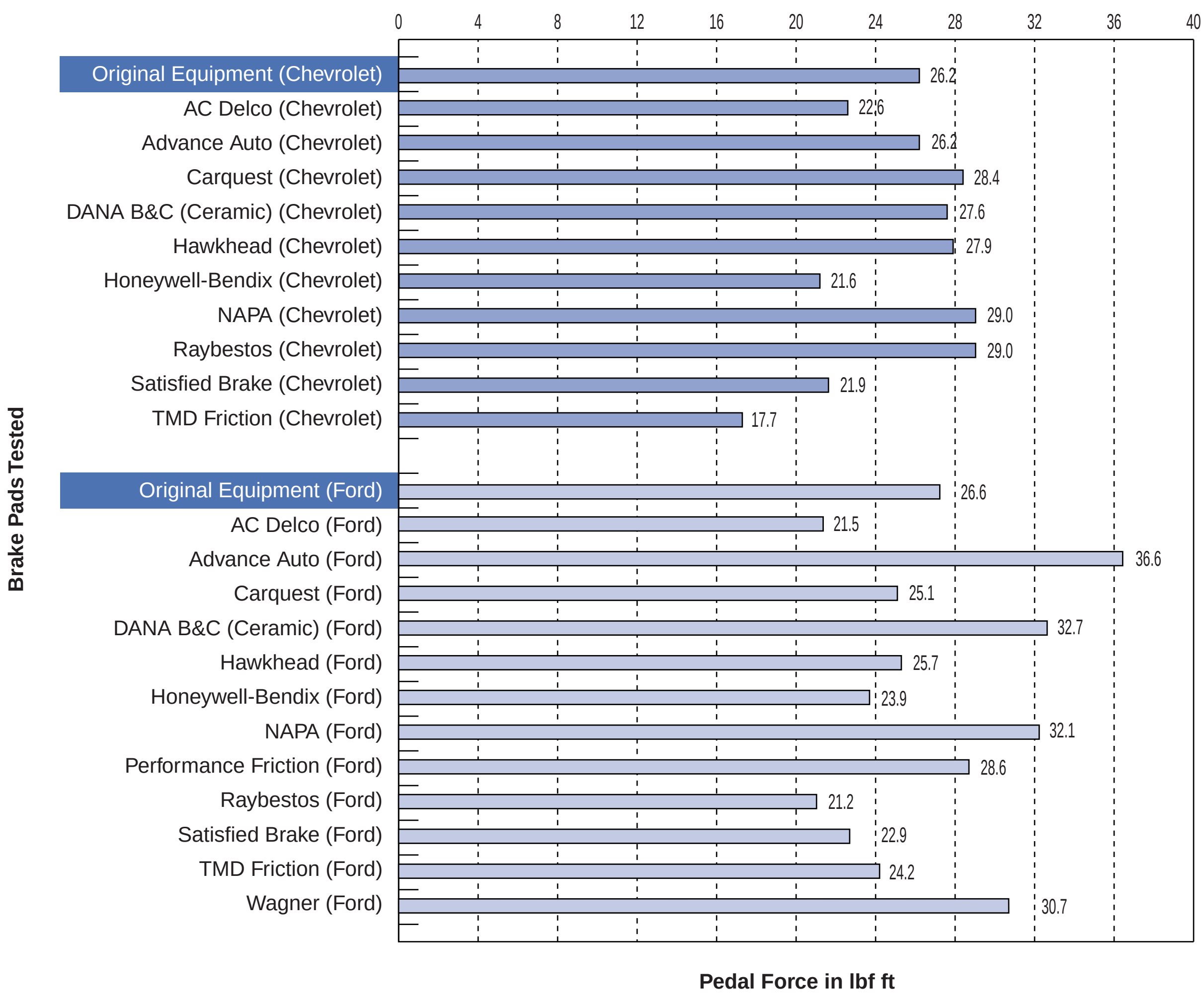


Table 6 **Panic stop (antilock brake mode) test results**

	Average initial speed* (mph)	Average deceleration rate (ft/s^2)	Projected stopping distance from 70 mph**
Chevrolet Impala			
Original Equipment (Chevrolet)	70.4	28.12	187.5
AC Delco	71.4	27.42	192.2
Advance Auto	70.7	27.39	192.4
Carquest	70.6	27.05	194.8
DANA B&C (Ceramic)	70.6	26.82	196.5
Hawkhead	70.5	28.25	186.6
Honeywell-Bendix	70.2	27.36	192.6
NAPA	70.4	25.32	208.2
Raybestos	70.5	27.45	192.0
Satisfied Brake	69.9	28.03	188.0
TMD Friction	70.6	25.88	203.6
Ford Police Interceptor			
Original Equipment (Ford)	69.5	28.56	184.5
AC Delco	70.9	27.95	188.6
Advance Auto	70.5	28.37	185.8
Carquest	70.2	28.77	183.2
DANA B&C (Ceramic)	71.1	28.67	183.9
Hawkhead	69.6	28.77	183.2
Honeywell-Bendix	70.8	28.46	185.2
NAPA	71.0	26.88	196.0
Performance Friction	70.7	28.48	185.0
Raybestos	70.0	28.76	183.3
Satisfied Brake	70.1	28.15	187.2
TMD Friction	70.7	28.04	188.0
Wagner	70.0	28.31	186.1

