The Real Root Cause of the Ford-Firestone Tragedy:

Why the Public Is Still at Risk

April 2001

Public Citizen and Safetyforum.com
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ISBN# 1-58231-023-8

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Summary

This report examines why Firestone tires on Ford Explorers are experiencing abnormally high rates of tread separations[1] and why these separations cause catastrophic rollover crashes that maim and kill drivers and passengers.

Based on an analysis of all of the available evidence, the tires fail because they are poorly designed. These design problems are exacerbated in some instances by poor quality control in the tire manufacturing process. Importantly, design and production deficiencies appear in Firestone's Wilderness AT tires regardless of the tire's size or plant of manufacture. In contrast to the repeated claims of Ford and Firestone, according to Firestone's own expert, Dr. Sanjay Govindjee, the non-Decatur-made Wilderness AT tires may actually be more prone to tread separations than those manufactured in Firestone's Decatur, Illinois plant. The devastating rollover crashes occur because the poor design of the Ford Explorer makes it difficult for motorists to maintain control of their vehicle if a tire's tread belts separate from the tire.

Although both Ford and Firestone are to blame for the multitude of deaths associated with the lethal combination of this tire and vehicle, the real problem begins and ends with Ford Motor Company. Many of the key decisions were made by Ford: Ford created the original and continuing performance specifications for Firestone's tires; Ford chose to let air out of the tires to cosmetically fix a serious problem that caused the Explorer's wheels to lift off the ground in turns; Ford's request triggered an effort to take weight out of the tire after their reduction in the tire's inflation pressure harmed the Explorer's fuel economy; and Ford ignored every opportunity to fix the rollover and stability problems that plague their Explorer vehicle, despite many loud and continuous signals that such changes were needed to protect vehicle occupants.

Although Firestone's role in the debacle cannot be downplayed, the "root" of the problem lies with Ford Motor Company.

I. Recommendations/Objectives

A. Really "Making it Right": Recalling All of the Defective Tires Is the Only Way

On August 9, 2000, Ford and Firestone announced the recall of 6.5 million tires. Their recall included all 15-inch ATX II tires and those 15-inch Wilderness AT tires manufactured by Bridgestone/Firestone at a Firestone plant in Decatur, Illinois (the "Decatur Plant"). The tires had been sold as original equipment on Ford's Explorer sports utility vehicle, and manufactured according to specifications from Ford. At that time, the companies' jointly had decided that Decatur was the appropriate focus for a recall of Wilderness AT tires, thus excluding millions of identical tires made in Firestone's Wilson, North Carolina and Joliette, Québec, Canada plants. This decision regarding the scope of the recall was later ostensibly justified by both Ford's and Firestone's "root cause" reports, issued in December, 2000, and January, 2001.

This report constitutes the consumer reply to the official Ford/Firestone story.[2] Its findings should cause grave concern about the limited scope of the tire recall conducted thus far, and about potential flaws in the millions of Firestone Wilderness AT replacement tires that have, since August, been retro-fitted on Ford Explorers. As this report documents in great detail, the initial recall should have included all 15-inch and 16-inch Wilderness AT tires used on Ford Explorers, regardless of the plant of manufacture.

This report reveals that Ford and Firestone's own data and the defect investigation database developed by the National Highway Traffic Safety Administration (NHTSA) show that the recalled Wilderness AT tires made in Decatur are no worse, and may in fact be better, than non-recalled Wilderness AT tires that were manufactured at Firestone's other plants.

Firestone's latest public relations campaign promises to "make it right" on consumer safety issues by upgrading manufacturing and quality control measures, "for as long as it takes to gain the public's trust." But only definitive action to address the continuing safety hazards posed by Ford and Firestone's limited tire recall should be the true measure of the companies' commitment to public safety.

Despite its recent promises to "make it right," Firestone has it wrong on the issue of tire size. When the documentation assembled for this report is combined with evidence in NHTSA's defect investigation file, it is clear that the tread separations afflicting Firestone's Wilderness AT tires are not limited to 15-inch tires. Sixteen-inch Wilderness AT tires are also highly prone to tread separation. Ford and Firestone should immediately recall all of the 15-inch and 16-inch Wilderness AT tires that have thus far not been recalled. This action to protect the lives of customers, rather than an empty advertising slogan, is what is needed for Firestone to gain the trust of the American people.

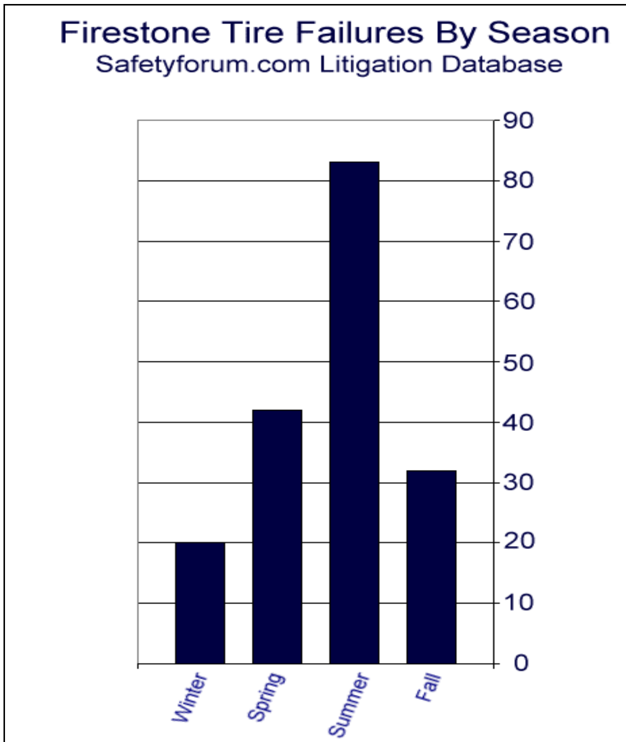
Firestone has also thus far made it wrong by replacing faulty tires with tires that are just as prone to fail. As this report demonstrates, the few distinctions between the 15-inch Wilderness AT tires manufactured in Decatur and those manufactured elsewhere fail to explain the wide-spread failure of tires from all three Firestone plants, and fail to address the "root cause" of these tire failures. Firestone's own expert consultant revealed, on page 50 of his "root cause" report, that according to a study conducted jointly by Ford and Firestone, the non-recalled tires are actually *more* prone to developing belt edge separations or cracks than are those made in Decatur.

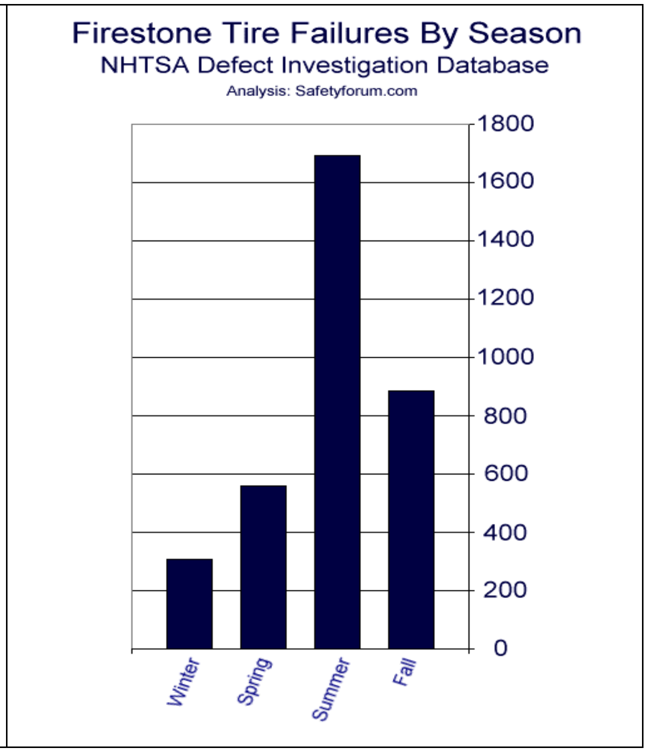
While the companies' reports have blamed a wide variety of generally shared causes, such as vehicle loading and instability of the Explorer, they have nonetheless both sought to justify the scope of the original recall by reference to a single difference in the manufacturing process for those tires made at the Decatur plant. But in light of all the evidence, this attempt to make the "ant's back bear the elephant" is deeply dangerous for consumers and misguided policy for Ford and Firestone.

In short, Ford and Firestone have replaced bad tires with new, but equally dangerous, ones. During 2001, some of the non-recalled and replacement tires will accumulate sufficient mileage, wear and heat exposure that a tread separation – with its frequently catastrophic consequences – may be expected. NHTSA, Ford and Firestone must act now to anticipate and prevent these failures and to provide a truly adequate recall and replacement remedy.

Our analysis of the Ford/Firestone lawsuits involving death and serious injury reveals the real urgency to complete a comprehensive recall before the heat of summer again takes its toll on tires, and, in turn, on the vehicles' occupants. While the companies' "root cause" reports acknowledged the role of heat in tire deterioration and ultimate failure, the company investigators did not attempt to establish the importance of heat build-up and heat-related wear in causing real-world tire failures.

This omission was short-sighted, and threatens to create another summer as disastrous as last year's proved to be. Almost half – 47 percent – of crashes in *Safetyforum.com*'s Ford/Firestone litigation database occurred during the hot summer months of June, July and August. That result is consistent with NHTSA's related defect investigation database, in which it was recorded that 49 percent of crashes occurred during the same summer months. (See charts below.)





Ford and Firestone should complete a further recall of all the defective tires before the summer heat increases the danger these tires pose to the driving public.

B. Stepping Up: Ford Should Notify Owners of the Explorer's Serious Operating Limitations

The two-door Ford Explorer for model years 1995-97 has the worst rollover death rate of all of the SUVs and pickup trucks listed in a recent report by the Insurance Institute for Highway Safety, at 150 deaths from rollover per million registered vehicles.[3] The 2-door Explorer also maintains the dubious distinction of having the worst death rate overall in those vehicle categories, at 231 deaths per million registered vehicles. While the 4-door Explorer is relatively better, at 103 deaths per million registered vehicles, its performance is still a far cry from the study's low-end averages for passenger cars of 20 or 25 deaths per million.[4]

As this report shows, many of the risks to consumers posed by Firestone tread separations are the result of deliberate design decisions by Ford Motor Company. Ford's customers should therefore be fully informed of the dangerous limitations in the Explorer's performance, especially in the face of years of Ford advertising aimed at portraying the Explorer as a safe and stable passenger-carrying vehicle, with the goal of encouraging families to trade station wagons for the Explorer.

Ford should be honest with its customers and tell them of the dangers associated with operation of the Explorer at highway speeds, about necessary precautions and any potential safety hazards inherent in use of the vehicle as a passenger car. At a minimum, this owner notification and public information campaign should include:

(1) Information and specifications for cargo weight limits, to avoid overloading the vehicles' tires, despite the vehicle's considerable interior space to carry larger burdens;

(2) The trade-off in performance, i.e., a reduced risk of tread separation, but a greater risk of rollover during emergency maneuvers, between Ford's original recommendation that tires be inflated at 26 pounds-per-square-inch (psi) and the company's subsequent recommended tire inflation of 30 psi;

(3) Customers' well-demonstrated difficulty in controlling the Explorer following a tread separation;

(4) The risks posed by the vehicle's weak roof, which frequently crushes in rollover crashes, endangering occupants' heads and necks and creating a greater risk of partial or full ejection, regardless of the fact that the roof may satisfy the existing, minimal, 30-year-old federal roof crush standard; and

(5) The company's failure to design the Explorer with a pretensioning safety restraint system (seat belt) that provides protection in a rollover-type crash.

C. Looking Ahead: Future Action For The Nation's Highway Safety Agency

For the future, federal safety standards should be issued to upgrade at least the following five key elements of vehicle safety, in areas of federal regulatory oversight that were shown by the

Ford/Firestone tragedy to be utterly inadequate to protect the public. NHTSA should:

(1) **Provide A Meaningful Tire Safety Standard:** The agency's antiquated tire safety standard is now more than 30 years old, and was not written for radial passenger tires. A new tire safety standard is required by the recent Transportation, Recall Enhancement and Documentation (TREAD) Act to be issued in final form by June 30, 2002. NHTSA is currently preparing a proposal for public comment.

(2) **Prevent Roof Crush:** The federal roof crush standard, which is now more than 30 years old, is a static test merely designed to determine whether the roof can withstand a static load of one and one-half times the weight of the vehicle. There is no dynamic test – or real-world test of the vehicle in motion – which is essential for real-world protection of consumers. There is currently no movement at NHTSA to address this issue. The agency should act quickly and comprehensively to develop a new dynamic standard.

(3) **Issue a Dynamic Rollover Standard:** There is no federal dynamic rollover prevention standard, but there should be. Although a member of Congress petitioned the agency sixteen years ago to issue one, and in 199l the Congress instructed NHTSA to conduct a rulemaking, the agency's efforts were diverted in 1994 to drafting a mere consumer information rule in lieu of the standard. Notably, the agency's work on a minimum safety standard was abandoned in large part due to an argument by the automobile manufacturers that even a minimum standard would prove impossible for SUV-type vehicles to meet. Finally, in late 2000, NHTSA issued its long-awaited consumer information static measurement ratings, available to consumers only over the Internet. But more on rollover is coming, due to instructions from Congress in the TREAD Act that NHTSA should develop a dynamic consumer information test. Good information could still be limited to the Internet, however: the auto manufacturers and dealers blocked a proposed TREAD Act rule that consumers would be informed of test results by vehicle window stickers on all new cars.

(4) **Provide Protection from Ejection In A Crash:** There is no federal window glazing or other occupant protection requirement to help ensure that occupants are not fully or partially ejected through side or rear windows when the vehicle rolls over. Nor are there restraint standards to adequately ensure that occupants are protected from the dynamics unique to rollover crashes, i.e., seat belt buckles that remain fastened, seat belts that pull occupants snug against their seats, or air bags that protect occupants during roof contact. These standards are sorely needed: the severity and frequency of rollover crashes causes one-third of all occupant fatalities.

