Report on Failure Testing of Forty-Two Tires

Introduction

This is the final report of an experiment done by UMTRI to determine the inflation pressure required to fail 16 inch light truck tires, when improperly mounted on 16.5 inch wheels. In an interim report titled "Report on Failure Testing of Thirty Tires" UMTRI reported on the test results of thirty tires from six different manufactures. In this final report, the test results of twelve more tires from two additional manufactures are also considered.

It is possible to improperly mount a 16 inch tire (metric 215/85, in this case) on a 16.5 inch tire wheel. When this is the case, the tire bead makes an air tight seal against the wheel, even though the bead is not properly seated. As inflation pressure is increased, this improper seating generates excessive stresses in the tire bead wire. Eventually, failure of the wire and explosive deflation of the tire will occur as the integrity of the bead seat is lost. Such a failure was obtained for each of the forty-two tires tested.

Test Sample

The tire sample consisted of six tires each, of the following:

i) Michelin Radial XCH4 All Season LT215/85, Load range D, rib
ii) Firestone, SteelTex Radial FSR, LT215/85, Load range D, rib
iii) BF Goodrich, The Edge, LT215/85, Load range D, rib
iv) Dunlop, A/P Radial Rover, LT215/85, Load range D, rib
v) Goodyear, Wrangler LT, LT215/85, Load range D, rib
vi) Cooper, Discoverer Radial, LT215/85, Load range D, rib*
vii) General, Ameri ✱ Steel Radial, LT215/85, Load range D, rib*

Test Procedure

Two special wheels, each equipped with two valve stem holes, were used in these tests. (These wheels were virtually identical. Two were used simply to facilitate the test set-up time.) A tire was mounted on one of the wheels using a typical industrial, tire changer. Then the tire/wheel combination was mounted on a structure suitable for safely constraining it at failure. A high pressure hose was attached to each valve stem hole. One

* Results for this type of tire were not included in previous report.

hose was used to connect the system to a compressed air source for inflating the tire; the other was used to mount electronic pressure transducers for measuring the inflation pressure of the tire. Physically separating these two functions served to insure that the accuracy of the inflation pressure measurement was not compromised by the dynamic effects of the inflation air flow. See Figure 1 for a schematic of the test set-up. Photos of the test facility including the restraint fixture, data acquisition system, inflation pressure source and tire mounting machine are also attached.

The primary inflation pressure source consisted of an electric compressor capable of producing up to 280 psi of inflation pressure. It was thought, however, that some of the tires might require an inflation pressure greater than 280 psi so a secondary inflation pressure source was introduced into the system. This source was a high pressure nitrogen tank. The nitrogen tank connection was via "T" fittings on the compressor outlet enabling pressure control to be transferred from the compressor to the nitrogen tank without disrupting the inflation process (See Figure 1). In all of the reported tests, the 280 psi supplied by the compressor was sufficient to cause failure, and the nitrogen source was not used.

Once the set-up was complete and the area cleared, the tire was inflated to a few psi in order to seal it against the rim. This seal was then verified, and the tire was slowly inflated (at approximately 1 to 3 psi per second). The data collection system produced a display of the tire pressure, allowing the rate to be easily monitored. Once the inflation pressure reached approximately 40 psi, the acquisition of data began and a continuous recording of inflation pressure was made until failure of the tire was achieved. This data was stored in permanent records on a tape for later analysis. Also, any pertinent information regarding peculiarities of the test or the tire, including a brief physical description of the failure, were recorded on the test data sheets. This procedure was then repeated with each of the remaining tires.

Results

Essentially, two "modes" of test progression were observed, viz.:

1) Inflation progressed "smoothly" over time, and no identifiable "events" occurred except for the explosive failure of the tire.
2) Inflation progressed smoothly up to an intermediate level at which a sharp "pop" occurred (apparently as the tire beads seated firmly against the wheel seat). The "pop" was accompanied by a quick reduction of inflation pressure of a few psi. Subsequently, inflation pressure again proceeded smoothly until failure occurred.

Appended to this report is a plot of the time history of inflation pressure for all forty-two trials. (The test log sheets for each trial are also appended.) The plots are organized by tire make. All trials of the "mode 1" type for an individual make are presented together on one plot. Each trial of a "mode 2" type has an individual plot accompanied by a "blow up" of the "pop" region of the data.

Mode 2 type results occurred for three of the six Goodyear tires, two of the six Dunlop tires, and only one of the six General tires. Also worth noting, is a test (Test ID 44) on one of the Cooper tires that failed to return to zero inflation pressure following explosion. This anomaly was caused by the explosion forces jarring the pressure sensor hose off the wheel valve stem. Once freed from the valve stem, the nozzle of the hose closed restricting the air release and not allowing the pressure to drop to zero. It is felt that this did not jeopardize the quality of the test.

Table 1 presents the failure pressure from each of the forty-two trials. Table 2 presents statistical results derived from the data of Table 1. Figures 2 and 3 present the more interesting statistical results in graphical form.

Table 1. Tire Failure Pressures, psi

Trial	Michelin	Firestone	Goodrich	Dunlop	Goodyear	Cooper	General
1	88.6	77.8	98.4	118.8	164.3	100.3	172.0
2	79.8	76.8	106.3	91.8	179.9	93.5	214.0
3	79.3	83.8	138.0	104.3	178.8	102.7	187.7
4	79.7	76.9	111.0	89.3	226.1	111.7	227.5
5	80.7	80.5	119.7	181.0	237.2	105.48	193.3
6	92.3	103.6	116.7	159.9	229.9	101.2	209.3

Figure 2 compares the means and the standard deviations of the failure pressures of the six trials of each tire make. The means of the six trials range from a low of 83 psi for the Michelin tires and the Firestone tires to a high of 203 psi for the Goodyear tires. The standard deviations of the six trails range from a low of 5.6 psi for the Michelin tires to a high of 37.9 psi for the Dunlop tires.

Figure 3 again presents the means of the failure pressures of the six trials of each tire make. It also shows the 95% and 99% confidence bands of those means.