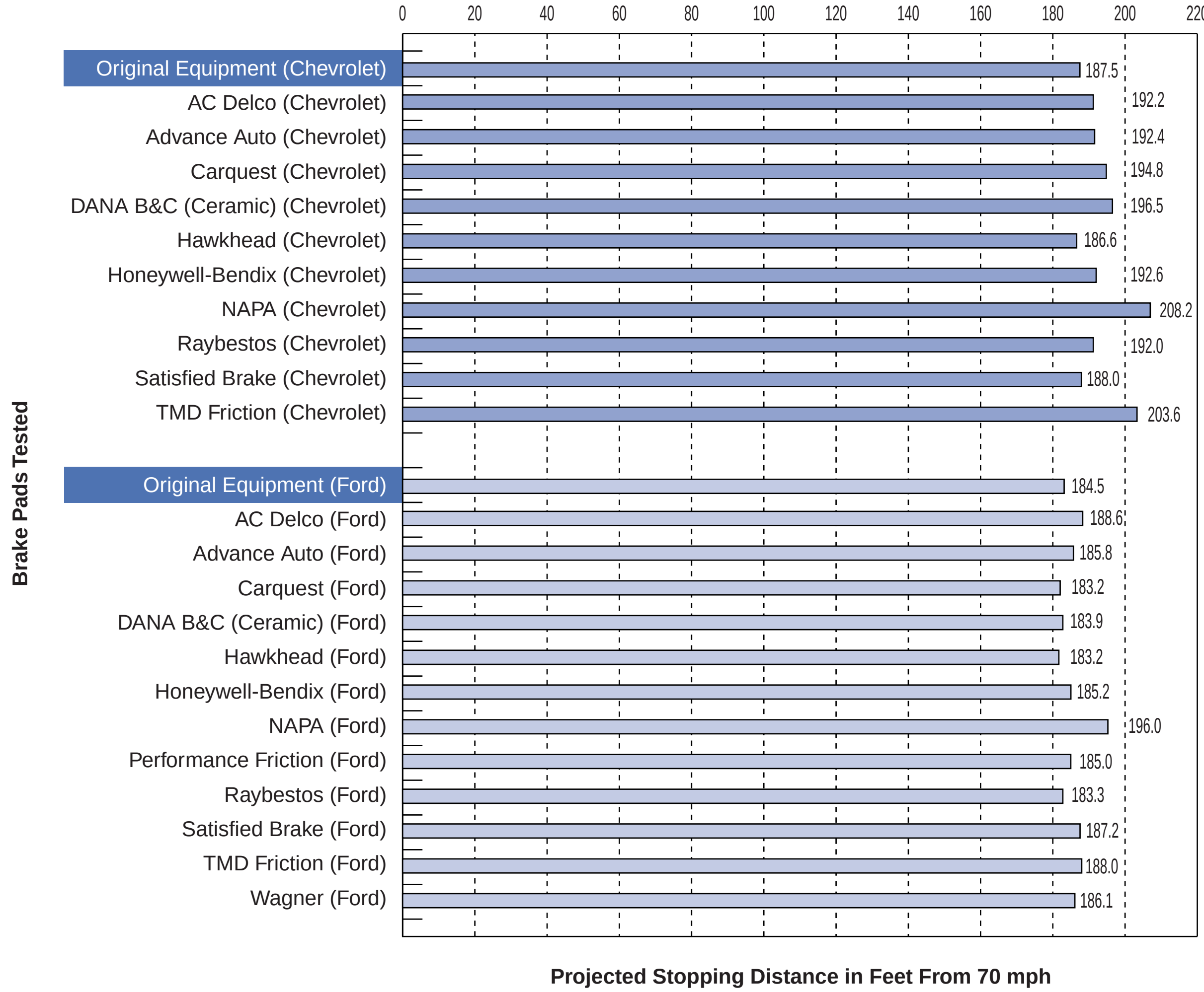
*Average initial speed was calculated from 12 decelerations with a 70 mph target speed.

**Projected stopping distances were calculated from average deceleration rates attained on the 70 mph target speed stops.

The National Law Enforcement and Corrections Technology Center is supported by Cooperative Agreement #96–MU–MU–K011 awarded by the U.S. Department of Justice, National Institute of Justice. Analyses of test results do not represent product approval or endorsement by the National Institute of Justice, U.S. Department of Justice; the National Institute of Standards and Technology, U.S. Department of Commerce; Independent Testing and Consulting, Inc.; or Aspen Systems Corporation.

The National Institute of Justice is a component of the Office of Justice Programs, which also includes the Bureau of Justice Assistance, Bureau of Justice Statistics, Office of Juvenile Justice and Delinquency Prevention, and Office for Victims of Crime.

Table 6a **Panic stop (antilock brake mode) test results (projected stopping distance only)**



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