(5) **Raise An Early Warning on Defects:** During the Congressional hearings, directed in part to an evaluation of why NHTSA was unaware of the ongoing Firestone/Ford Explorer tragedy, it became obvious that the agency has no standing information-gathering program on potential safety defects. New authority for requiring manufacturer submission of early warning information was provided in the TREAD Act. In January 2001, NHTSA issued an advance notice of proposed rulemaking laying out a preliminary plan for gathering regular information on deaths, injuries, crashes, lawsuits, consumer complaints, etc., by make and model and potential defect. This rule needs to be issued promptly and must require that summary information be submitted

monthly in electronic format so the agency is not overwhelmed with minutia.

D. A Call To Action For All Auto Manufacturers

The American public has for years wrongly believed that SUVs are safer than other passenger vehicles. In point of fact, as many have now learned, this is simply untrue. While the sheer mass of SUVs does make them a more aggressive vehicle in multi-car crashes, their poor record in single-vehicle and rollover crashes more than compensates for this somewhat suspect relative advantage. It turns out SUVs are very dangerous for their occupants overall. In addition, as William Clay Ford, chief executive officer of Ford Motor Company, has acknowledged, SUVs cause unnecessary harm to the occupants of other vehicles on the highway.

Rather than ramping up vehicle size for a new round of mega-vehicle competition, as we have seen for the next model year, SUVs need to be made far safer and more socially responsible. Manufacturers should reduce the size of SUVs to improve fuel efficiency and reduce harm to others, design them to be lower and wider in order to prevent rollover crashes and make any additional design changes that are required to reduce the likelihood that higher-framed SUVs will override the lower frames of smaller vehicles and crush their occupants.

Any less comprehensive approach will merely auger future adjustments, after another far-too-costly learning experience is triggered by the suffering and outrage of the American public. After Ford/Firestone, the public won't easily be fooled again.

II. Defining the Problem: Evidence of Multiple Ford/Firestone Design and Production Flaws

This report examines why Firestone tires on Ford Explorers experience abnormally high rates of tread separations and why those separations cause rollover crashes that maim and kill.

Although both Ford and Firestone have published multiple "root cause" reports, all of which make valid technical points about the bad tires, neither company has satisfactorily explained to the consuming public why these tires are failing, whether consumers are at risk in continuing to operate on non-Decatur-made Wilderness AT tires, or why the Explorer is so difficult to control given a tread separation event at highway speeds.

The purpose of this report is to pull together all available evidence and provide consumers with answers to the questions that Ford and Firestone have continued to dodge throughout this lengthy ordeal. The following is a summary of the more significant points on causation:

- The design of the tire, particularly at the belt edges in and around the area of the wedge, is insufficiently robust for the loads applied by the Explorer at the inflation pressures recommended by Ford. Although both Ford and Firestone have made reference to Firestone's redesign of the wedge in 1998 due to tread belt separations, neither company has fully addressed the fact that the wedge gauge (thickness) is unusually small or that the placement of the wedge (length) has a direct impact on durability of the tire at the belt edges.

- Reducing the tires' weight in the mid-1990's resulted in insufficient coverage over the belt edges between the tire's tread blocks ("pockets") and eliminated any margin for error. The material removed from the tires to reduce weight restricted the engineers' ability to specify a durable belt edge design with a smooth transition from the rigid belt edges to the flexible upper sidewall. While the tire may have performed marginally when produced precisely to specification and operated lightly loaded and at maximum inflation pressure, the high incidence of failure indicates that the design was unacceptable when the tire was exposed to the Explorer loads and normal variations encountered during volume production. Firestone has acknowledged the weight reduction that occurred, but Ford continues to sweep the issue under the rug because the weight reduction in the tire was directly related to the fact that the Explorer was so poorly designed that its wheels would not stay on the ground during foreseeable turning maneuvers.

- The tire design is both unreasonably sensitive to variations in the production process and unreasonably sensitive to operating conditions, affording no margin of safety.

- The "pocket" shoulder design contributes to the generation of excessive internal heat at the belt edges.

- Radiographic analysis reveals "waviness" at the belt edges on both the 15- and 16-inch tires. This indicates that there is significant movement of the tread rubber to fill the shoulder blocks of the tread pattern during curing, causing increased stresses on the belt edges. The significant material flow during curing makes it more difficult to control the thickness of the tread rubber over the belt edges in the areas between the tread blocks. The waviness results in the creation of localized high stress areas, which result in crack formations at the belt edges. Neither Ford nor Firestone has addressed this "waviness" as a potential trigger for the development of the crack.

- Radiographic evidence demonstrates that the wire alignment within the belts is not uniform. It also reveals bad splices and excessive belt placement variation. The frequency with which these conditions appear indicates that they have a direct relationship with the tire's design.

- The wire cord chosen for use in the tires (1x5) is old technology chosen to reduce cost. It exacerbates the problems created by the shoulder design because it allows oxygen to interact with the rubber, resulting in degradation of the skim compound. The cord's characteristics increase the tendency of the belt edge cracks to spread inward between the steel belts. Neither Ford nor Firestone have addressed the role of the 1x5 wire cord characteristics as a contributing factor which enables the spreading of cracks, despite the history of this problem as revealed by the 1978 Firestone 500 recall.

- The tire's "skim compound" has inadequate rubber-to-wire adhesion for the particular design characteristics of the tire and steel wire. As the rubber loses adhesion from the steel belt cords, cracks develop at the belt edges, particularly in the wedge.[5] The cracks propagate between the belts, resulting in separation.

- Inherent design problems in the Explorer created a danger that the Explorer would roll over in foreseeable turning maneuvers. Instead of modifying the design of the Explorer to fix the instability, Ford unilaterally chose to recommend that the tires be operated at 26 pounds per square inch (psi), significantly below the maximum allowed inflation pressure. Ford's recommendation was an attempt to cosmetically make the Explorer perform better in quick-turn, emergency-avoidance maneuvers, but the lower tire pressure increased the rolling resistance of the tires, thereby raising their operating temperature and decreasing belt-adhesion.

- The decreased inflation and increased rolling resistance also lowered the Explorer's fuel efficiency. To correct the fuel economy problem, Ford changed the tire design to make the tire lighter in weight, less durable, and more prone to the stresses created by use on an Explorer at Ford's recommended inflation pressure.

The combination of the foregoing factors cause unusually high stresses and heat at the belt edge area of the tires. This directly results in small cracks that spread inward, ending in complete tread belt separations, especially when the tires are used in hot climates in a loaded condition and at high speeds.

III. HISTORY AND CONTEXT

A. The Recall

On August 9, 2000, Ford Motor Company and Bridgestone/Firestone, Inc. jointly announced the recall of approximately 6.5 million ATX, ATX II and Wilderness AT tires. The recall included the P235/75R15 (15-inch) ATX and ATX II tires, but only those Wilderness AT tires manufactured at Firestone's Decatur, Illinois, plant.[6] The majority of the recalled tires were offered as standard equipment on Ford Explorers. The latest count by NHTSA shows that failures associated with these tires resulted in 184 deaths and more than 700 injuries.

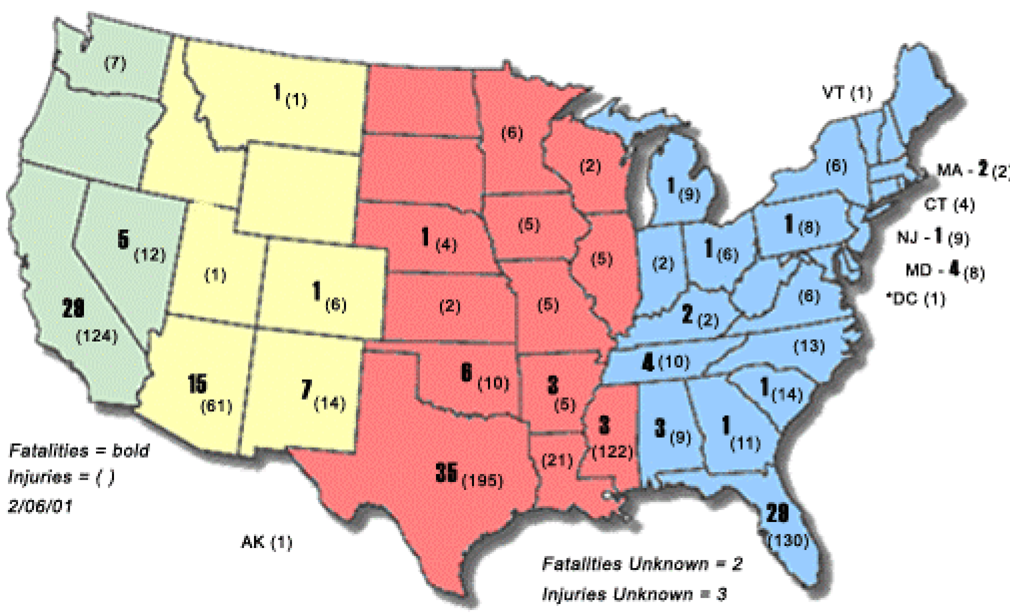
The number of fatalities resulting from the combination of the ATX/Wilderness AT tires and the Ford Explorer is extraordinarily high.

	ODI Consumer Complaint Database	Firestone Reports	Ford Reports	State Farm Reports	*Safetyforum.com*	FARS	**TOTAL**
Number of Non-Duplicative Fatalities Reported, by Source	126	19	5	3	19	2	174

In order to put these statistics in perspective, the 1978 Firestone 500 automobile tire recall was initiated following the reporting of 34 fatalities, which prompted the House Subcommittee on Oversight at that time to make the following observation:

> The Subcommittee is aware of only one other vehicle safety defect which has amassed a number of associated fatalities exceeding 34. This defect is that of the gas tank in certain Ford Pintos which the Ford Motor Co. recently agreed to recall following negotiations with the NHTSA.[7]

A majority of the recent Ford/Firestone tire failures that caused injury or death were crashes that occurred in the south and southwest regions of the United States. Virtually all of these cases involved Ford Explorers. The following chart illustrates the distribution of fatalities and injuries associated with the combination of Firestone tire failures on Ford Explorers, as collected by NHTSA.



B. NHTSA Investigation

The Motor Vehicle Safety Act, 49 U.S.C. § 30118(b) empowers the NHTSA Administrator, as the Secretary of Transportation's delegate, to require a manufacturer of a motor vehicle or equipment "contains a defect related to motor vehicle safety" to furnish notification of the defect to owners, purchasers and dealers and to remedy it without charge. Section 30102(1) of the Act defines "motor vehicle safety" as the protection "against [the] unreasonable risk of accidents occurring as a result of the design, construction or performance of motor vehicles and against unreasonable risk of death or injury in an accident and includes non-operational safety of a motor vehicle."

The Safety Act, 49 U.S.C. § 30102(a)(2), further defines "defect" as including "any defect in performance, construction, a component, or material of a motor vehicles or motor vehicle equipment." A showing of a safety-related performance problem, or a large number of failures in use, is sufficient to establish the need for a recall under the law, regardless of whether a particular "abnormality" is identified as the root cause.[8] Stated simply, knowing the "root cause" is not essential to a finding of a defect, if a clear pattern of safety-related failures that can cause death or injury is present in an identifiable group of tires.

Automobile safety recalls have been ordered by NHTSA (and sustained in court challenges to the recall) when only a "risk" of accident or injury exists. Recalls are also sometimes deemed "imperative" when the fatalities caused by the defect are well-documented.[9]

The agency initiated its Ford/Firestone investigation in May 2000. Subsequent to the August 9, 2000 agreement to recall 6.5 million tires, the agency has also issued two consumer advisories on Firestone tires made for the Ford Explorer and a consumer advisory on Firehawk and other tires that it has since also urged Firestone to recall. NHTSA is continuing an investigation to determine whether additional Wilderness AT tires (i.e., those not manufactured in Decatur) should be recalled.

A decision could be announced at any time. NHTSA originally had indicated that the Ford/Firestone investigation would be complete by March 2001.

C. Firestone Interim Report And Root Cause Analysis

On December 19, 2000, in a report, Firestone acknowledged design flaws in its 6.5 million recalled tires and blamed both itself and Ford for the consequences of the tire failures.[10] The report concluded that the scope of the recall of the company's tires was sufficient to protect consumers. Firestone cited four major causes of the tire failures and crashes of the Explorers:

- Design problems in the Explorer triggered Ford's recommendation that the tires be inflated to 26 psi, significantly lower than the maximum level of inflation allowed. According to Firestone, the lower inflation level "increased the running temperature of tires and contributed to a decreased belt-adhesion level."

- Problems in the tire manufacturing process included the composition of the rubber used and the adhesion characteristics of tires made in Firestone's Decatur plant. According to Firestone, the recalled tires from Decatur "exhibited different belt-adhesion characteristics, including lower initial adhesion, than those same size and line of tires produced at other plants."

- A problem in the design of the shoulder of the tire, according to Firestone, "could lead to cracking . . . in the wedge area of the tire [and] result in a reduction of resistance against belt detachment or tread separation."

- Customers were misusing the tires. Firestone reiterated its recurrent contention that "many tread separations can be caused by various forms of tire damage encountered in daily use, such as punctures, improper repairs, [and] severe impacts."

Despite overwhelming evidence of a safety-related problem that cause in catastrophic injuries and death, Firestone persists in its claims that its tires have an "adjustment rate" that is within the norm,[11] and that the tires are "safe" and "not defective."

This position is reminiscent of the company policy on the dangers of its Firestone 500 tires in the late 1970s. The House of Representatives summarized Firestone's corporate attitude in August 1978 as follows:

> In this case, however, an entrenched and recalcitrant manufacturer [Firestone] has refused to take remedial action and moreover has sought to prevent the responsible Federal agency from doing so.[12]

The 1978 Committee further noted that Firestone seemed "committed, as a matter of apparently irreversible corporate policy, to stonewalling on the issue of a safety recall of the affected tires," and that Firestone steadfastly refused to acknowledge any safety problem that was responsible for the fatality and injury-producing failures.[13]

History is now repeating itself, as Firestone stonewalls and refuses to recognize the significant risk created by its choices to continue to place money before safety.

D. Firestone Consultant's "Root Cause" Report

Firestone retained Dr. Sanjay Govindjee, a professor from the University of California at Berkley, to conduct an "independent analysis" of the Firestone tires used on the Ford Explorer. On January 30, 2001, Dr. Govindjee issued a formal "root cause" report. Although not an expert in tire design, Dr. Govindjee specializes in materials. In brief, he concluded:

- The problem is "understood to include" the propagation of a fatigue crack in the bulk of the rubber separating the two steel belts of the tire, not at the interface between the steel and the rubber.