Figure 1. UMTRI Tire Failure Test
Experimental Setup

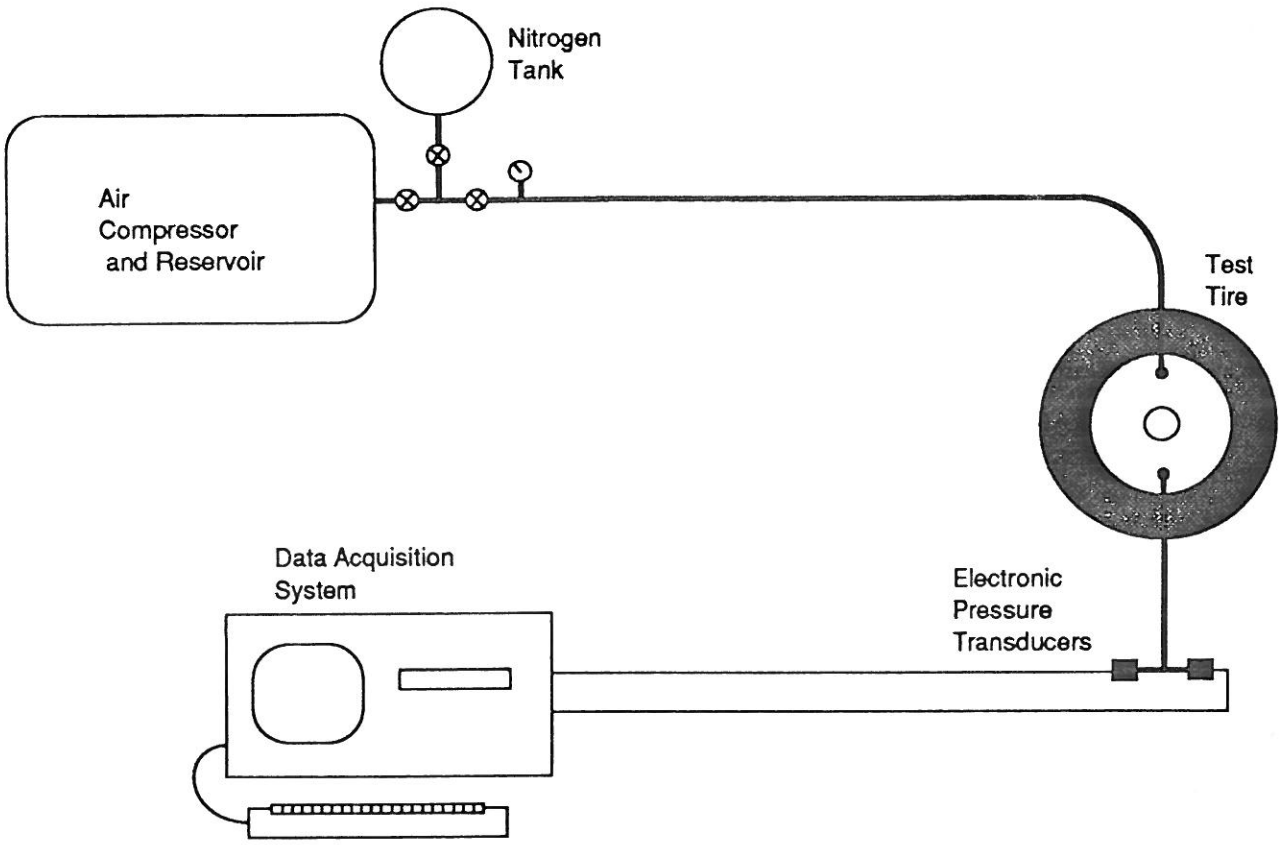


Table 2. Failure Pressure Test Statistics

Michelin

Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
83.388	5.577	2.277	31.103	6.688	6
Minimum:	**Maximum:**	**Range:**	**Sum:**	**Sum Squared:**	**# Missing:**
79.33	92.25	12.92	500.33	41877.199	0
t 95%:	**95% Lower:**	**95% Upper:**	**t 99%:**	**99% Lower:**	**99% Upper:**
5.854	77.535	89.242	9.18	74.208	92.569

Firestone

Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
83.23	10.346	4.224	107.036	12.43	6
Minimum:	**Maximum:**	**Range:**	**Sum:**	**Sum Squared:**	**# Missing:**
76.77	103.64	26.87	499.38	42098.579	0
t 95%:	**95% Lower:**	**95% Upper:**	**t 99%:**	**99% Lower:**	**99% Upper:**
10.859	72.371	94.089	17.031	66.199	100.261

Goodrich

Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
115.005	13.564	5.538	183.995	11.795	6
Minimum:	**Maximum:**	**Range:**	**Sum:**	**Sum Squared:**	**# Missing:**
98.35	137.95	39.6	690.03	80276.876	0
t 95%:	**95% Lower:**	**95% Upper:**	**t 99%:**	**99% Lower:**	**99% Upper:**
14.237	100.768	129.242	22.329	92.676	137.334

Dunlop

Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
124.19	37.947	15.492	1439.959	30.555	6
Minimum:	**Maximum:**	**Range:**	**Sum:**	**Sum Squared:**	**# Missing:**
89.29	181.02	91.73	745.14	99738.731	0
t 95%:	**95% Lower:**	**95% Upper:**	**t 99%:**	**99% Lower:**	**99% Upper:**
39.828	84.362	164.018	62.465	61.725	186.655

Goodyear

Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
202.685	31.761	12.966	1008.739	15.67	6
Minimum:	**Maximum:**	**Range:**	**Sum:**	**Sum Squared:**	**# Missing:**
164.25	237.19	72.94	1216.11	251530.951	0
t 95%:	**95% Lower:**	**95% Upper:**	**t 99%:**	**99% Lower:**	**99% Upper:**
33.336	169.349	236.021	52.282	150.403	254.967

Table 2. Failure Pressure Test Statistics (Cont.)

Cooper

Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
102.473	6.029	2.461	36.352	5.884	6
Minimum:	**Maximum:**	**Range:**	**Sum:**	**Sum of Sqr.:**	**# Missing:**
93.48	111.72	18.24	614.84	63186.466	0
t 95%:	**95% Lower:**	**95% Upper:**	**t 99%:**	**99% Lower:**	**99% Upper:**
6.328	96.145	108.802	9.925	92.548	112.398

General

Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
200.627	20.096	8.204	403.855	10.017	6
Minimum:	**Maximum:**	**Range:**	**Sum:**	**Sum of Sqr.:**	**# Missing:**
171.97	227.51	55.54	1203.76	243525.629	0
t 95%:	**95% Lower:**	**95% Upper:**	**t 99%:**	**99% Lower:**	**99% Upper:**
21.093	179.534	221.719	33.081	167.546	233.707

Figure 2. Failure Pressures by Tire Make
—The Mean Values and Standard Deviations
from Six Trials of Each Make—

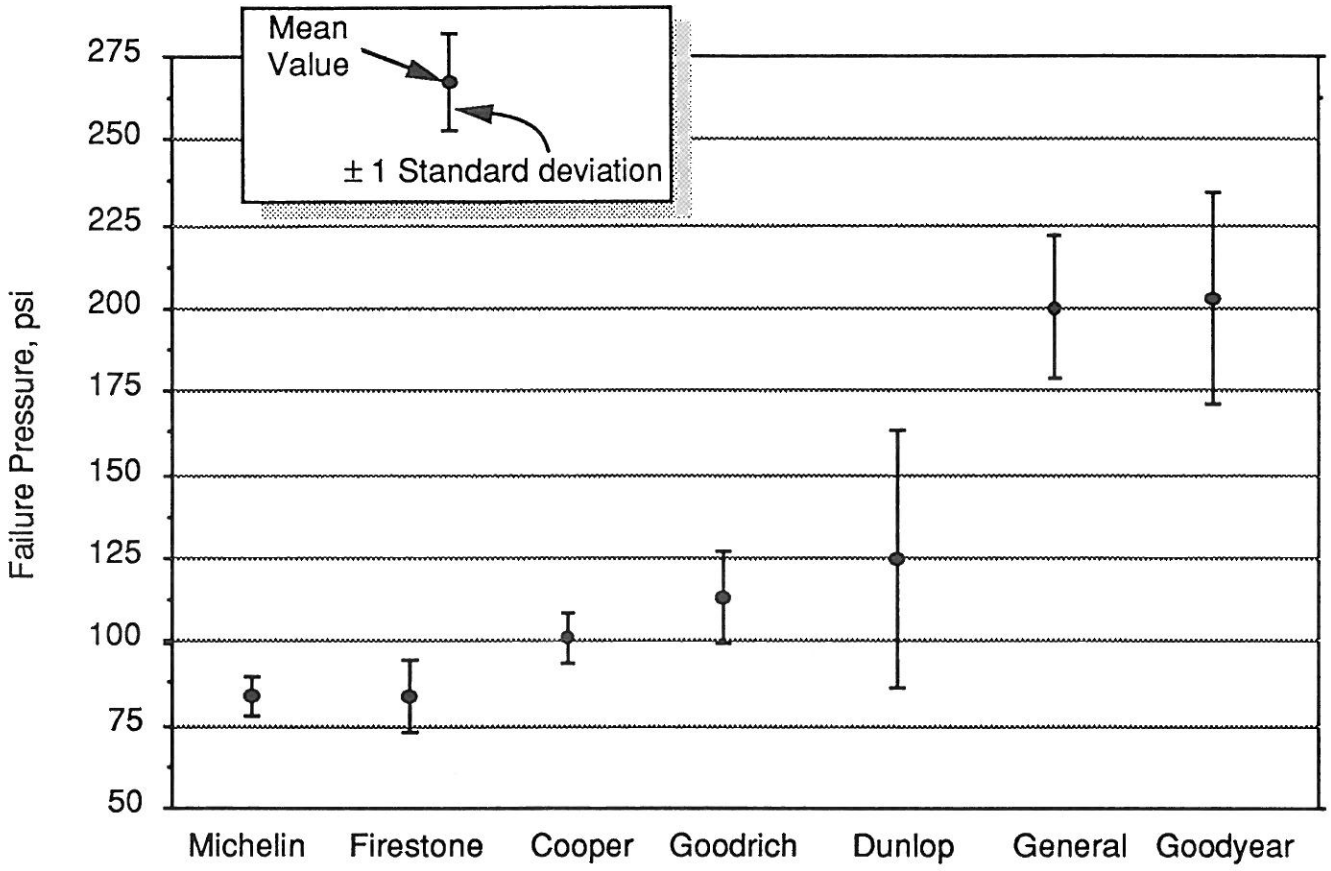
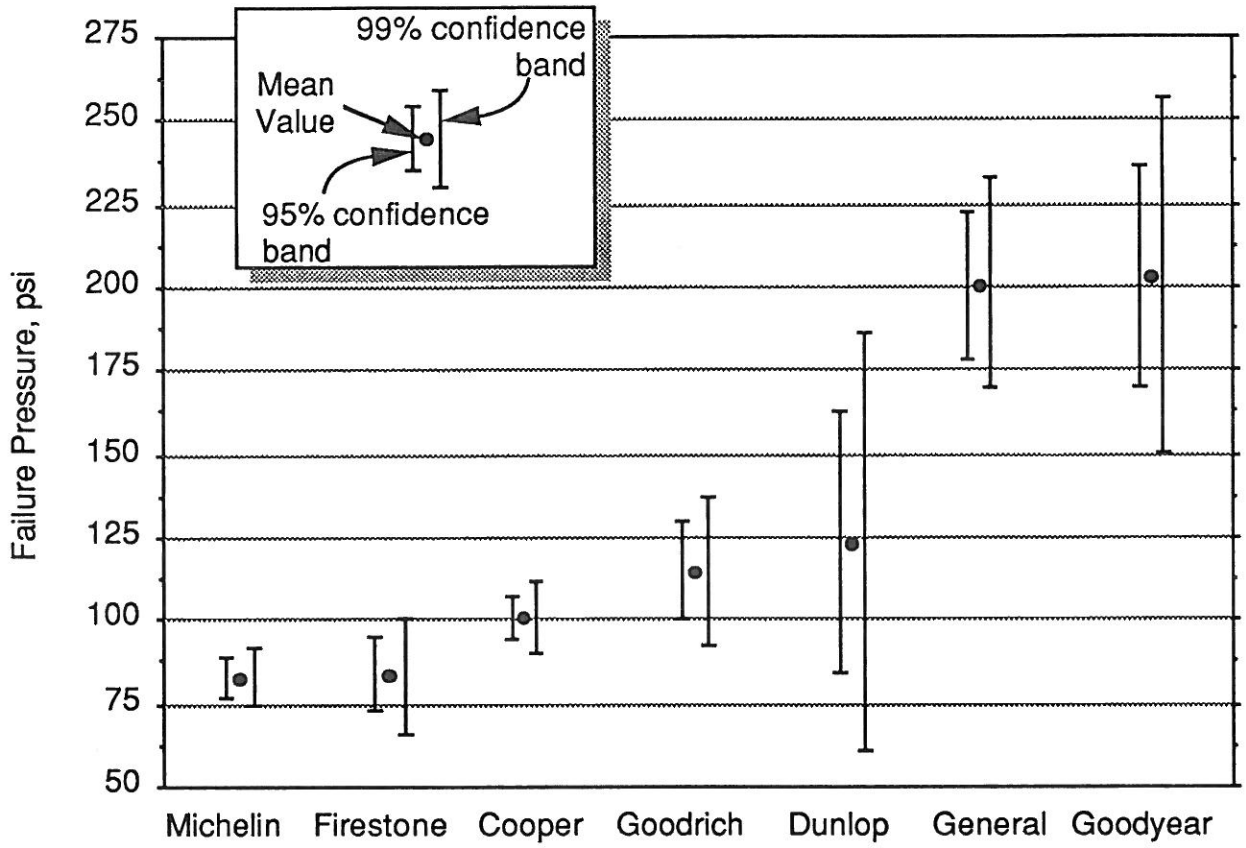
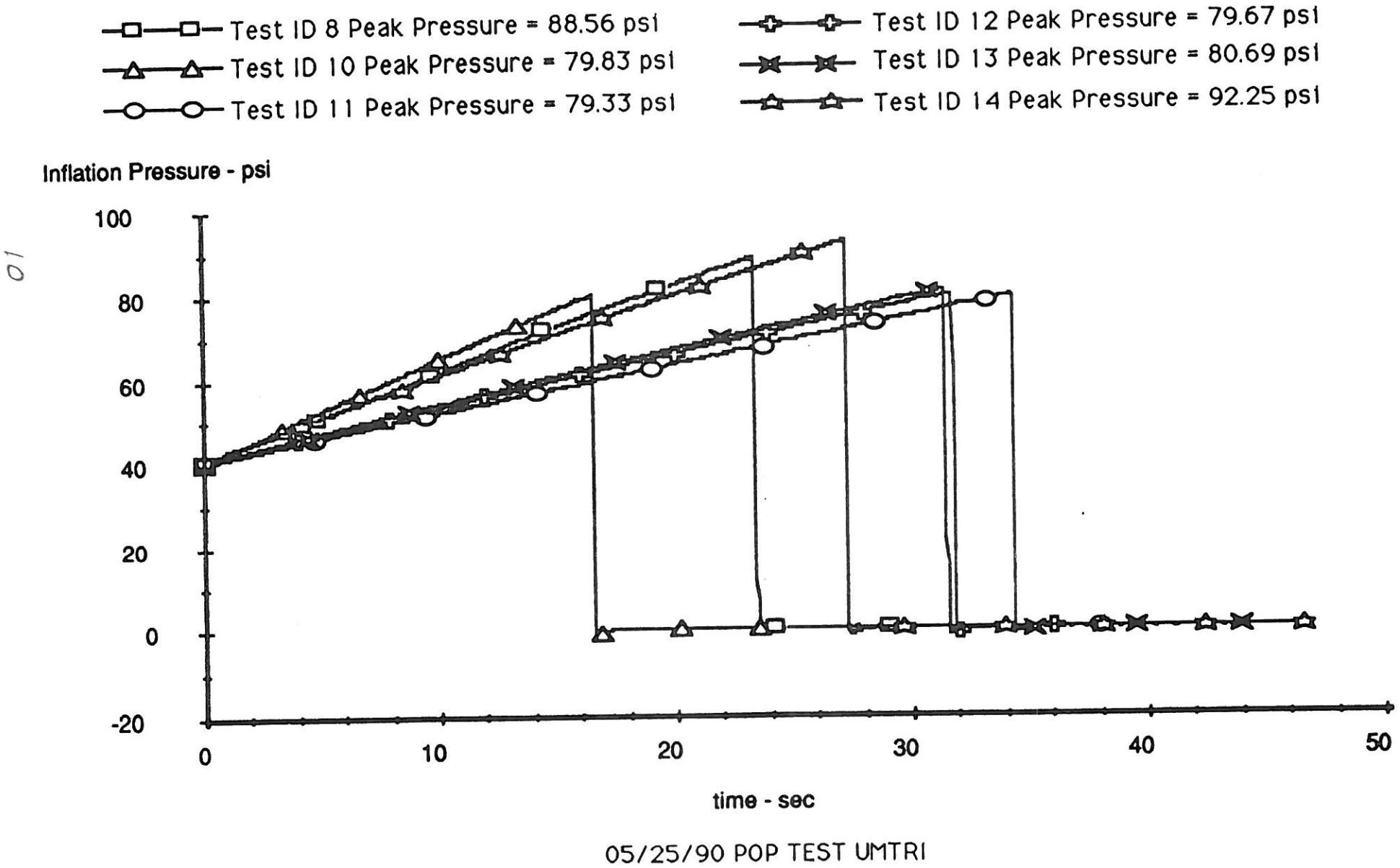


Figure 3. Failure Pressures by Tire Make
—The Mean Values and their 95% and 99% Confidence Bands from Six Trials of Each Make—