- The cracks occur in both new and used tires.

- Contrary to Firestone's limited recall of Wilderness AT tires, the cracks or belt edge separations were found in a greater percentage of tires produced at the Joliette and Wilson Firestone plants than the Decatur plant.

- The problem is "rather complex" and determining a "single cause" is an "unrealistic expectation."

- There are no "well-established criteria for in-service tire failures against which tire components are designed."

- The industry is not clear how its tire testing relates, if at all, to in-service – that is, real-world – tire failures.

- The materials from tires in southern climates have “reduced ductility” and “higher stiffness,” independent of service condition.

- Aging contributes to degradation of internal components of the Firestone steel belted radial tires.

- The capacity of the belt skim compound to resist fracture is “markedly reduced” for tires manufactured at the Firestone Decatur, Illinois plant, although their properties are within the approved specifications for the tires. Although Firestone identified a manufacturing process called “pellitizing” as unique to Decatur and therefore supporting the limited recall, Dr. Govindjee’s search into the process found no causative agent for the degraded material properties from the Decatur plant related to this process.

- The belt edges of the subject tires have a “pronounced” heat build-up as inflation pressure is lowered with a heavy cargo load and operated at high speeds.[14]

- The impact of tire design on tire temperature “has not yet been established.”

E. Ford Interim Report and Root Cause Analysis

In its official “root cause” report of December 19, 2000, Ford also blamed the failures of the tires on a combination of design problems and manufacturing difficulties encountered at Firestone’s Decatur plant. Ford, however, disputed Firestone’s claim that design flaws in the Ford Explorer played a role in the crashes.

Ford reported that its “engineers and scientists” were involved in an “ongoing statistical analysis” and that the company’s “test data” appeared to agree with many of Firestone’s preliminary conclusions.[15] Ford’s report included the following findings:

- Testing on Ford and other makes of vehicles and on tire test rigs showed that the P235/75R15 ATX and Wilderness AT tires do become hotter during use than similar competitive designs, although Ford did not know why.

- Test data showed that belt-area rubber cohesion is lower in Decatur-built tires. The data, however, did not identify what aspect of manufacturing may cause this.

- Ford did not test or analyze tires which had a puncture repaired, but reasoned that a tire already sensitive to heat because of design and manufacturing conditions could be progressively damaged if it was further heated because of lower inflation pressures before or after such a repair.

Although not mentioned by Ford in its root cause analysis, internal Ford records document that failed tires from Venezuela showed “no apparent reason for failure,” from external damage such as punctures, cuts, etc., and that there was no evidence of "reversion," defined as the overheating of rubber that is typically present when a tire is operated in an under-inflated condition.[16]

As for tires operated in the U.S., Ford noted that under-inflation was not a reasonable explanation for the significant number of failures because U.S. consumers typically "over inflate tires."[17]

While Ford did not define fully the cause of the tread separation problem, its "preliminary root cause hypothesis" was that:

> The design of the tire generates high stresses and heat in the wedge and belt area. Manufacturing processes at Firestone's Decatur Plant reduce the cohesion level of the rubber in that same area of the tire. This reduced strength permits cracks to propagate between the steel belts. We believe it is a combination of manufacturing factors and the reaction of the tire design to field operating conditions including hot weather and very low tire pressure that have caused the increased failure rate of these tires.

F. The Unanswered Question

Despite the differences of opinion between Ford and Firestone relating to the role of the Explorer in causing tread separations, crashes, and, most importantly, deaths and injuries, and despite the companies' ongoing refusal to define the cause of the problem, both Ford and Firestone have argued continuously that the current recall was "adequate" to protect consumers.

The companies therefore have asserted that the non-recalled tires were safe despite their lack of knowledge of the "root cause" of the problems, and the many holes in existing data.

IV. TIRE HISTORY

A. Relevance of Tire Development History

Every tire design begins with the consideration of factors such as customer or market demand in terms of size, load carrying capacity, intended use, and any special tread design requirements. A typical radial tire has approximately 24 separate components and 12 or more rubber compounds, all of which impact load carrying capacity, proper inflation pressure, and intended use.[18]

Despite slight differences among companies, the basic manufacturing process is the same. The tire components are assembled and then cured or vulcanized. The purpose of curing the tire – sometimes called "cooking" – is to create both a mechanical and chemical bond between the internal components.

The bonding process, sometimes referred to as "adhesion," is impacted by the stress and forces applied to the tire. The shape of the tread, the internal design of the tire's components, and the material properties of those components dictate what stresses will be applied to each component while the tire is in operation. The forces and stresses exerted on a tire are subject to the combined effect of tire size, inflation pressure, dimensions, component gauges and vehicle characteristics.

Any examination of the cause of repeated tread separation events requires a thorough investigation of the history of the tire, its design, development, and the market needs that it was designed to satisfy.

B. Development of the Tire For the Ford Explorer

A fuller history of the ATX II tire was provided in a report published by Public Citizen and *Safetyforum.com* on January 4, 2001, entitled *Spinning Their Wheels*.[19] The following is a brief summary of the tire's design history.

The Firestone P235/75R15 ATX – informally referred to as the ATX II – was created for use on the Explorer.[20] Earlier versions were produced as a flotation[21] tire for Recreational Vehicles (RVs) and designed with aggressive tread patterns and zigzag treatment on the tire sides, or "shoulders." As the market for sports utility vehicles (SUVs) shifted to include traditional users of station wagons and other family passenger cars, Ford instructed Firestone to develop a "hybrid tire" which looked like an aggressive truck tire but performed like a passenger car tire.[22] Company documents show that Ford ordered this modified ATX tire from for marketing reasons: Ford believed that larger tires would better fit the image of the Explorer and help to increase vehicle sales.

Since the introduction of the ATX II tire, Firestone manufactured approximately 22,800,000 ATX and Wilderness AT 15-inch and 16-inch tires. Some 14,400,000 of the tires have been recalled. Of the remaining 8,400,000 tires sold, 3,500,000 are P255/70R16 Wilderness AT tires and 4,900,000 are non-Decatur-made Wilderness AT tires. Of course, some number of the tires sold are likely no longer in use.

The ATX II tire developed for the Explorer is commonly referred to as a "P Metric" or "passenger" tire. Although the Explorer is a light truck under applicable government regulations, Ford did not request, nor did Firestone provide, a "Light Truck" or "LT" metric tire for use on the vehicle. "Light Truck" tires are typically rated by load range from C-E, which means up to 3000 lbs with inflation pressure ranging from 50-80 psi. For "Light Truck" tires, the Tire and Rim Association (TRA) does not recommend operating "Light Truck" tires at speeds in excess of 65 mph unless the operator: (a) decreases the load on the vehicle; and (b) increases the inflation pressure of the tires.

The Wilderness AT tire was designed to replace the ATX II tire beginning with Ford's 1995 Explorer model.[23] Tires of both types were manufactured primarily at three Firestone facilities: Decatur, Illinois, Wilson, North Carolina, and Joliette, Québec, Canada. According to information provided by Firestone, the production of ATX II and Wilderness AT P235/75R15 tires varied by year and plant site.

The Ford Explorer was first produced in 1990 to replace the Bronco II. The Bronco II was known to have a dangerous tendency to flip over during typical emergency turning maneuvers. The Explorer was referred to as the "4-door Bronco II" during development. That name was changed when the Bronco II came under sharp scrutiny as deaths mounted in Bronco rollover crashes.

The stability problems of the Explorer were known early and were well documented. As further reported in *Spinning Their Wheels*, Ford management knew the Explorer had a stability problem, ignored its engineers' recommendations to fix the problem, and consciously disregarded the safety of the consuming public because of the potential impact the changes would have on cost and market timing. The alternative Ford chose – deflating the tires – was a cosmetic attempt to improve the vehicle's stability. Ford's adaptation further undermined the capacity of the Firestone tires, with disastrous consequences.

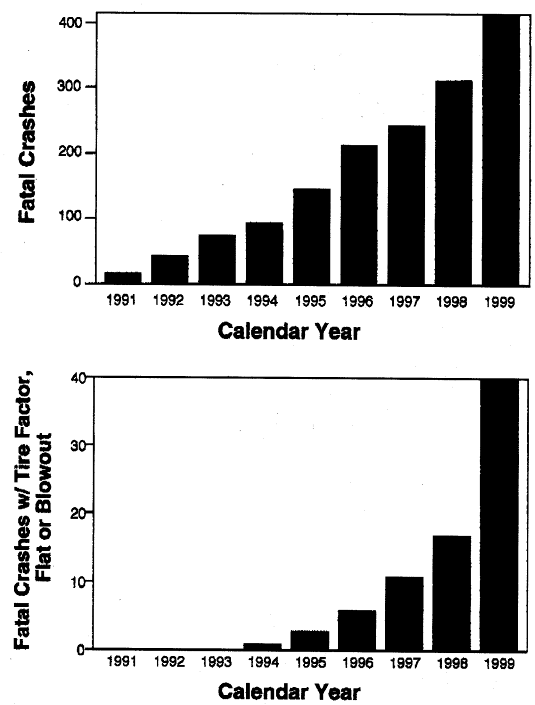
The tread separation problems of ATX tires on Explorers began not long after the SUV went on sale in 1990. Both corporations have been settling lawsuits over the defective tires ever since, typically after securing agreements to maintain the confidentiality of company documents. But, according to available records, these lawsuits were fairly sporadic until a tire weight design change was made in the mid-1990s, following the decision by Ford to deflate the tires when introduced. A summary of Ford's design decisions follows.

Following introduction of the Explorer, Ford initiated design changes in the tires used on the Explorer to correct rolling resistance problems that had been created by the company's decision to recommend lower tire pressure. One consequence of tire deflation was increased rolling resistance, or friction between the tire and the highway, which produces lower fuel economy. To improve rolling resistance and fuel efficiency, Ford decided to lower the tire's weight.

According to Firestone, the weight decrease in the tire was achieved by reducing the gauge of various internal components, modifying the sub tread compound, using a lightweight belt package, and making specific modifications to the tire sidewall.[24] In short, Firestone removed weight from the tire by reducing its rubber and steel components. The tire was made lighter, less durable – and therefore, as defined below, less "robust" – and more susceptible to tread separations.

After that change, tire failures and crashes – including deaths and injuries – escalated rapidly.[25] The following charts graphically illustrate this increase in tire-related deaths associated with Explorers.

Fatal, Ford Explorer Crashes in 1991-1999



Source: National Highway Traffic Safety Administration, Fatality Analysis Reporting System (FARS), Model Years 1991-2000

Quality Control Systems Corp.
2 November 2000

The upper graph shows fatal injuries in Ford Explorers from all forms of crashes beginning in 1991, when the Explorer was introduced. The lower graph reflects those Explorer-related fatal injuries in which a tire-related problem was implicated. As the lower graph depicts, fatal crashes involving tire-related factors began to mushroom in 1995-96.

To improve tread wear and fuel economy, and in keeping with Ford's desire for an aggressive tire image, Ford again asked Firestone to redesign the ATX.[26] In 1995, Firestone released for production the Wilderness AT design, a tire specifically designed to accommodate Ford's request for a truck-looking tire that performed like a passenger car tire. The tire was a standard load[27] tire that incorporated internal components that were virtually identical to the ATX tire, but the new tire was equipped with a different, more aggressive-looking, tread pattern.[28]

The design for the Wilderness AT tire did not incorporate internal components of the size and gauge that a tire expert would typically expect to be included in a light truck tire because Ford had specifically requested that the tire deliver passenger car performance. The Wilderness AT tire was assigned a "C" rating for temperature/heat resistance, the lowest possible rating allowed under NHTSA's passenger car Uniform Tire Quality Grading System.[29]

Within 12 months of production of the first Wilderness AT tire for use on Ford Explorers, Firestone's engineers began trying to improve the tire's durability, and to reduce the risk of tread separation, by making certain design changes to the tire.[30]

V. METHODOLOGIES AND RESULTS OF THIS CONSUMER TIRE INVESTIGATION

A. Methods Used

The information in this report is based on: 1) the physical examination and photographing of more than 100 tires obtained from consumers in the U.S. and abroad, including tires that failed and ones that did not; 2) x-rays of a sample of tires produced at each of the three Firestone plants where tires for the Explorer were made (A chart listing the sample tires chosen for x-ray may be found at Appendix 1); 3) examination of indoor and outdoor test results produced by both Ford and Firestone; 4) examination of design documents from both Ford and Firestone; 5) examination of the internal components of the tire sizes in question; 6) independent laboratory tests and 7) actual vehicle testing of a Ford Explorer in a simulated tread separation event.

B. Investigation Results for the P235/75R15 (15-inch) and P255/70R16 (16-inch) Wilderness AT Tires

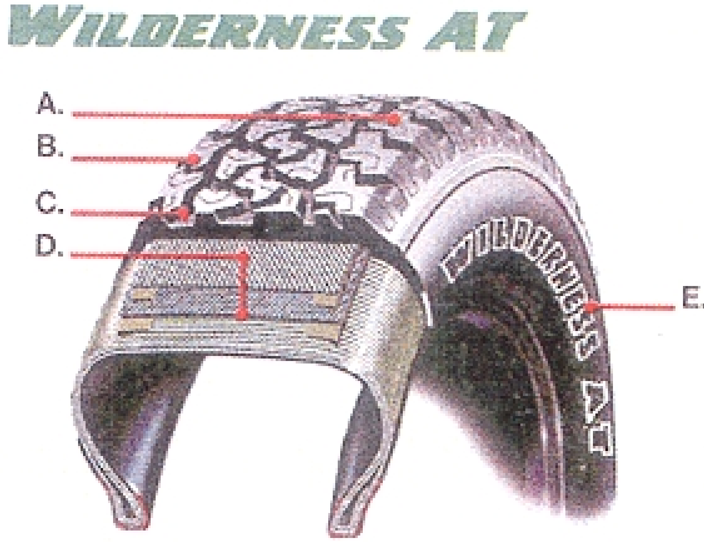
1. Tire Design

A tire's belt edge is a structural discontinuity that produces high local stress and can be a starting point for cracks. However, crack formation, and accompanying propagation, is usually not a problem because as the crack progresses inward, the stresses are relieved and the separation is limited.