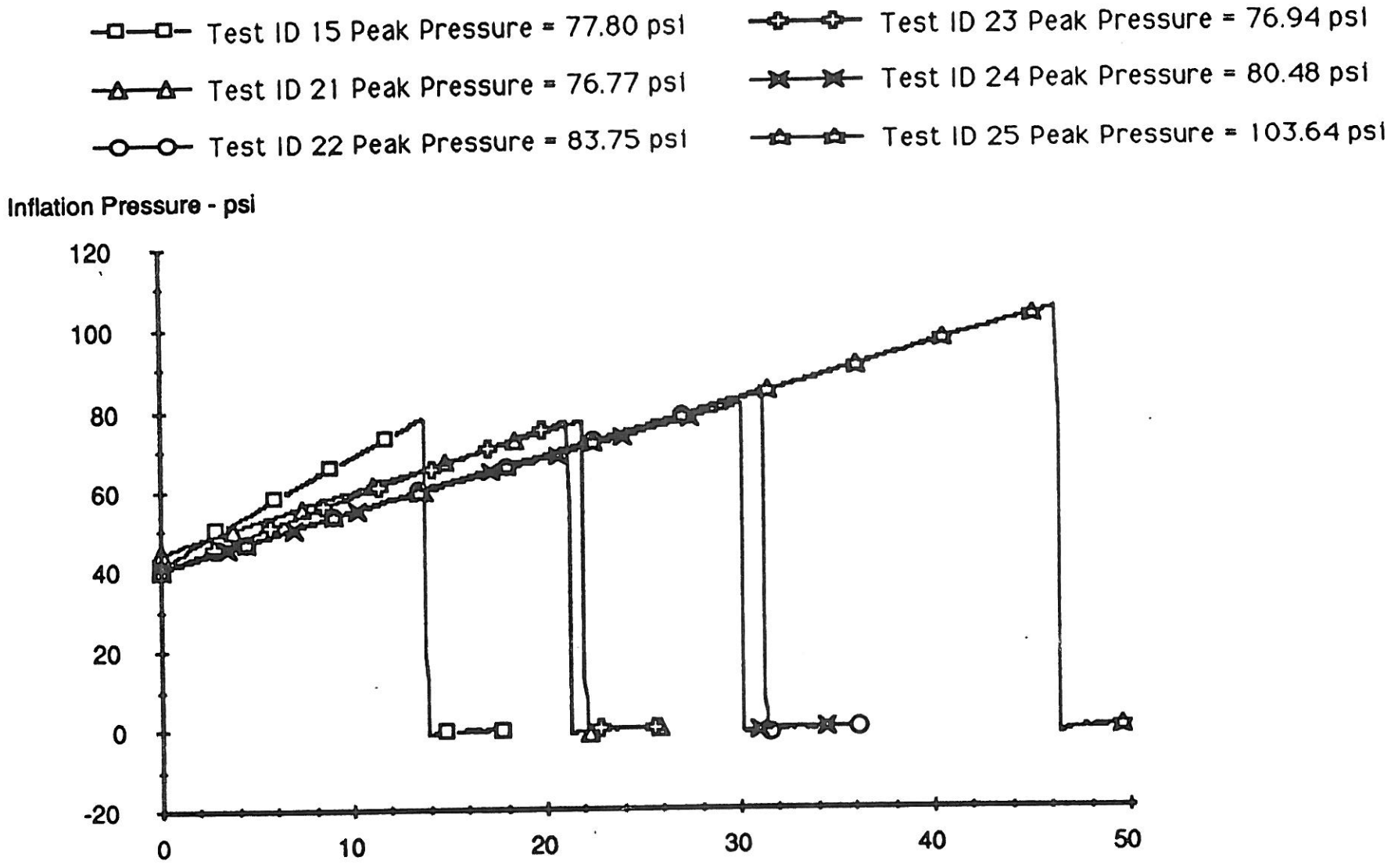
Data Appendix

Michelin Radial XCH4 All Season LT215/85 R16



05/25/90 POP TEST UMTRI

Firestone SteelTex Radial FSR LT215/85 Rib



05/25/90 POP TEST UMTRI

BF Goodrich The Edge LT215/85 Rib

Test ID 9 Peak Pressure = 98.35 psi

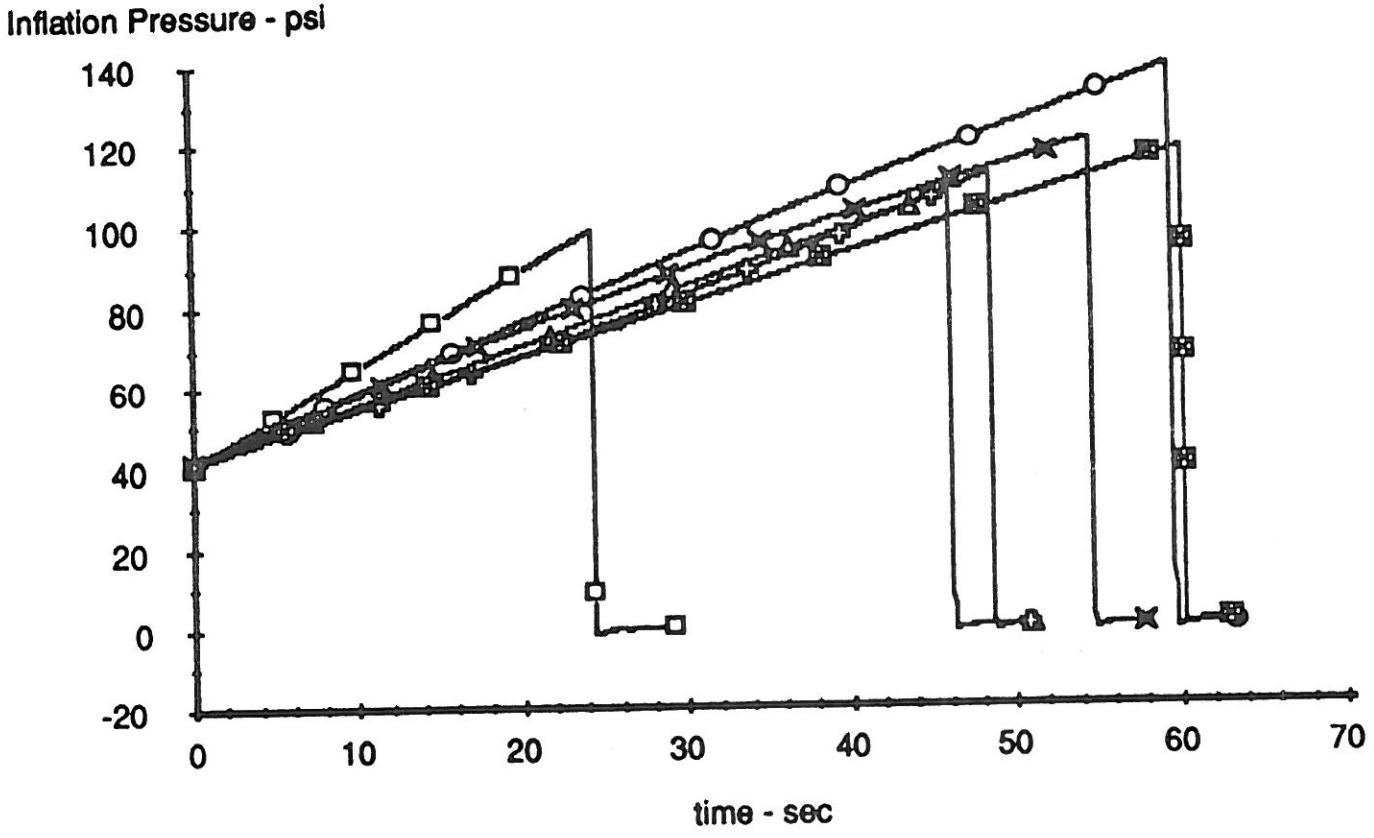
Test ID 26 Peak Pressure = 106.34 psi