The fundamental elements of strength between the steel belts are the adhesion strength of the rubber encasing the steel cords ("skim stock") and the design configuration of the material. Belt edge separations occur when the stresses at the belt edges exceed the adhesion strength of the skim compound between the belt edges and between the materials surrounding the belt edges, including the "wedge," a piece of rubber located between a tire's two steel belts. The concentration of stresses at the belt edges occurs because the steel belt wires are much more rigid than the rubber or the polyester radial plies.

Design strategy should seek to reduce this concentration of stress as much as possible. The features used to achieve this and improve durability at the belt edges include the geometric design of the internal components, belt edge step-off (the bottom belt is made wider than the top belt), the wedge between the belt edges, the distance from the top of the steel belt that is closest to the tread and inside the shoulder pocket, the configuration of the shoulder pocket, and the tapering of the total thickness of the tire from the belt edges to the upper sidewall area.

The following illustration shows the internal components of the Wilderness AT tire.



2. Description of the Failure Mode

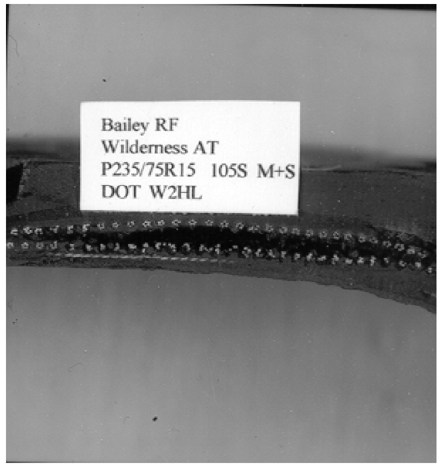
Several investigators have referred to the tire failures in question as "fatigue" failures, which is a general term used to scientifically describe the sudden and catastrophic separation of a device into two or more pieces caused by the application of loads or deformations over time. Fatigue failure typically occurs through the initiation and spreading of a crack. The loads and deformations typically necessary to cause failure by fatigue are less than those necessary for static failure.

To date, investigators from both Ford and Firestone agree that the tires at issue are experiencing steel belt separations (cracks) that begin at the belt edges. The separations most frequently begin at the edge of the #2 belt (the upper belt), which is the highest stress point in the tire.

The cracks found in field tires are not resulting in reversion of the rubber (melting), as one would typically expect to find in the case of excessive heat. The lack of rubber reversion indicates that the tires are suffering from very high shear strain, which is due to heavy loading. The heavy loading strains the rubber beyond its capability and results in the formation of cracks. The existence of high temperatures tends to accelerate the growth of the cracks between the #1 (lower) and #2 (upper) belt. The growth rate of the separation cannot be defined precisely, and appears to vary by tire, load condition, inflation pressure and ambient temperature.

From the wedge, the tear tends to grow toward the center of the tire between the steel belts. The crack also tends to grow circumferentially. The final stage is total or partial separation of the #2 belt from the #1 belt and tire carcass.

The following figure shows the crack after it has spread inwardly between the two steel belts. The cross-section shown below was taken from a Wilderness AT tire manufactured in Wilson, North Carolina. When inspected, this tire's internal separation had not yet grown into a total separation.



The next pair of photographs shows a virtually identical condition in an ATX tire manufactured at Firestone's Wilson plant and a Wilderness AT tire made at Firestone's Decatur plant. Both of these tires have been recalled. Although the Wilson-made Wilderness AT tire in the photograph above shows the identical pattern of cracking and separation as in the two recalled tires below, the tire in the photograph above has *not* been recalled. The most striking feature of these three photographs is the identical nature of the crack and propagation spreading inward between the belts. The photographs demonstrate that the same failure mode is present in both recalled and non-recalled tires.

The individual filaments of the cut wire ends at the belt edge have razor-sharp profiles that introduce high stress conditions and cause the rubber to separate. As the rubber along the cord continues to tear, it typically leaves a ring pattern referred to as "socketing." When the degree of socketing allows sufficient movement of the belt, the torn rubber surfaces begin a polishing action. The extent of "polishing" is one indicator of the amount of movement that has occurred at the belt edges.

3. The Tire Design Lacks Adequate Durability

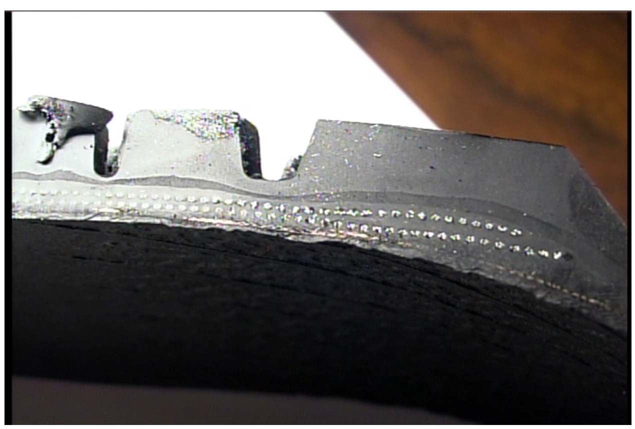
All SUV tires must be designed to carry both the heavy SUV and the occupants and cargo when the vehicle is fully loaded. The tire should be designed to accommodate a wide range of loads and inflation pressures in order to ensure safe operation at freeway speeds. This margin of safety should likewise include a consideration of the plant-to-plant manufacturing variances that are known to occur during mass production.

Ford Motor Company responded on February 5, 2001, to a report by Firestone's independent consultant concerning carrying capacity with the following statement:

> Ken Zino, a Ford spokesman, said today that the problem was that the tires were unusually sensitive to the loads on them, and not that the Explorer was too heavy for its tires. "We have studied that, and there's nothing unusual in the Explorer as far as loads," he said.[31]

All tires should be designed to be "robust."[32] That is, they should be designed to meet the customer's expectations of wear and durability on the vehicle for which they were designed during the life of the tire.[33] "Robustness" includes the ability to perform safely and appropriately given the conditions and load carrying capacity for which the tire was designed.[34] The tire should have appropriate internal components so that it can withstand the forces and loads it was designed to encounter in the real world.[35] A tire that is not robust presents the likelihood of catastrophic failure, such as tread separation.

The design of the ATX II and Wilderness AT tires is not robust. Representatives of Ford Motor Company have testified under oath that 15-inch Wilderness tires are not "robust" for the use for which they were created.[36] The following is a cross-sectional view of a Wilderness AT tire at the belt edge.



The cracks that start at the #2 belt edge result from a combination of a wedge that is poorly designed, both in its gauge and placement, a less-than-robust wedge compound, and a skim compound that is inadequate given the tire's other design characteristics.

The purpose of the wedge is to help separate the steel belts, assist in the local distribution of shear forces, and to provide durability in the sensitive area at the belt edges. Firestone chose a wedge design for the ATX and Wilderness AT tires that was designed for use in a passenger car. The gauge, or thickness, of the wedge is less than that found in other truck-type tires and results in low tearing forces, and therefore poor durability, at the belt edges. Firestone's placement of the wedge is also an important factor because the distribution of the stress/strain forces has a relationship to the distance between the edge of belt #2 and the shoulder of the tire. Greater distance between these points results in the tires that run hotter, and in more stress build-up in the tire.

The tires in question have a larger-than-expected distance between the edge of belt #2 and the tire shoulder. Ford's decision in the mid-1990s to reduce the tire's weight resulted in insufficient coverage over the belt edges between the tread blocks (or "pockets"), increased stress and strain on the already weak wedge section, and eliminated any margin for error. The significant amount of material removed from the tires to achieve the weight reduction restricted the engineers' ability to specify a durable belt edge design with a smooth transition from the rigid belt edges to the flexible upper sidewall.

While the tire may have performed adequately when produced precisely to specification and operated at maximum inflation pressure at low to moderate speeds, the high incidence of failure indicates that the design was unacceptable when exposed to the normal variations encountered during volume production, normal usage by consumers and the low inflation levels recommended by Ford (26 psi).

4. The Shoulder Design Creates Additional Heat and Stress

The ATX and Wilderness AT tires are designed with a pattern of cavities between the "lugs" around the edges of the tread on the tire's shoulder. Firestone refers to these spaces as "shoulder pockets."

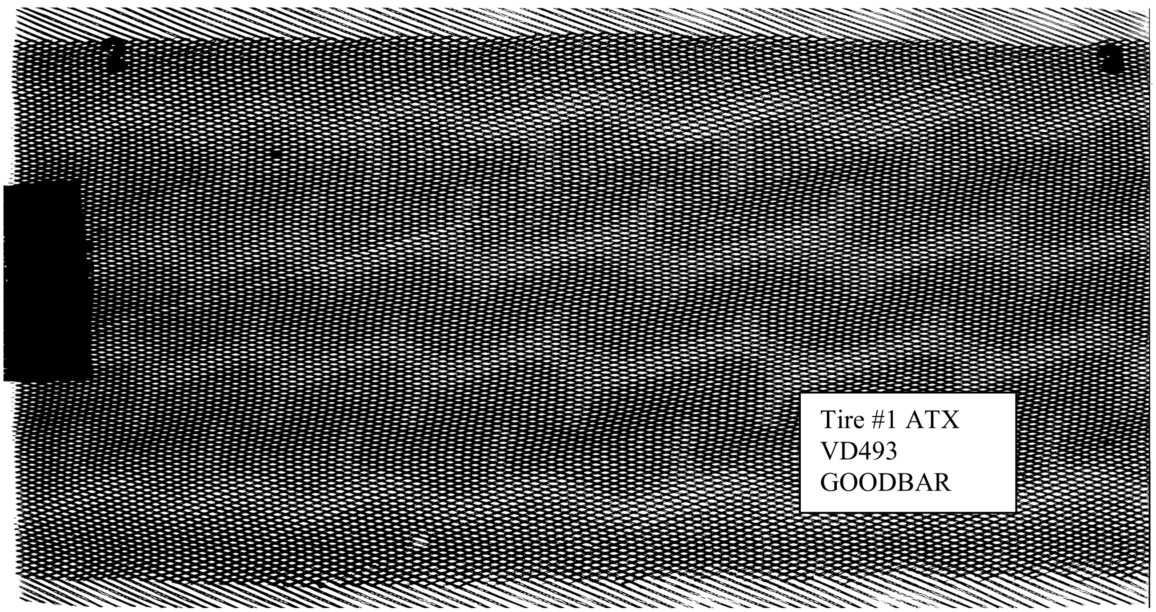
The "pocket" design invites additional stresses to occur inside the shoulder pocket, causing excessive heat at the belt edges internally and allowing small cracks to develop. An analysis confirmed that the temperature profile for the Firestone tire was "more severe" than Goodyear's, given the same speed, loading and pressure.[37] A Finite Element Analysis likewise confirmed that extremely high stress is exerted on the belt edges because of the tire's design. Analysis also found that the level of stress is elevated when the tire is exposed to high speed, low inflation and high ambient temperatures.[38]

The "pocket" design also has a tendency to allow the development of external cracks, both small and large.[39] These cracks tend to enlarge during rolling deformations and can act as a pump that allows the introduction of water or moisture when driven in wet conditions. If the moisture reaches the steel cord network, where belt separation resistance is lowest, separation can begin or be exacerbated.

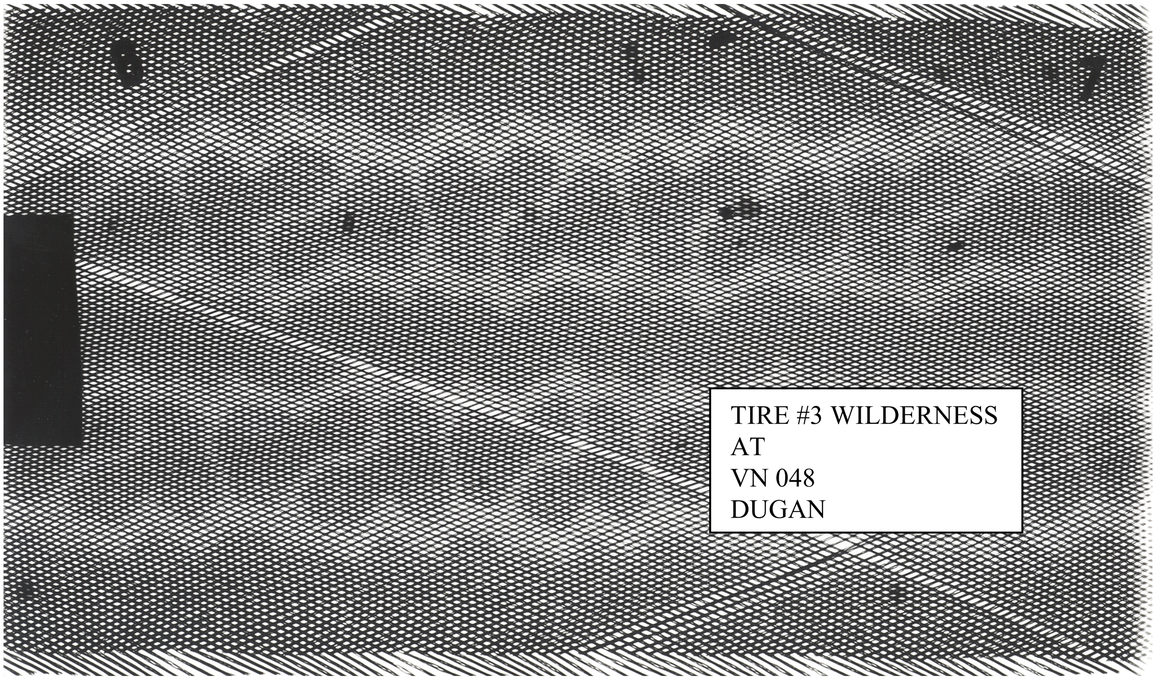
5. Radiographic Evidence Verifies the Design Problems

The belt edges radiographically demonstrate “waviness,” which indicates significant movement of the tread rubber to fill the shoulder blocks of the tread pattern during the curing stage of manufacturing. This waviness results in increased stresses on the belt edges. Significant material flow during curing makes it more difficult to control the thickness of the tread rubber over the belt edges in the areas between the tread blocks.