Test ID 27 Peak Pressure = 137.95 psi

Test ID 28 Peak Pressure = 110.98 psi

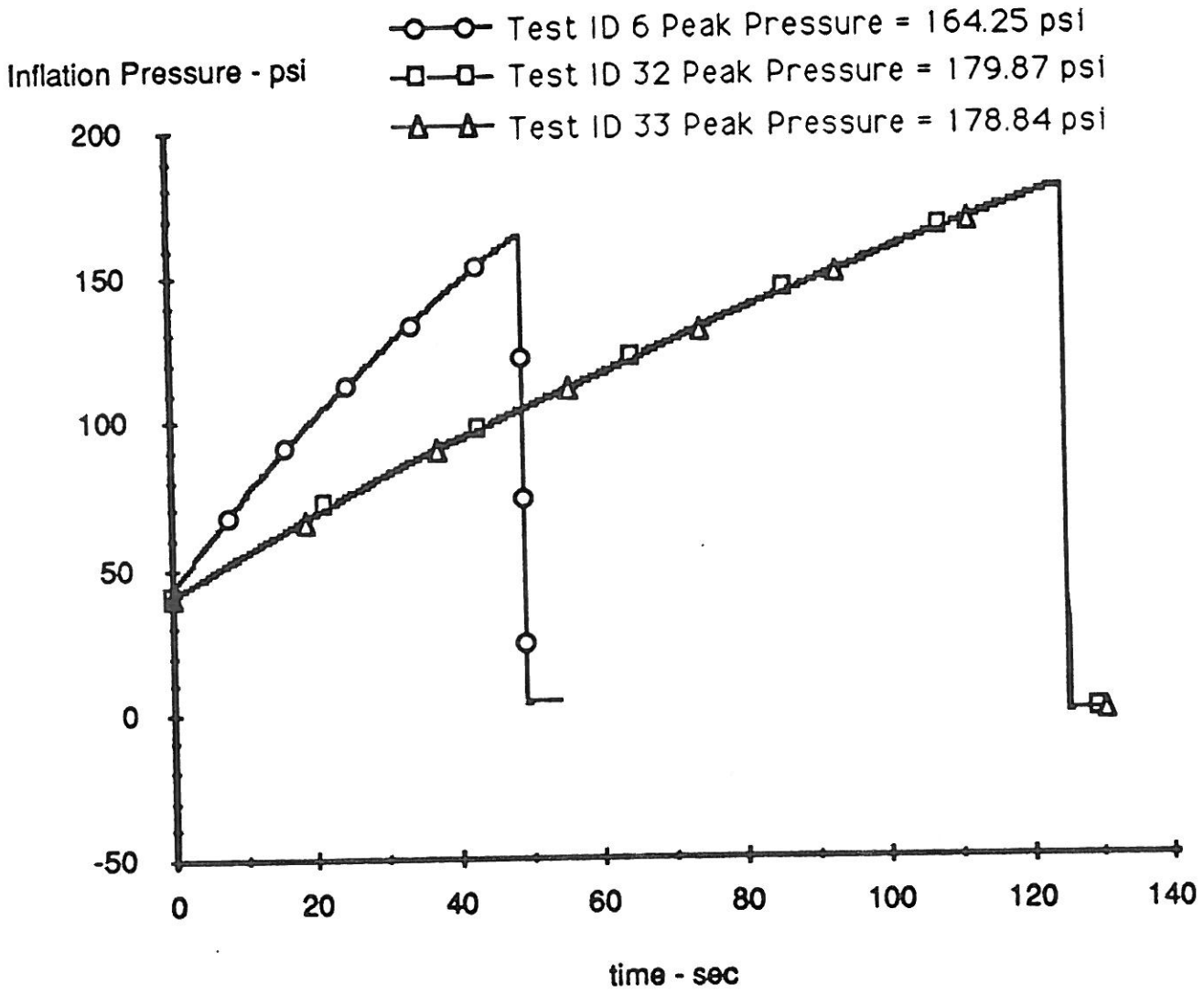
Test ID 29 Peak Pressure = 119.68 psi

Test ID 30 Peak Pressure = 116.73 psi



05/29/90 POP TEST UMTRI

GoodYear Wrangler LT LT 215/85 Rib



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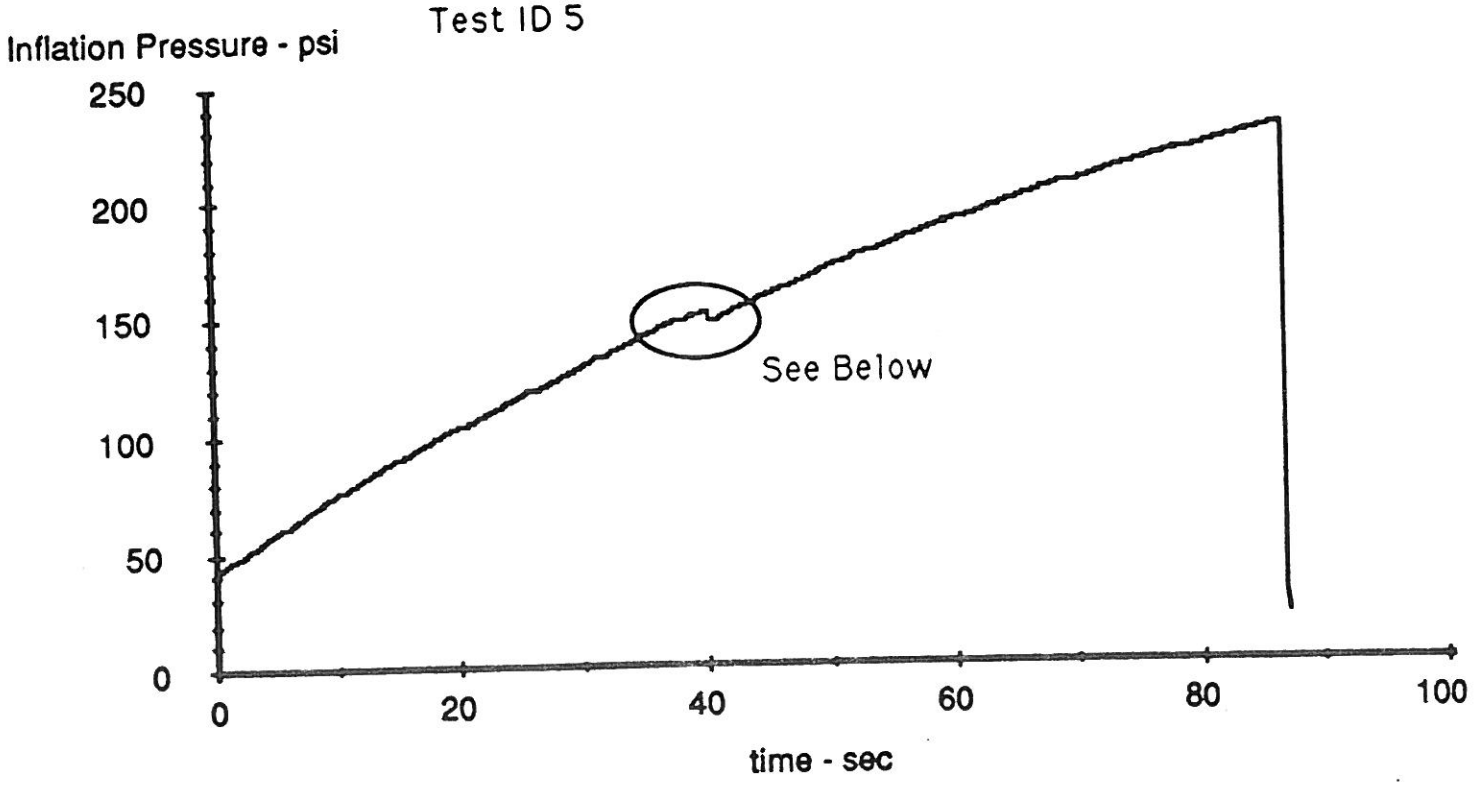
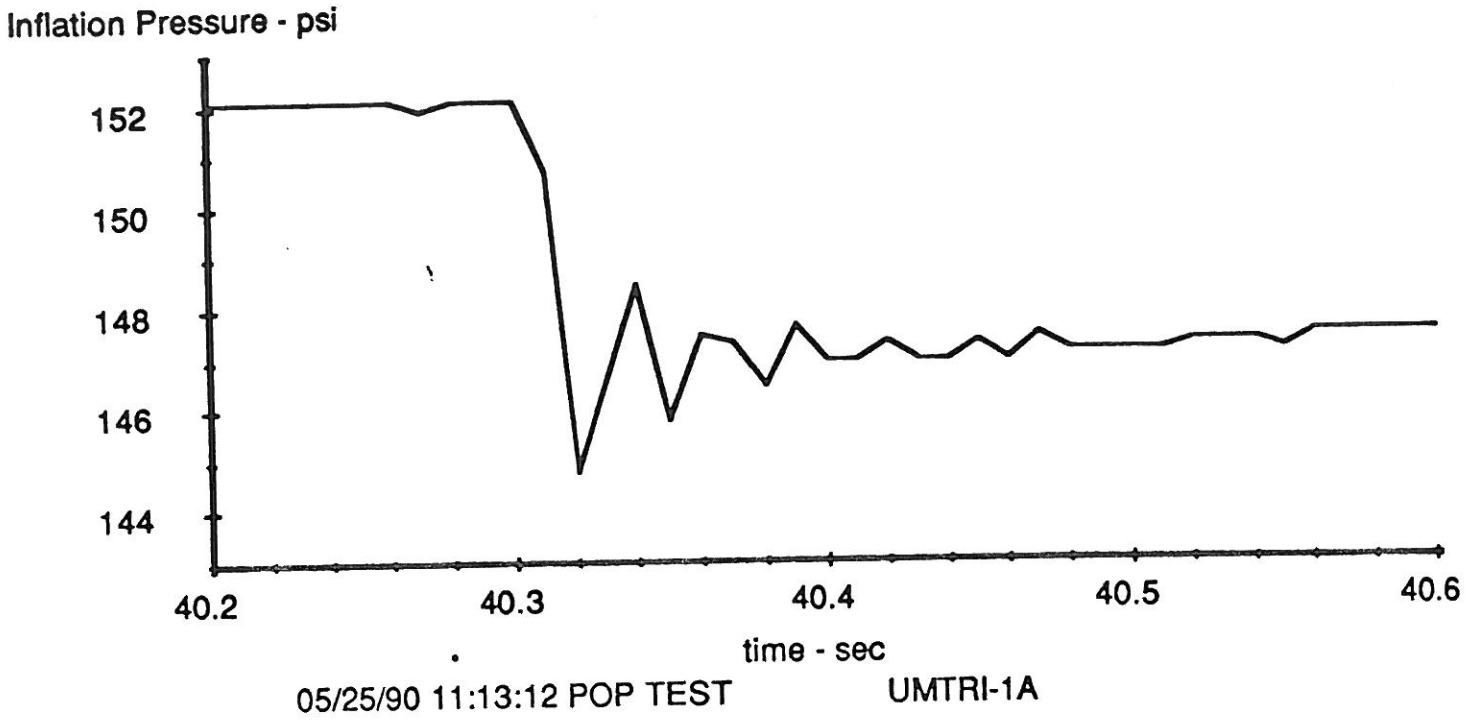
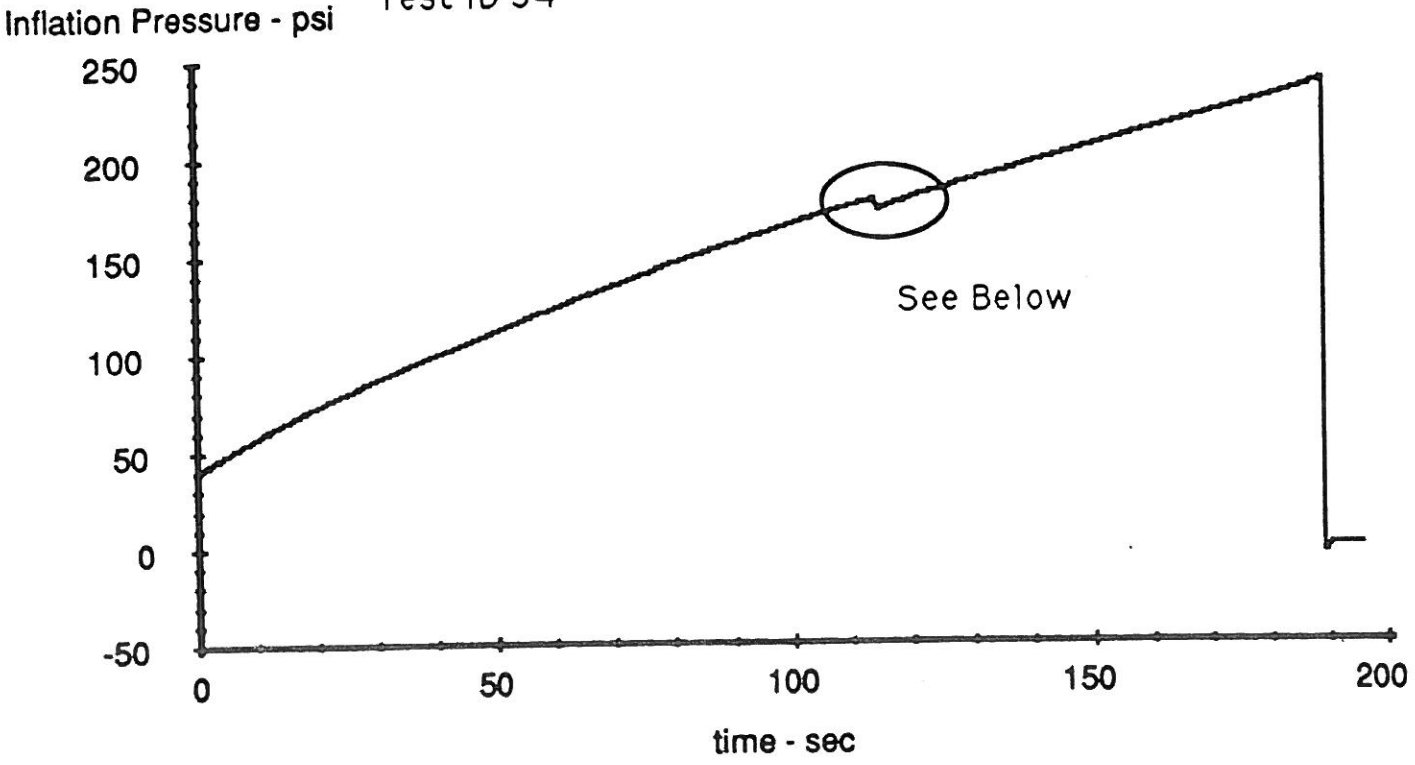
GoodYear Wrangler LT LT 215/85 Rib
Peak Pressure = 229.86 psi
Popped Pressure = 152.057 psi
Test ID 5



"Pop" Region



GoodYear Wrangler LT LT215/85 Rib
Peak Pressure = 237.19 psi
Popped Pressure = 177.47 psi
Test ID 34