The following figure, an x-ray of an ATX tire made in 1993 at Firestone’s Decatur, Illinois Firestone plant, shows this “waviness.”



The next figure, an x-ray of a Wilderness AT tire made in 1998 at the Joliette, Québec, Canada plant, also shows the waviness common to Wilderness tires.

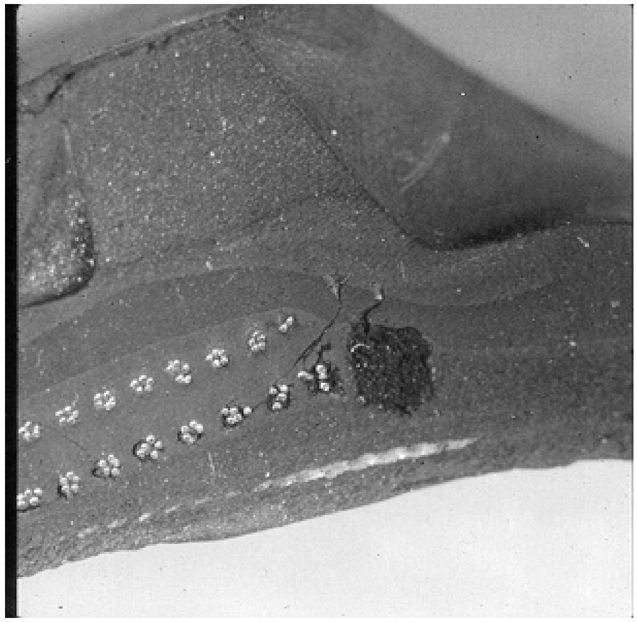


This “waviness” is not present in the P255/70R16 Wilderness AT “Special Services” tire. The “Special Services” was a tire produced for the Saudi Arabian market and was obtained by *Safetyforum.com* as part of this investigation. That tire includes a nylon overlay, which not only adds to the tire’s durability, but also reduces material flow during the curing process.

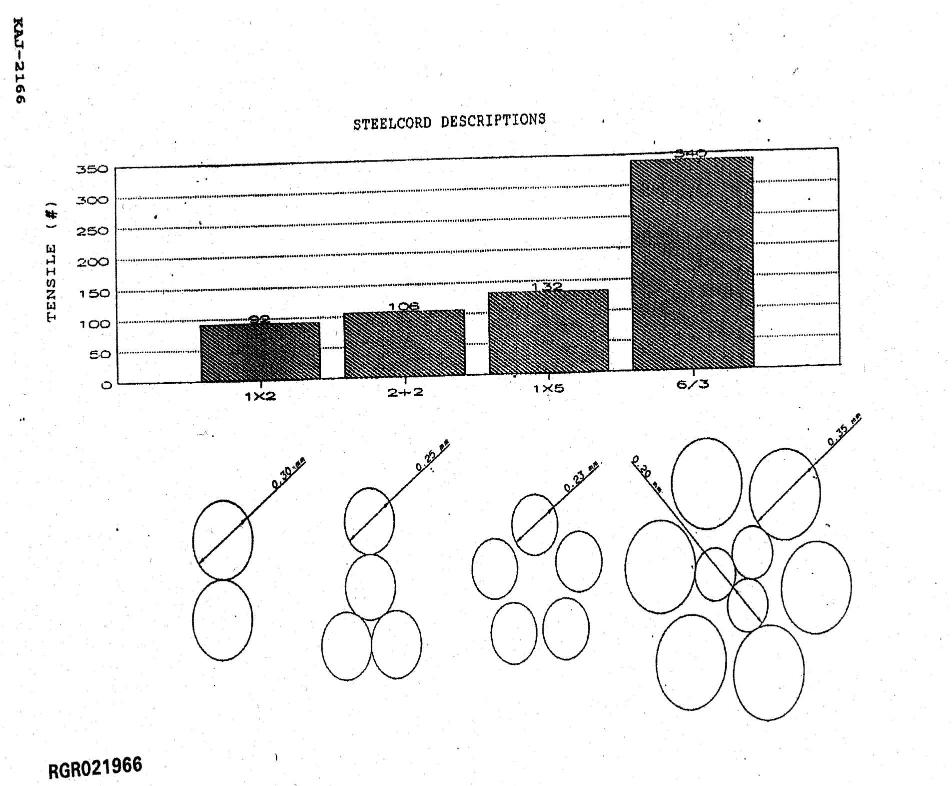
Radiographic evidence of a sampling of both recalled and non-recalled tires also demonstrates non-uniformity in the wire alignment within the belts, bad splices and excessive belt placement variation. The frequency with which these conditions appear on the sampled tires indicates a direct relationship with the design of the tire.

6. The 1x5 Wire Cord Increases the Likelihood of Failure

The wire cord (1x5) chosen for use in the tires is inappropriate given the shoulder design and the anticipated loads and usage of the Explorer. The chosen cord increases the tendency of the tires to develop separations and lose adhesion qualities. The illustration below shows the 1x5 wire configuration in the P235/75R15 (15-inch) Wilderness AT tire. The illustration documents the existence of breakdown at the belt edge, including cracks that are beginning to spread inward and the loss of adhesion between the steel cords and the skim or rubber surrounding the cords.



The following is a diagram illustrating the design and tensile strength characteristics of various wire designs, including the 1x5 design. Note the additional strength characteristics of the 6x3 cord design, which is a design typically incorporated into light truck-type tires.



The 1x5 wire design is old technology. Its use is one strategy for reducing the cost of production. In this design, the individual strands of steel are tightly wrapped and do not allow for rubber to penetrate to the core of the bundle. If the rubber does not penetrate to the core, the entire belt structure can become a conduit for circulating air through the belt. Inflation air can therefore permeate through the inner liner. Ford's specifications to Firestone did not include loss over time, so Firestone was free to choose a less expensive (and less reliable) inner liner compound, which allowed more air permeation into the tire.

Excessive moisture also contributes to tread separations. Moisture can enter through punctures, cracks, factory or manufacturing problems, as well as the simple permeation of air and moisture through the inner liner of the tire. Moisture tends to combine with chemicals in the tire's stock to erode the adhesion bond between the steel wires in the belts and the surrounding rubber matrix. This causes tread distortion and, ultimately, separation.

Firestone used the same 1x5 wire design in the Firestone 500 tires that were produced – and recalled – in the 1970's.

7. The Skim Compound has Poor Rubber-to-Wire Adhesion Characteristics

As a general proposition, tire compounds are polymer rubbers or polymer blends with fillers (highly developed carbon blacks), processing aids such as softeners, plasticizers or reclaimed rubber, vulcanization accelerants (sulfur and zinc oxide), and chemical protective agents, sometimes known as antioxidants and antiozonants.

Modulus and hardness can be controlled by varying either the amount of carbon black, the amount of extender-oil or softener, the fineness and structure of the black, or the number of molecular crosslinks introduced during the curing process. The high modulus of skim helps wire adhesion. Aging resistance is provided by the anti-oxidants and the zinc oxide. The gauge of the steel cord and the number of twisted strands chosen for the wire are additional important factors when considering skim compound.

The skim compound or "skim stock" is a rubber coating that surrounds the steel belts. The gauge of the steel cord and the number of twisted strands chosen for the wire are important factors when considering skim compound. One purpose of the compound is to hold the belts at a specific spacing to allow relative movement of the belts without fatigue or fracture.

The peel resistance of skim rubber loses an average of 50 percent of its initial strength during the first two years, primarily from oxidation. The belt wedge, on the other hand, oxidizes more slowly because it is thicker and has less contact with the belts. As Ford's internal documents show, the aging of the ATX and Wilderness AT tires, especially the aging in the belt wedge, was "classic" oxidative aging and was not due to excessive heat build-up. This means that the physical evidence does not support customer abuse – extreme under-inflation – as a cause of tire degradation in these tires.

The following table provides an overview of several critical components of the ATX II and Wilderness AT tires. Note the similarities between the various design characteristics, including the compounds.

CHARACTERISTIC	ATX II	WILD AT 15"	WILD AT 16"
Tread Depth	0.42	0.42	0.37
Load Reserve (F/R)	193/118	193/118	513/413
Inflation	26/26	26/26	30/30
Tread Compound	NA	V6607	V6187
Subtread Compound	V4277	V3647	V4277
BEI Compound	V1697	V1697	V0027
Skim Compound	J2757	J2757	J2757
Wedge Size	.20 x .75	.20 x .75/.4 x 1	.20 x .75
Wedge Compound	J2917	J2917 to J2757	J2919 to J2757

SOURCE: Ford Motor Company

The "wedge compound" and the gauge of the wedge were changed for the Wilderness AT tire in March, 1998. The changeover was completed the following month. Testing shows that wedge compound J2757, the revised wedge compound, is 25 percent stiffer, and has approximately 5 percent more hysterisis and 5 percent better adhesion to steel than compound J2917, which was used from 1995 to 1998.[40]

The increased durability characteristics chosen for the replacement wedge compound in 1998 can be viewed as direct evidence that Firestone knew the wedge compound initially chosen for the Explorer lacked appropriate "robustness." Notably, the gauge of the wedge on the Goodyear version of the Explorer tire is significantly more robust.[41]

In the case of the ATX and Wilderness AT tires, the skim compound has inadequate rubber-to- wire adhesion characteristics for the design characteristics of the ATX II and Wilderness AT tires. This contributes to more rapid loss of adhesion and the spread of belt edge separations.

By comparison, the Goodyear tire, for instance, has a similar tendency to "crack" at the belt edges, but propagation of the cracks through the skim compound (between the belts) does not occur as easily or as often as in the Firestone tires because of the significant difference between the tires in the amount of heat build-up. Aging and plant-to-plant variations also contribute to loss of adhesion characteristics of the skim.

Firestone conducted tests to measure the force required to pull apart a one-inch strip of material similar to that used in the belt package to compare the adhesion strength.[42] After sampling strips from various plants, Firestone concluded that Decatur-made tires exhibited "different belt adhesion characteristics," including lower initial adhesion. Firestone speculated that the reduced adhesion levels, although still within required tolerances, provided less strength than tires produced at its other plants.[43]

The decreased adhesion was thought to correlate with the existence of residual materials (processing lubricants) in the skim stock that were added during a process called "pelletizing."

However, Firestone's consultant was unable to find a correlation between the manufacturing process (pelletizing) and the material degradation at Decatur.

8. Ford's Recommended Inflation Pressure of 26 psi Exacerbates the Tire's Design Flaws

The tire industry universally accepts that low inflation pressure can adversely affect tread life, increase tire rolling loss, generate excessive heat, lower gas mileage, and lead to the sudden total failure of a tire during operation which, at highway speeds, can have catastrophic results in certain poorly designed vehicles.

All tires are designed to deflect under load. This deflection is what enables the tire to support a load. Deflection of the lower sidewall tends to alter the angle of the cord tension and reduces the vertical component acting on the "bead wires," the individual filaments that make up the steel belt. The upper sidewall tension pulls on the bead wire and actually provides support for the load from the top. The deflection of the tire also benefits traction and tread wear due to size and shape of the contact patch, or footprint, of the tire.

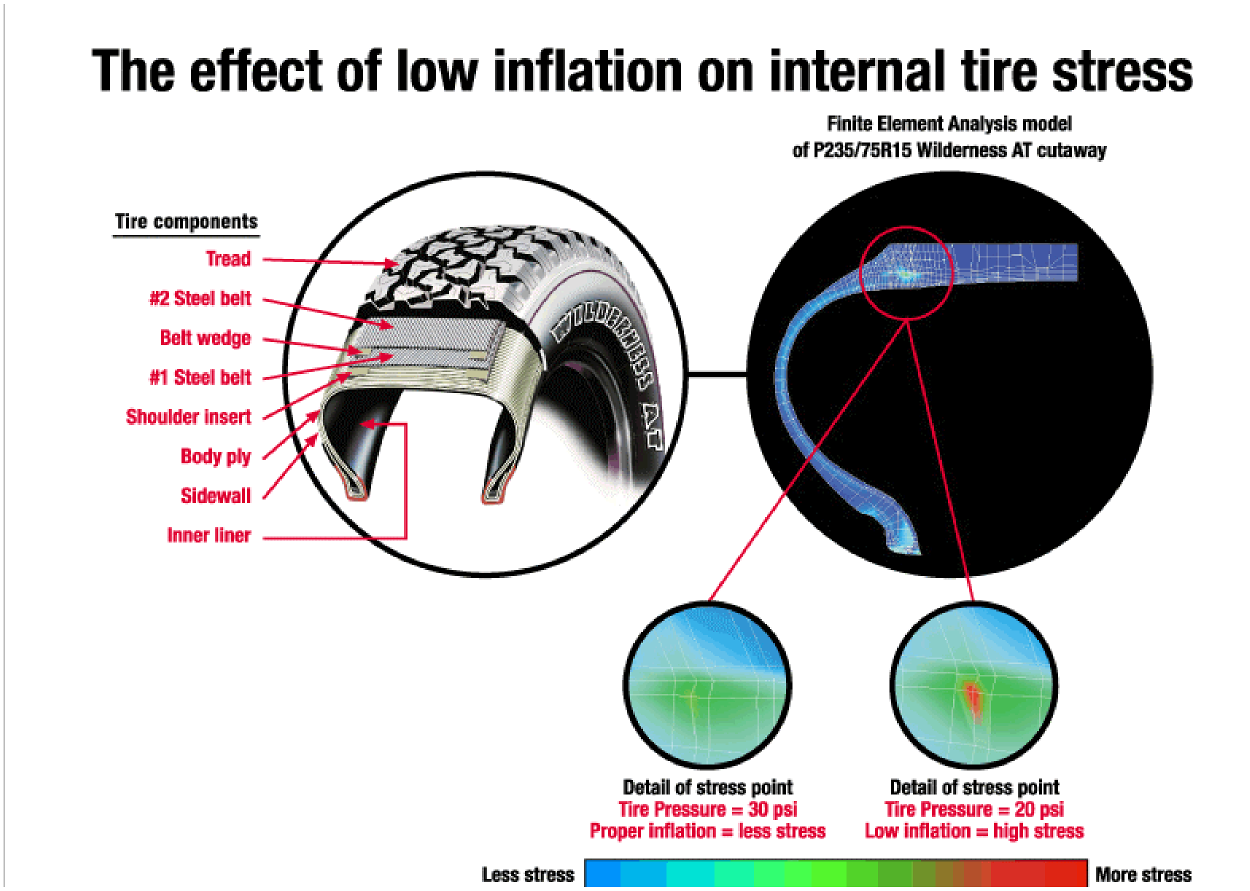
The mechanism by which inflation pressure affects tire performance and durability is straightforward. Low inflation tends to make the sidewall of the tire flex, or deflect more than it is designed to do. Flexing the sidewall builds up heat, which can cause irreversible damage to the internal components of the tire. The more under-inflated a tire is, the faster it rotates, or the more load it is made to carry, the more the tire tends to flex and the more quickly it degrades.