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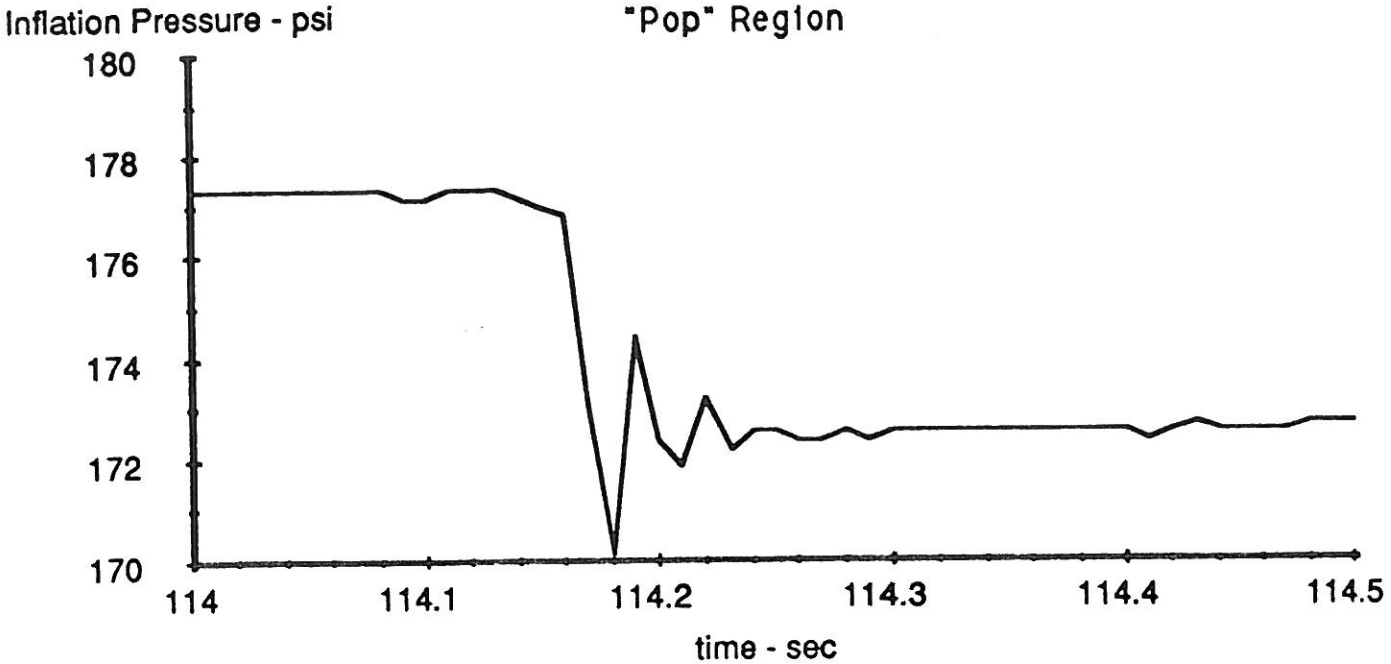

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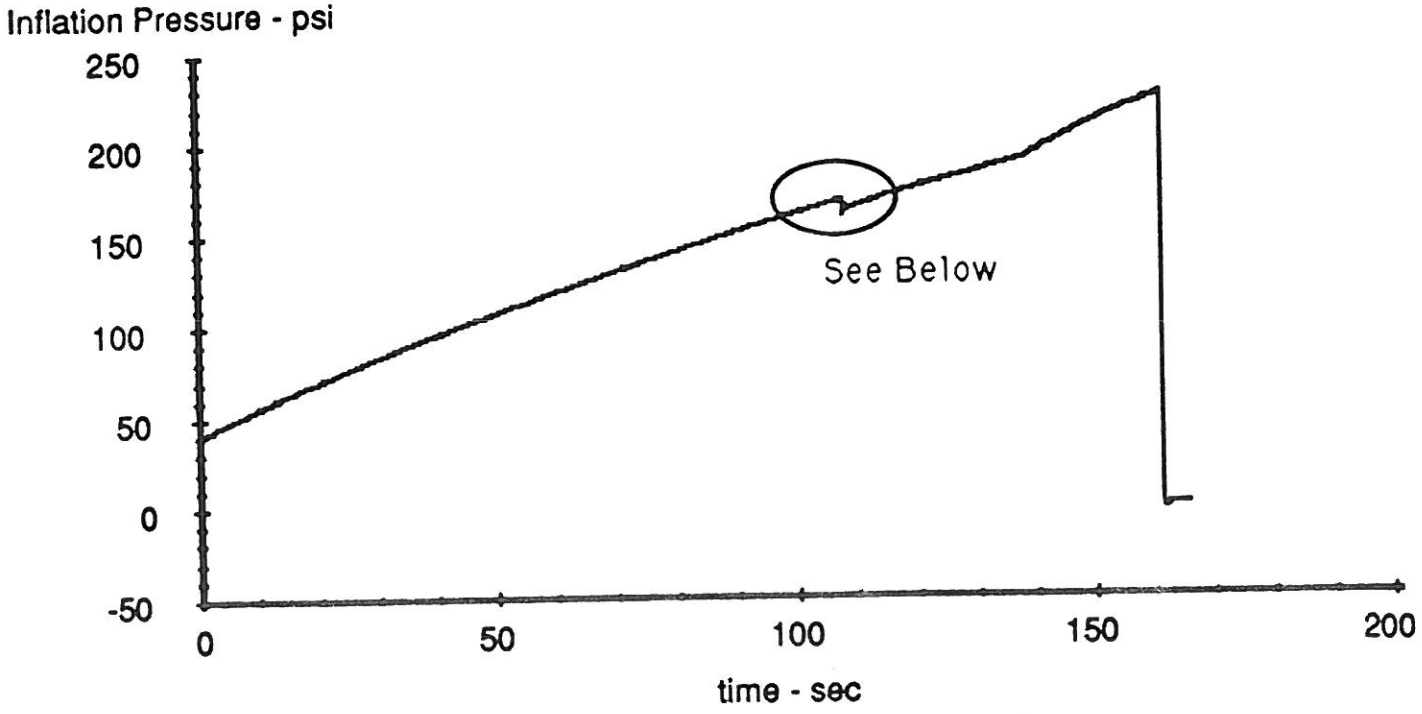
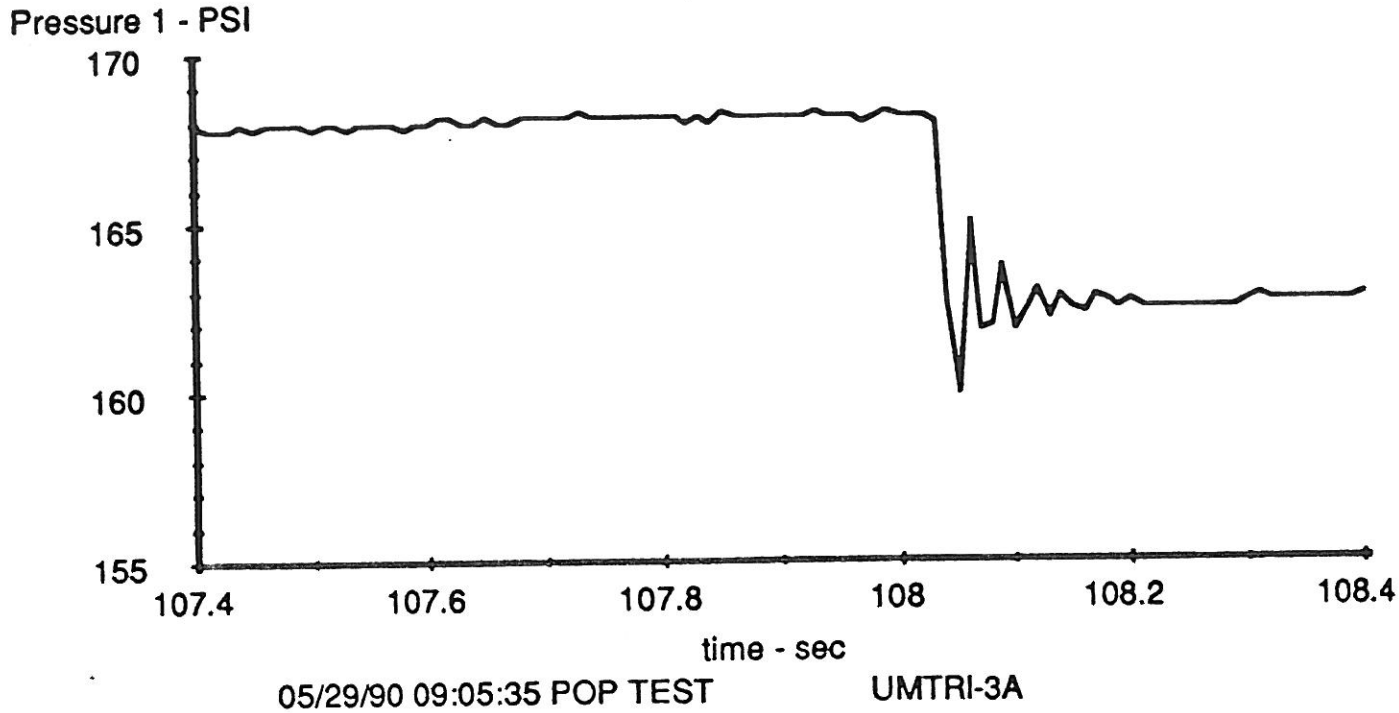
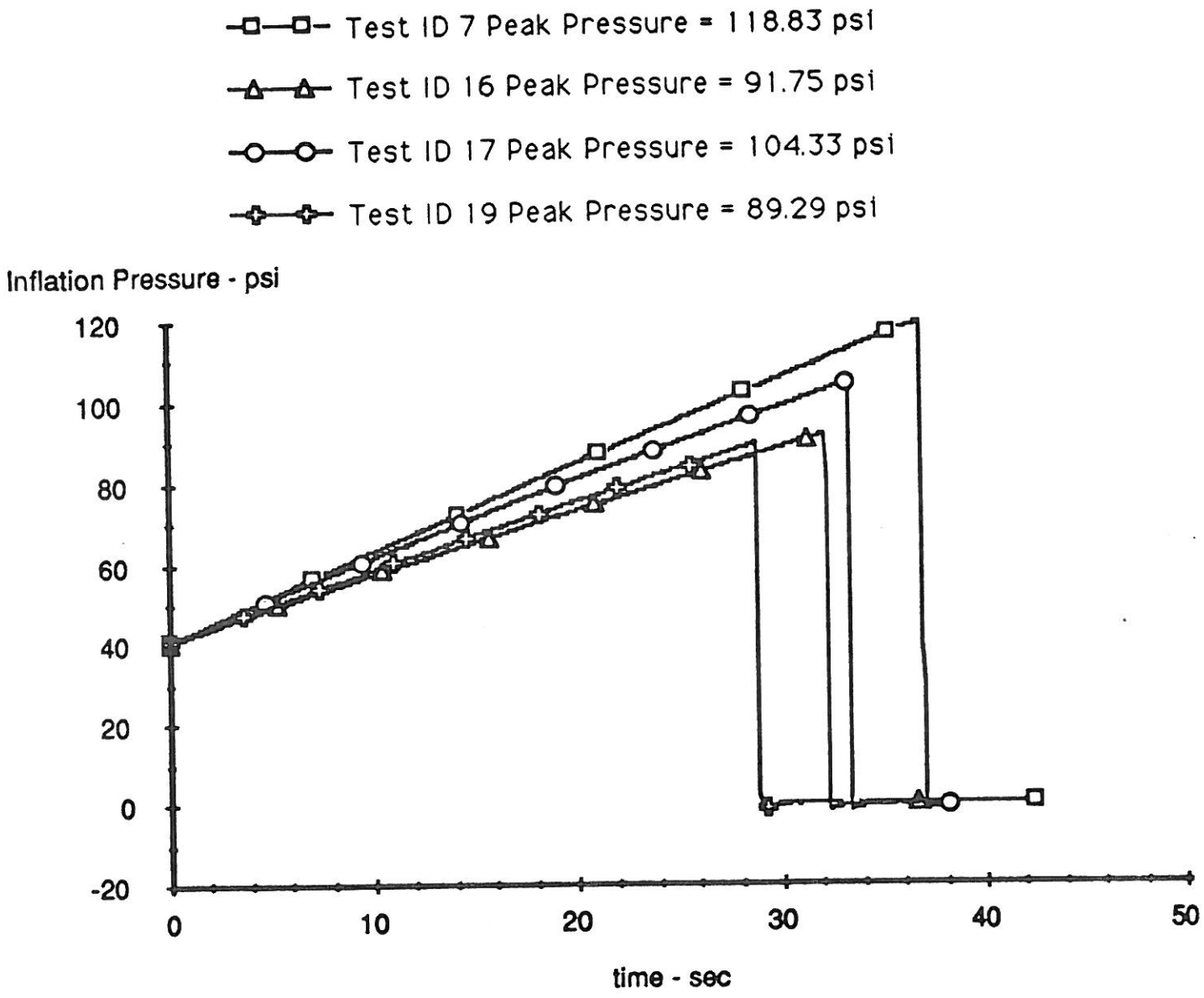
GoodYear Wrangler LT LT215/85 Rib
Peak Pressure = 226.1 psi
Popped Pressure = 168.26 psi
Test ID 31