As a general rule, puncture resistance increases with lower inflation, but lower inflation also directly impacts the fatigue life of the tire. Key factors associated with fatigue life are the temperature inside the tire, the stress/strain field, and cycles at each condition. The operating variables that influence these parameters are speed, load, pressure and time. Speed and deflection (load and pressure) have the greatest influence on tire temperature, while deflection determines the stress/strain field of the tire.

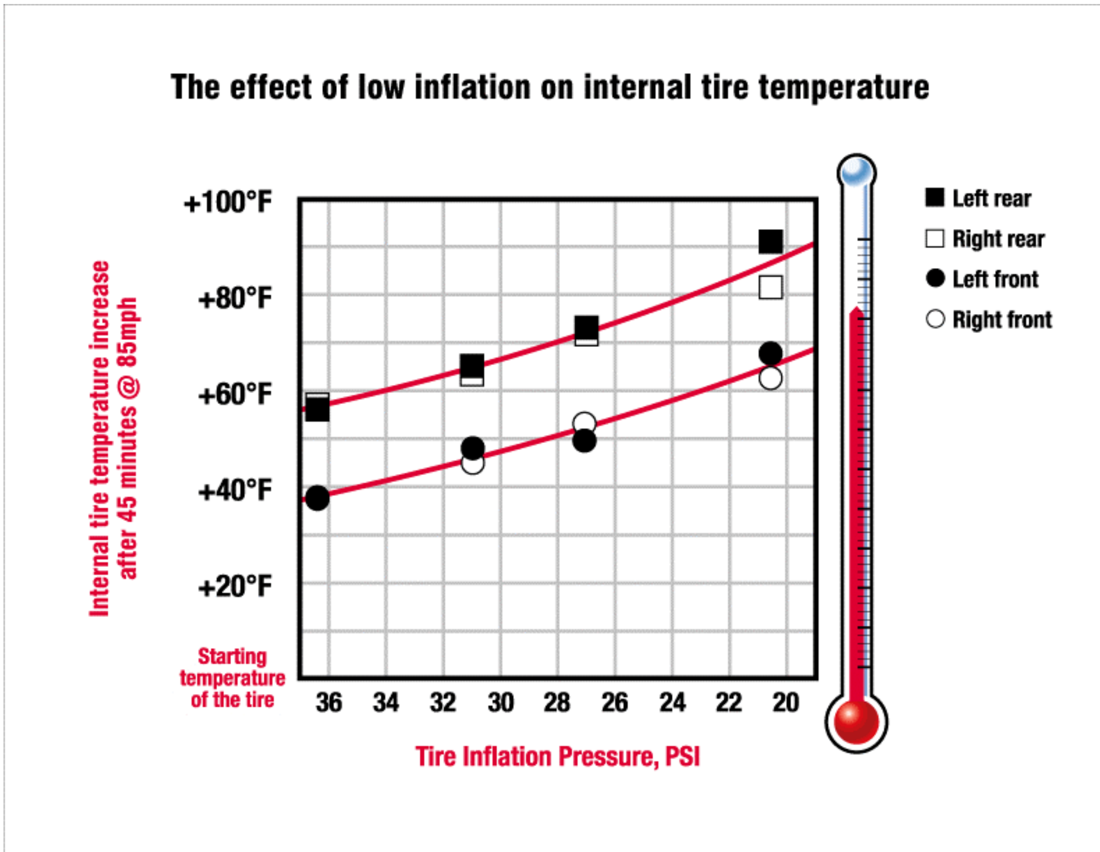
Historically, the tire industry has held that under-inflating a tire by 4 psi or more can be dangerous to the internal components of the tire.[44] Studies by traffic safety groups dating back 20 years have shown that between 50 and 80 percent of all surveyed vehicles are running on tires at a lower inflation pressure than is recommended.

Both Ford and Firestone concede that the Firestone tires in question operate at higher temperatures than similar tires. Thermal imaging studies performed at Ford's request indicated that the left side of the vehicle operates hotter than the right side, and the temperature profile of the Firestone tire is higher than for equivalent Goodyear tires at a given speed, load and inflation pressure. Ford has also suggested that the shoulder design is a factor in the tire's increased internal operating temperatures.

The relationship between inflation pressure and tire performance is well known and well-accepted. The following diagram demonstrates this fundamental proposition.



The effect of low inflation on internal tire temperature is illustrated by the following chart.



As depicted, with decreased inflation pressure, internal tire temperature increases after 45 minutes of operation at 85 mph.

Inherent design problems in the Explorer created the risk that the Explorer would roll over during foreseeable turning maneuvers. Instead of modifying the design of the Explorer to fix this known instability, Ford unilaterally chose to recommend that the tires on its SUVs be operated at 26 psi, significantly below the maximum allowed inflation pressure. Ford's recommendation was a cosmetic attempt to make the Explorer perform better in these quick-turn maneuvers. The direct consequence of this decision was that the Ford-recommended lower inflation level increased the operating temperature of the tires, triggering a decrease in belt-adhesion properties over and above the inadequacies that already existed.

The decreased inflation pressure that was recommended by Ford also harmed the rolling resistance of the tire and, consequently, the fuel efficiency of the Explorer. To correct that fuel economy problem, Ford initiated design changes that compounded the tread separation problem: Ford ordered a lighter tire that was less durable and more prone to the stresses created by their use on an Explorer at the reduced inflation pressures chosen by Ford.

In addition to the low inflation problem that resulted from the Explorer's stability problems, testing by Firestone reportedly found that Explorer load levels, when coupled with Ford's specified tire pressure of 26 psi, resulted in a tire that was "approaching the limits of its load carrying capacity."[45]

In sum, the tire specified for the Explorer when operated at 26 psi has virtually no margin of safety or "robustness" for operation in the real world. Unless the tire is in perfect condition, operated at perfect load levels, and maintains perfect inflation (in this case, 35 psi), the tire is highly susceptible to failure.

9. Lack of Adequate Quality Control Further Exacerbates the Tire Design Flaws

By the very nature of their construction, tires have anomalies caused by splices, belt misplacement, uneven cords, cord angle and cord count variation, as well as other variables. These potentially harmful variations must be kept within controlled limits during the manufacturing process, before the tires are placed in service. These variations, all subject to human inexactness, are the reason that manufacturing tolerances are created with both upper and lower bounds of acceptability.

Lack of adequate quality control of the manufacturing processes at all of the Firestone plants where the tires were manufactured led to poorly manufactured tires, thus increasing the likelihood of catastrophic failures. Descriptions of the quality control problems are documented in sworn testimony by employees at the various plants.[46] Moreover, Ford's "root cause" analysis confirmed production problems that ranged from variation in inner liner[47] gauge to "large variability" in belt "step-off"[48] and in belt placement in an axial direction.[49]

10. Decatur Does Not Explain the Poor Performance of the Tires

Ford and Firestone have strained from the outset to limit the recall to only those Wilderness AT tires manufactured in Decatur. Unfortunately, their own findings do not support this attribution. The following chart reflects data produced by Firestone's consultant, Dr. Sanjay Govindjee, as a result of a survey of returned tires which had not failed. Each tire was cut in a cross-section and examined to determine whether belt edge cracks existed. This investigation was conducted jointly by Ford and Firestone.

CATEGORY	BELT EDGE CRACKS (%)	SAMPLE SIZE
Joliette South	61%	46
Wilson South	48%	50
Decatur South	26%	172
Joliette North	23%	31
Wilson North	16%	31
Decatur North	4.6	152

Data published by Govindjee from Returned Tire Survey, p. 50, prepared for Firestone Tire Co.

As noted in the chart, the percentage of Decatur tires exhibiting evidence of belt edge cracking was lower than the percentages of tires manufactured at either the Joliette or Wilson plants.[50] Despite this clear evidence from Ford and Firestone's own returned tire survey, both companies have continued to advise consumers that the non-Decatur Wilderness tires are "safe" and "world class performers."

While Ford and Firestone delay recalling the tires, 61 percent of consumers in the south with Joliette-made Wilderness tires and 48 percent of consumers in the south with Wilson-made Wilderness tires are likely operating their Explorer with tires that are already exhibiting belt edge separations. Many of these consumers are operating their Explorers with the Wilderness AT tires because Ford and Firestone have publicly represented that these tires are safe, free of any defect, and will not suffer catastrophic failure while in operation. By continuing to ignore reality, both Ford and Firestone are consciously placing the consuming public at risk.

With regard to the issue of differing manufacturing processes used at Decatur versus those used at other plants, the following chart demonstrates the plant-to-plant differences that do exist between Decatur, Wilson and Joliette. As the chart below shows, however, there is no pattern of differences that would indicate that Decatur was in some way unique in terms of manufacturing processes. The * signifies that the process used at that particular plant is different from the other plants producing the tires in question. As noted, Wilson has the most differences in the manufacturing process.

PROCESS	**DECATUR**	**WILSON**	**JOLIETTE**
Banbury	*		
Steel Cord			*
Tire Assembly Machine		*	
Curing		*	

The Banbury process is both a machine and a stage of production, wherein the rubber is mixed with steel cords. The Decatur plant uses "pellitizing" in its Banbury process and the other plants use slabs. If, as Firestone has stated, the "pellitizing" process introduces adhesion-damaging lubricants into the process in Decatur, are *all* Decatur tires failing like the ATX and Wilderness AT tires? If so, shouldn't they be recalled as well?

Statistical evidence has been produced by several different sources on a number of different occasions refuting the argument that Decatur should be stuck with the entire blame for the bad tires.[51] Moreover, Firestone has repeatedly refused to make adjustment data comparing the failure rates for all tires manufactured at Decatur during the relevant time periods publicly available.

11. Road Hazards and Repairs are Not Major Factors Associated with Failures

All tires are exposed to road hazards, punctures and repairs. According to Ford's analysis of claims filed following tread separations, only about 3 in 10 failures involved tires that had evidence of puncture repair. This means that 7 of 10 failures that resulted in claims were failures of puncture-free tires. This is consistent with analysis that the root cause of Firestone tire failures is not a customer problem, but a design problem. It should likewise be noted that neither Ford nor Firestone advises against puncture repair of steel belted radial tires.

12. The P255/70R16 (16-inch) Wilderness AT Tire Fails for the Same Reasons

In the mid-1990's, Firestone developed a P255/70R16 Wilderness AT tire for, among other things, use on the Ford Explorer. Due to a pattern of failures in the Gulf Coast countries, including Saudi Arabia and other nations, and in Venezuela, Ford moved quickly to recall 16-inch tires.

Both Ford and Firestone have refused to recall the 16-inch tires in the U.S., claiming that the environmental "circumstances" in the Gulf Coast countries and Venezuela were "unique." Both Public Citizen and *Safetyforum.com* have objected to this refusal and, citing repeated failures of 16-inch Firestone tires in the U.S., have urged an expansion of the recall to include these tires.

Evidence shows that the 16-inch tires remain a hazard. A case in point: Indoor wheel testing of a 16-inch Wilderness AT tire was performed at an independent laboratory using routine procedures designed to obtain the tire force and moment characteristics for use in computer simulation analyses of the Ford Explorer. During the testing, which included the use of new production tires, one of the 16-inch Wilderness AT tires suffered an unexpected tread separation. The following photo was taken following the testing.

The testing was not designed to evaluate the durability of the tire. To the contrary, the testing was designed to evaluate certain force and moment characteristics of the tires in turning maneuvers. Although the test protocol requires severe slip angles in order to evaluate the performance capability of the tire in severe maneuvers, the tire should not fail during testing. This type of failure is further evidence of the lack of robustness present in the tires from a design standpoint.

VI. THE ROLE OF THE EXPLORER

A. Firestone Speaks Out on Rollover

In October, 2000, John Lampe, Firestone's Executive Vice President, made the following statement:

> Tires will fail, and do so for a number of reasons. In most cases, a vehicle that experiences a tire failure can be brought safely under control. However, we have seen an alarming number of serious accidents from rollovers of the Explorer after a tire failure.

Ford's own internal investigation of Explorer rollover crashes in Venezuela that involved tire failures concluded that the problem was "unique" in that a "high incidence of vehicle roll over after a tire blow out or tread loss ha[d] not been detected for other vehicle brands," such as Toyota, General Motors and Chrysler.

Following an analysis of national and Florida crash statistics by the *Washington Post* which found that the Explorer has more tire-related crashes than other SUVs, James Fell, a retired NHTSA chief researcher, stated:

> The [findings] give an indication that there may be a factor with the Ford Explorer beyond the tire issue. It's a first indicator that they may have a stability problem.

Likewise, former NHTSA Administrator Sue Bailey verified that the Explorer was part of the agency's tire investigation:

> The Explorer is part of the ongoing investigation because we are concerned about the rollover capability.

Firestone's position regarding the Explorer is based on its own analysis of warranty records. Relying on adjustment data that it has refused to make public, Firestone says that its ATX and Wilderness AT tires do not fail more frequently than other tires, but that a failure on an Explorer more often results in someone dying or being injured. In other words, Firestone claims that the real culprit in the deaths and injuries is Ford.

B. In Their Research, Ford and Firestone Have Ignored the Risks Posed By the Explorer

Neither Ford nor Firestone have chosen to directly focus their "root cause" investigations on the role of the Explorer in causing the injuries and fatalities that result from tread separations. In its report of December 19, 2000, Firestone stated:

> This summary report does not address vehicle performance or driver response issues after a tread separation occurs. That interaction, which is certainly an important factor in determining the cause of the serious accidents related to tires and the vehicles upon which they are mounted, is beyond the scope of the company's review and this summary.

C. The Unique Role of SUVs and the Explorer in Rollover Crashes

The greatest harm associated with tread separations of the Firestone ATX, ATX II and Wilderness AT tires is rollover-related fatalities and injuries. According to the NHTSA defect investigation database, 86 percent of the fatalities associated with the defective tires are fatal injuries that were suffered when an Explorer rolled over after the tread separation. According to Firestone, the Explorer's rollover experience after a tread separation is unique in Firestone's history of providing radial tires to the auto industry.[49]

Almost 200 U.S. citizens have died when their Explorers rolled over following a tread separation on a Firestone tire. Although this toll is alarming, the overall death toll for rollover crashes in the U.S. is even more astonishing. Rollover deaths comprise nearly one-third of the total number of occupant fatalities in both 1999 and 2000.

Crashes in which a vehicle rolled over accounted for 56 percent of single-vehicle crash deaths and 11 percent of multi-vehicle crash deaths in 1999.[52] As this suggests, vehicle rollovers produce catastrophic crashes that are heavily associated with occupant fatalities. As yet another indicator, nearly 20 percent of fatal crashes are rollover crashes. In comparison, rollovers constitute 5 percent of the crashes that produce injury, and a mere 1 percent of the crashes that produce only property damage.

Using data from 1995-1999 in the National Accident Sampling System (NASS), NHTSA estimates that an average of 253,000 were towed from a rollover crash in each of those years and that 27,000 occupants of these vehicles were seriously injured, as defined by NHTSA's Abbreviated Injury Scaling System. The vast majority of those crashes, numbering some 205,000, were single-vehicle rollovers, incurring 19,000 serious injuries.[53]

Surprisingly, 35 percent of those who suffered a serious injury in a single-vehicle tow-away rollover were wearing safety belts at the time of the crash.[54] Safety belt use is always referenced as a "top priority" in reducing injuries in rollover and other types of crashes. Nonetheless, according to NHTSA, over 3 of every 10 consumers suffer serious injury, such as a broken hip, in single-vehicle rollovers, despite their use of a safety belt.

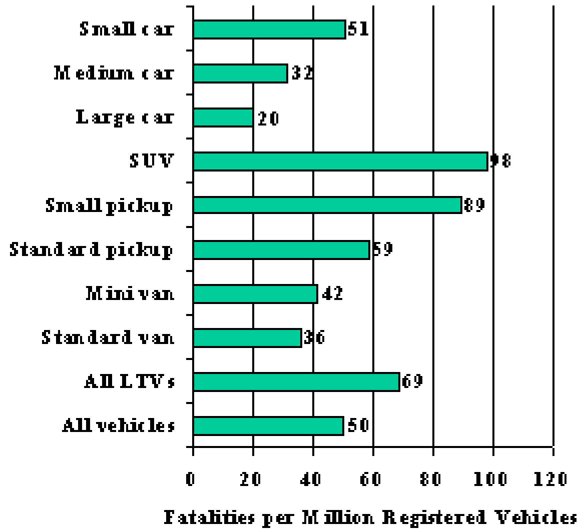
Deaths in pickups and utility vehicles have more than doubled since 1975.[55] According to NHTSA's National Center for Statistics and Analysis, in 1999, 10,133 people were killed as occupants of passenger vehicles in rollover crashes, including 1,898 people who were occupants of SUVs.[56] In even more recent data, SUVs continue to demonstrate that they pose a rollover hazard in comparison to other classes of vehicles.

In 2000, the number of rollover deaths in most vehicle categories remained the same, or decreased, in comparison to 1999 levels. The sole exception to this general positive trend was the higher number of rollover fatalities for occupants of SUVs. For the year 2000, the number of SUV occupants killed in a rollover crash rose 2.8 percent from 1999 levels to a total of 4,661 deaths.[57]

If the data are sorted based upon the outcome of crashes for occupants, SUVs fare badly. NHTSA notes that in 1999 "compared with other vehicle types, utility vehicles experienced the highest rollover rates: 37.8 in fatal crashes, 10 percent in injury crashes, and 2.5 percent in property-damage-only crashes."[58]

The following graph illustrates the elevated risk of fatality in rollover crashes in SUVs, and shows that SUVs have the highest number of fatalities in rollover crashes per million registered vehicles.

Fatality Rates in Rollover Crashes
1991-98 FARS Average Annual

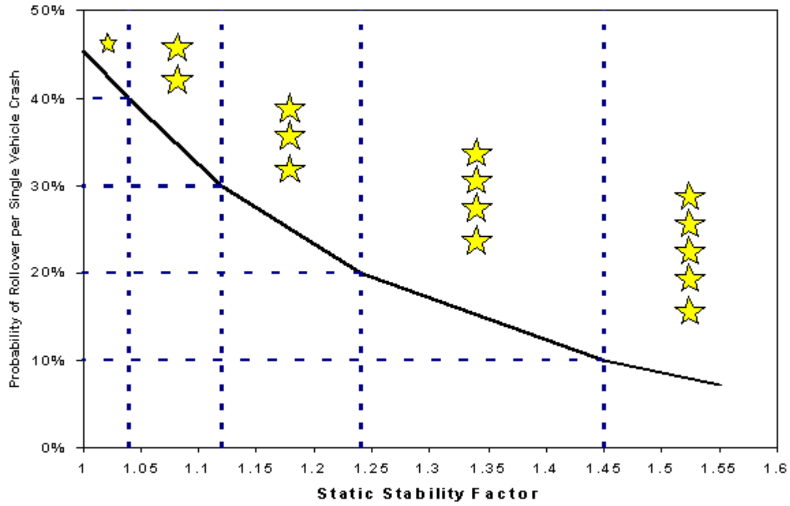


Such statistics make it abundantly clear that rollover crashes result in harm, that they are an especially severe problem for light vehicles and SUVs, and that the problem needs to be addressed from the standpoint of both crash prevention and crash protection. Addressing this issue in the context of catastrophic tire failures, although of critical importance given the Explorer's current tire-related problems, should properly be viewed as but one element of a much broader concern for occupant protection that requires prompt NHTSA and auto manufacturer action.

D. The SUV Design Characteristics That Lead to Vehicle Rollover

Applying some of the fundamental laws of physics, the stability of a vehicle can be characterized by a static measurement that is a ratio between the height and width of the vehicle's track. This is called the vehicle's static stability factor, or SSF (SSF = T/2H where T is the track width and H is the center of gravity height).

A vehicle's roll gradient – the tendency to lean during cornering – is defined as the amount of tip angle per cornering acceleration (i.e. degrees per "g" force). In layman's terms, it is a measurement of how much the vehicle tends to tilt sideways as the tires begin to slide on the pavement. As the following NHTSA graph shows, a vehicle's propensity to roll over increases as its SSF decreases. Another way of stating this is that the lower the SSF, the more likely it is that the vehicle will roll over in the real world.



NHTSA, starting this year after more than a decade of rulemaking discussion and delay, recently measured a variety of vehicles, including SUVs, to determine their SSF. As the following table indicates, the Ford Explorer, in all model years, has an SSF that is among the lowest of all SUVs measured. In fact, the only ones with worse SSFs are vehicles that are no longer manufactured or sold in the U.S. Also of significance is that the post-1995 model Explorers is worse, not better, than earlier ('90-'94) Explorers.

VEHICLE	MY	SSF
Toyota 4Runner	90-95	1.01
Isuzu Trooper	88-91	1.02
Bronco II	88-90	1.04
Explorer (4-door)	95-98	1.06
Isuzu Rodeo	91-97	1.06
Honda Passport	91-97	1.06
Toyota 4Runner	96-98	1.06
Explorer (4-door)	91-94	1.07
Isuzu Trooper	92-94	1.07
Grand Cherokee	93-98	1.07
Nissan Pathfinder	88-95	1.07
Jeep Cherokee	88-97	1.08
S10 Blazer	95-98	1.09
Acura SLX	95-98	1.09
Suzuki Samurai	88-95	1.09
S10 Blazer	88-94	1.11
Nissan Pathfinder	96-98	1.11
Geo Tracker	89-98	1.13
Honda CR-V	97-98	1.19
Jeep Wrangler	88-96	1.21

In addition to static measurements, NHTSA also conducted dynamic proving ground rollover resistance testing of a variety of vehicles, including a 1998 Ford Explorer. The J-Turn testing of the

Explorer was limited to approximately 53 mph due to the vehicle's tendency to "oversteer," or "spin-out," during the maneuver. During the higher speed testing that was conducted, the driver was required to "counter-steer" in an effort to keep the vehicle from spinning out. In laymen's terms, the design of the Explorer placed the test driver at risk, due to the tendency of the vehicle to go out of control during a turning maneuver that imitates the letter "J".

E. In Consumer Tests, the Explorer Performed Poorly

To assess the handling characteristics of an Explorer exposed to a simulated tread separation , a post-1995 model, 4-door Explorer was purchased to measure its static design characteristics. Initially, the vehicle was tested based on accepted industry procedures. Basic handling and stability characteristics were measured and converted to a computer simulation.

The measurements showed that the Explorer had design characteristics that directly influenced rollover propensity, including a poor static stability factor (T/2H), a tendency to over-steer at high levels of lateral acceleration, and a rear suspension compression bump-stop[59] influence on directional stability under severe maneuvering conditions that aggravated the vehicle's tendency to over-steer.

The over-steer phenomenon occurs when large roll angles cause rear suspension bump-stop contact, which then significantly increases the effective rear suspension roll stiffness, leading to rear tire side force saturation. To translate: "side force saturation" (i.e., the vehicle's tires are not gripping the road, but are sliding sideways) results in an over-steer response (the vehicle's back-end begins to slide around sideways), which in turn leads to larger side slip angles under emergency maneuvering conditions, followed by the tip-up of the vehicle and rollover.

The handling characteristics of the Explorer were then evaluated through both an on-track testing of simulated catastrophic tread separations and a computer simulation. The computer simulation, created for the U.S. Department of Transportation, evaluated the Explorer's performance in a variety of maneuvers, including a reversal steer maneuver designed to analyze the vehicle's directional stability and rollover propensity. The vehicle parameters were obtained for the simulation through the testing of an Explorer in a shop. Tire characteristics were obtained from Veridian (Calspan) tire tests using methods accepted by the industry. The Veridian test data were submitted to fitting procedures that were developed at Systems Technology, Inc., for preparing a tire model parameter file for use in a computer simulation. These tests confirmed the Explorer's tendency to lift its wheels off the pavement in turning maneuvers at reasonably anticipated speeds/steering wheel inputs.

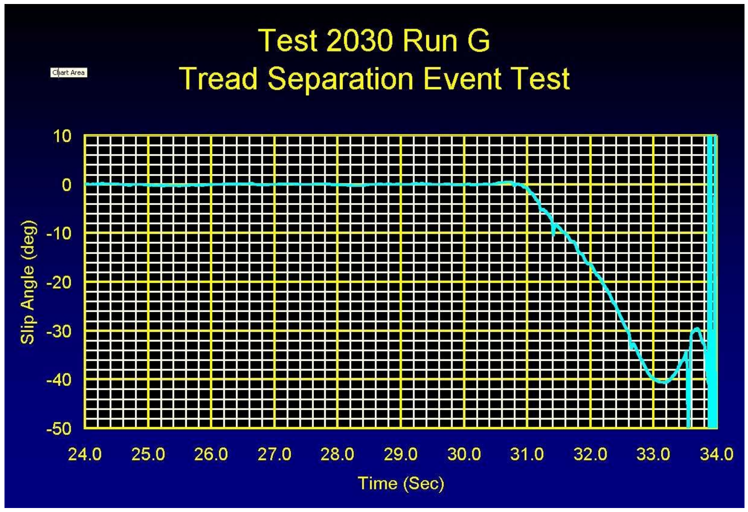
The on-track testing was conducted in Arizona using an Explorer that had been outfitted with instruments to collect information about handling characteristics. One of the rear tires was prepared to experience a simulated tire tread separation while the vehicle was operated on a straight, flat asphalt surface at 60 mph. The following photograph shows the preparation process that was used to create a simulated tread separation on that vehicle.

The next figures show the prepared tire mounted on the rear of the instrumented test vehicle.

The test evaluated the vehicle's response to the simulated tread separation event. The steering wheel was held in a fixed position at 0±2 degrees, before and during the event, and the tread-separation event occurred over at least one second. The tests were videotaped.

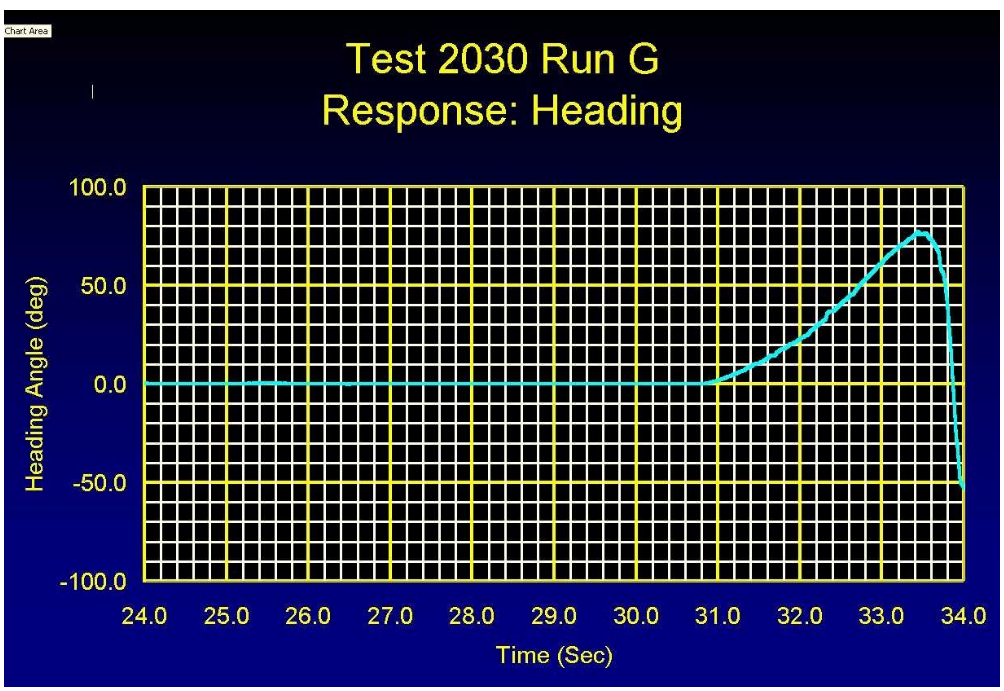
The following figure shows the Explorer after one of the early tread separation runs, in which the vehicle rolled completely over after it jerked uncontrollably when the tread separated. The rollover occurred despite the fact that outriggers were attached. The professional driver was protected by both a five-point racing harness and a roll bar.

The next figure displays slip angle data for the Explorer in the simulated tread separation run. At approximately 31 seconds into the run, the Explorer began developing a high slip angle that exceeded 40 degrees during the maneuver.



The next figure shows the vehicle's heading during the run. At approximately 31 seconds into the run, the vehicle violently changed: within one second, it jerked approximately 25 degrees; at two seconds, it changed directions by more than 50 degrees, and in less than three seconds the change in direction peaked at about 75 degrees.

Given that typical reaction time in emergency situations is approximately 2.5 to 3 seconds, an ordinary driver would have had no ability to control the violent jerk exhibited by the Explorer following tread separation.



Once the test driver began to lose directional control of the vehicle, the Explorer became unreasonably prone to vehicle rollover because of its high center of gravity, relatively narrow track width, short wheelbase, and sensitive steering. Compounding the problem was that the vehicle is marketed for a use for which it is not designed: freeway driving as the functional equivalent of a station wagon. The relatively large tires contribute to the Explorer's propensity to roll over.

CONCLUSION

The summer heat is almost upon us once more, yet some of the Ford Explorers on the highway may still be at risk of catastrophic rollover crashes caused by tread separations on their faulty Firestone tires. A new round in this tragedy would devastate consumers, and further harm the reputations of Ford and Firestone, who have promised since the end of last summer that the problem was fixed.

This report shows that the design and subsequent re-designs of the Firestone tire are the result of a long series of cost- and weight-saving miscalculations and gambles by Ford. Ford addressed the handling and stability problems in the design of their Explorer vehicle by tinkering with the inflation levels and weight of its tires, thus making what was already a bad problem into a lethal one.

A direct and comprehensive solution is required. It must include the recall of all the defective tires, including the non-Decatur 15-inch Wilderness AT tires and all 16-inch Wilderness AT Tires, and a full public information and customer notification program to tell owners of Ford Explorers and the public about the demonstrated hazards associated with these vehicles. New safety standards and informational outreach on the part of NHTSA are also imperative.

The companies have thus far produced only false reassurances and partial explanations. As this report points out, since August of last year Ford and Firestone have failed to acknowledge the many weaknesses and omissions in their official account of the causes of these tragic crashes. It is time for them to step up, to fulfill their duties as corporate citizens, and to really "make it right" — before any more of their customers are unnecessarily injured or killed.

Appendix I

The following chart provides a list of the sample tires chosen for the x-ray portion of the project:

Tire #	Tire Size	Design	Plant	Date
24	P235/75R15	Wilderness AT	Wilson	396
43	P235/75R15	Wilderness AT	Decatur	219
46	P235/75R15	Wilderness AT	Wilson	047
38	P235/75R15	Wilderness AT	Joliette	165
26	P235/75R15	ATX	Decatur	024
7	P235/75R15	ATX	Joliette	272
27	P235/75R15	ATX	Joliette	272
3	P235/75R15	Wilderness AT	Joliette	048
4	P235/75R15	Wilderness AT	Joliette	058
5	P235/75R15	Wilderness AT	Joliette	058
6	P235/75R15	Wilderness AT	Joliette	058
25	P235/75R15	ATX	Decatur	535
28	P235/75R15	Wilderness AT	Wilson	059
45	P235/75R15	Wilderness AT	Wilson	147
40	P235/75R15	ATX	Oklahoma City	119
30	P235/75R15	ATX	Oklahoma City	119
33	P235/75R15	ATX	Joliette	283
1	P235/75R15	ATX	Decatur	493
2	P235/75R15	ATX	Decatur	493
14	P235/75R15	Wilderness AT	Joliette	2300
15	P235/75R15	Wilderness AT	Joliette	2300
16	P235/75R15	Wilderness AT	Joliette	2300
17	P235/75R15	Wilderness AT	Joliette	2300
13	P235/75R15	Wilderness AT	Aiken	1900
21	P235/70R16	Wilderness HT	Wilson	397
22	P235/70R16	Wilderness HT	Wilson	027
23	P235/70R16	Wilderness HT	Wilson	226
20	P235/70R16	Wilderness HT	Wilson	226
31	P235/75R15	Wilderness AT	Decatur	118
32	P235/75R15	Wilderness AT	Decatur	118
34	P235/75R15	Wilderness AT	Decatur	118
36	P235/75R15	ATX	Wilson	377
39	P235/75R15	ATX	Decatur	447
35	P235/75R15	ATX	Decatur	447
37	P235/75R15	ATX	Decatur	408

12	P255/70R16	Wilderness AT	Joliette	279
19	P255/70R16	Wilderness AT	Joliette	139
42	P235/75R15	Wilderness AT	Decatur	457
44	P235/75R15	Wilderness AT	Decatur	457
29	P235/75R15	Wilderness AT	Decatur	457
41	P235/75R15	Wilderness AT	Decatur	457
8	P235/75R15	Wilderness AT	Decatur	377
9	P235/75R15	Wilderness AT	Decatur	377
10	P235/75R15	Wilderness AT	Wilson	487
11	P235/75R15	Wilderness AT	Oklahoma City	049
18	P225/70R15	Wilderness HT	Wilson	397

Endnotes

[1] The word "tread separation" in the context in which it is used in the present report refers to a "belt leaving belt" condition, which is sometimes referred to as BLB. Although the tread clearly separates from the tire, the separation is actually between the two steel belts.
[2] Tab Turner is *Safetyforum.com*'s "attorney of record" for tires and vehicle stability.
[3] Insurance Institute for Highway Safety, *Status Report: Driver Death Rates*, Vol. 35, No. 7, Aug. 2000.
[4] Id.
[5] Belt Wedges are circular wedges placed around the circumference of both sidewalls between the two steel belts to stiffen and strengthen the tire. The function of the wedge is to: a) separate the edges of the two steel belts, thus minimizing strain; b) help distribute the shear forces (stress and strain) to adjacent components; and c) help the adhesion of the surrounding components.
[6] Approximately three weeks after the recall was announced, NHTSA asked Firestone to expand the recall to include other tires because of the consumer complaints that the agency had received and the early results from its own defect investigation revealed that other models were experiencing rates of tread separations that exceeded those of the recalled tires, sometimes by a large margin. Firestone refused to expand the recall. NHTSA responded by issuing a "consumer advisory" designed to warn consumers that about 1.4 million other Firestone tires, about half of which were still on the road, were experiencing high tread-separation rates, many of them other models of ATX and Wilderness tires made in the early 1990s. After being chastised during congressional hearings the following month, Firestone promised to replace the tires listed in NHTSA's consumer advisory at the consumer's request, but still refused to expand the scope of the recall. The burden of requesting that tires listed in the consumer advisory be replaced fell upon the consumer.
[7] *The Safety of Firestone 500 Steel Belted Radial Tires*, Report by the Subcommittee on Oversight and Investigations of the Committee on Interstate and Foreign Commerce, July 16, 1978, at 15.
[8] *The Safety of Firestone 500 Steel Belted Radial Tires*, Report by the Subcommittee on Oversight and Investigations of the Committee on Interstate and Foreign Commerce, July 16, 1978, at 34.
[9] *The Safety of Firestone 500 Steel Belted Radial Tires*, Report by the Subcommittee on Oversight and Investigations of the Committee on Interstate and Foreign Commerce, July 16, 1978, at 15.
[10] See Firestone press release, Dec. 19, 2000.
[11] *The Safety of Firestone 500 Steel Belted Radial Tires*, Report by the Subcommittee on Oversight and Investigations of the Committee on Interstate and Foreign Commerce, July 16, 1978, at 1. An "adjustment rate" is the percentage of tires produced by a company which it accepts back from customers because of some problem with tires that occurs before their useful tread is worn. The customer is allowed a credit (or adjustment) for the remaining tread life, to be applied toward the purchase of replacement tires. The adjustment rate for the Firestone 500 tire was 17.5 percent. In the case of the present ATX/Wilderness AT investigation, Firestone has not revealed a total adjustment rate for the tires thus making a comparison impossible.
[12] *The Safety of Firestone 500 Steel Belted Radial Tires*, Report by the Subcommittee on Oversight and Investigations of the Committee on Interstate and Foreign Commerce, July 16, 1978, at v.
[13] *The Safety of Firestone 500 Steel Belted Radial Tires*, Report by the Subcommittee on Oversight and Investigations of the Committee on Interstate and Foreign Commerce, July 16, 1978, at 3.
[14] *The Safety of Firestone 500 Steel Belted Radial Tires*, Report by the Subcommittee on Oversight and Investigations of the Committee on Interstate and Foreign Commerce, July 16, 1978, at 13. In response to Firestone's excuse that "high speed" was involved in many of the reported Firestone 500 crashes, the Subcommittee observed that it was "not willing to excuse Firestone from responsibility in these instances on the basis of evidence of high speed driving."
[15] *See* Ford Motor Company press release of Dec. 19, 2000, <http://media.ford.com/article_display.cfm?article_id=6790>.
[16] Ford internal document no. PE00-20 4018, July 26, 1999.
[17] Id.
[18] Deposition by Tab Turner of James Gardner, Product Analysis Engineer, Firestone, Dec. 13, 2000.
[19] *Spinning Their Wheels: How Ford and Firestone Fail to Justify The Limited Recall*, by Public Citizen and *Safetyforum.com*, Jan. 4, 2001.
[20] Deposition by Tab Turner of Robert Martin, Vice President, Quality Assurance, Firestone, Nov. 27, 2000.

[21] A flotation tire is a large tire that is typically designated with a light truck designation and is designed to operate at high inflation pressures.
[22] Deposition by Tab Turner of Robert Martin, Vice President, Quality Assurance, Firestone, Nov. 27, 2000.
[23] Deposition by Tab Turner of Michael Reep, Design Engineer, Firestone, Dec. 13, 2000.
[24] Deposition by Tab Turner of James Gardner, Product Analysis Engineer, Firestone, Dec.13, 2000.
[25] Deposition by Tab Turner of Michael Reep, Design Engineer, Firestone, Dec.13, 2000.
[26] Id.
[27] "Standard Load" refers to a passenger tire with a maximum inflation pressure of 35 lbs. An "extra load" tire, on the other hand, is a passenger tire with a maximum inflation pressure of 41 lbs, which allows for greater load carrying capacity.
[28] Deposition by Tab Turner of Michael Reep, Design Engineer, Firestone, Dec.13, 2000.
[29] Deposition by Tab Turner of James Gardner, Product Analysis Engineer, Firestone, Dec.13, 2000.
[30] Deposition by Tab Turner of Brian Queisar, Firestone Design Engineer, Dec. 20, 2000.
[31] Keith Bradsher, "Expert Says Car Weight Was Key in Tire Failures," New York Times, Feb. 3, 2001.
[32] Deposition by Tab Turner of Brian Queisar, Firestone Design Engineer, Dec. 20, 2000.
[33] Id.
[34] Id.
[35] Id.
[36] Deposition by Tab Turner of Thomas Baughman, Chief of Engineering, Ford Motor Company, Dec. 21, 2000.
[37] Ford Motor Company press release, Dec. 19, 2000, <http://media.ford.com/article_display.cfm?article_id=6790>.
[38] Id.
[39] External cracking can also result from the failure to incorporate sufficient amounts of antioxidants in the compound.
[40] Bridgestone/Firestone Root Cause Report, by Firestone consultant Dr. Sanjay Govindjee, Feb. 2, 2001.
[41] Ford's "root cause" analysis speculated that Firestone had chosen a "cheaper" inner liner gauge because Ford did not specifically call for a requirement of air loss versus time in the initial tire specifications. Ford also noted a significant variability in the inner liner gauge from tire to tire as manufactured. See Ford Motor Company press release of Dec. 19, 2000, <http://media.ford.com/article_display.cfm?article_id=6790>.
[42] Firestone press release, Dec. 19, 2000, at 4-5.
[43] Id. at 5.
[44] *The Safety of Firestone 500 Steel Belted Radial Tires*, Report by the Subcommittee on Oversight and Investigations of the Committee on Interstate and Foreign Commerce, page 36, citing testimony of Firestone engineer Robert Lee, July, 16, 1978.
[45] Firestone press release, Dec. 19, 2000, at 6.
[46] Depositions by Tab Turner of Joe Roundtree and Derald Burke, Bridgestone/Firestone employees at the company's Decatur, Illinois, plant, July 23, 2000.
[47] The inner liner is the layer between the air inside the tire and the internal components of the tire.
[48] Belt "step-off" means that the lower belt is wider than the upper belt.
[49] Axial refers to an up and down direction.
[50] Bridgestone/Firestone Root Cause Report, by Firestone consultant Dr. Sanjay Govindjee, Feb. 2, 2001at 27, 50.
[51] See, e.g., *Spinning Their Wheels: How Ford and Firestone Fail to Justify The Limited Recall*, by Public Citizen and *Safetyforum.com*, Jan. 4, 2001.
[52] Data according to an interpretation of the Department of Transportation's Fatality Analysis Reporting System (FARS) by the Insurance Institute for Highway Safety, *Fatality Facts,* Oct. 2000.
[53] Consumer Information Regulations; Rollover Resistance, 49 CFR Part 575, Vol. 66, No. 9 Fed. Reg. Jan. 12, 2001.
[54] Id.
[55] Data according to an interpretation of the Department of Transportation's Fatality Analysis Reporting System (FARS) by the Insurance Institute for Highway Safety, *Fatality Facts,* Oct. 2000.
[56] National Center for Statistics and Analysis, *2000 Motor Vehicle Crashes Injury and Fatality Estimates Early Assessment*, Mar. 2001.
[57] Id.
[58] National Center for Statistics and Analysis, *Traffic Safety Facts 1999*, Dec. 2000, at 61.
[59] "Bump stop" refers to an elastic component of the suspension that is designed to limit compression travel of the

suspension system as the vehicle rolls.