"Pop" Region

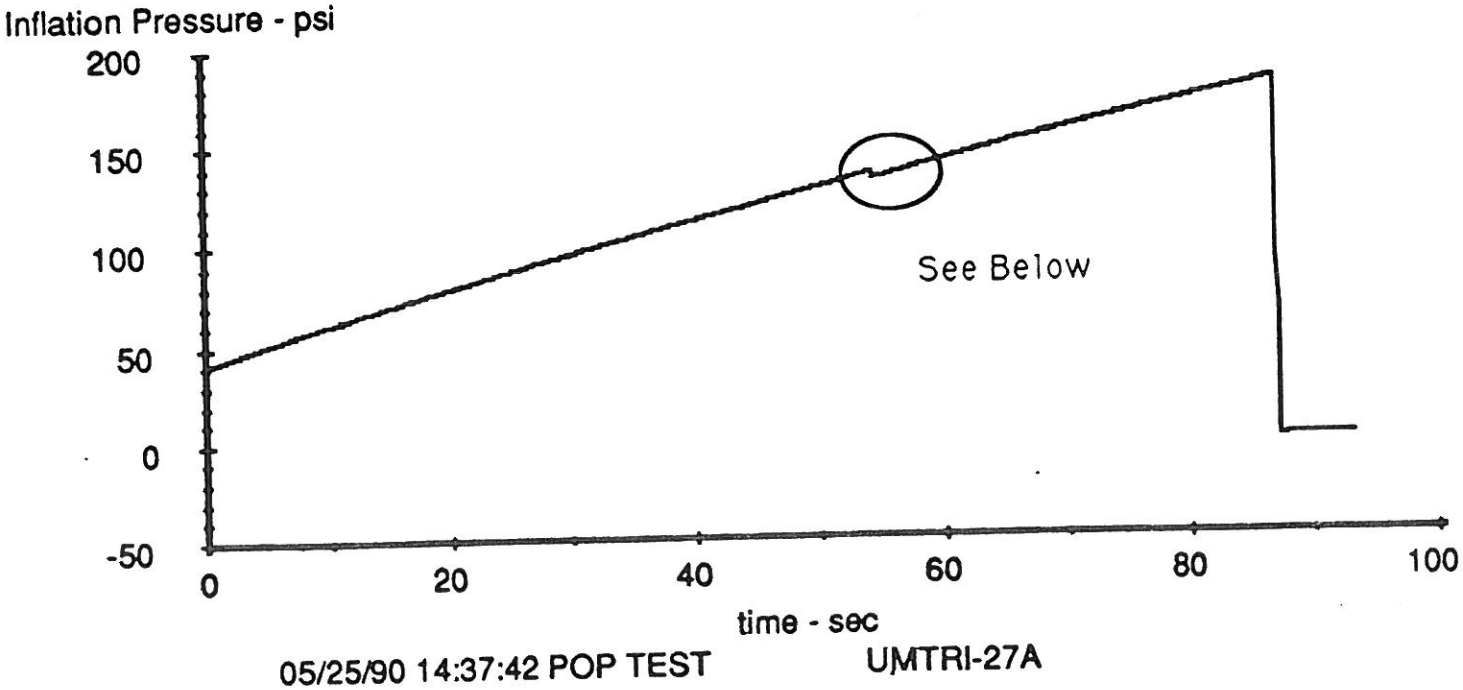


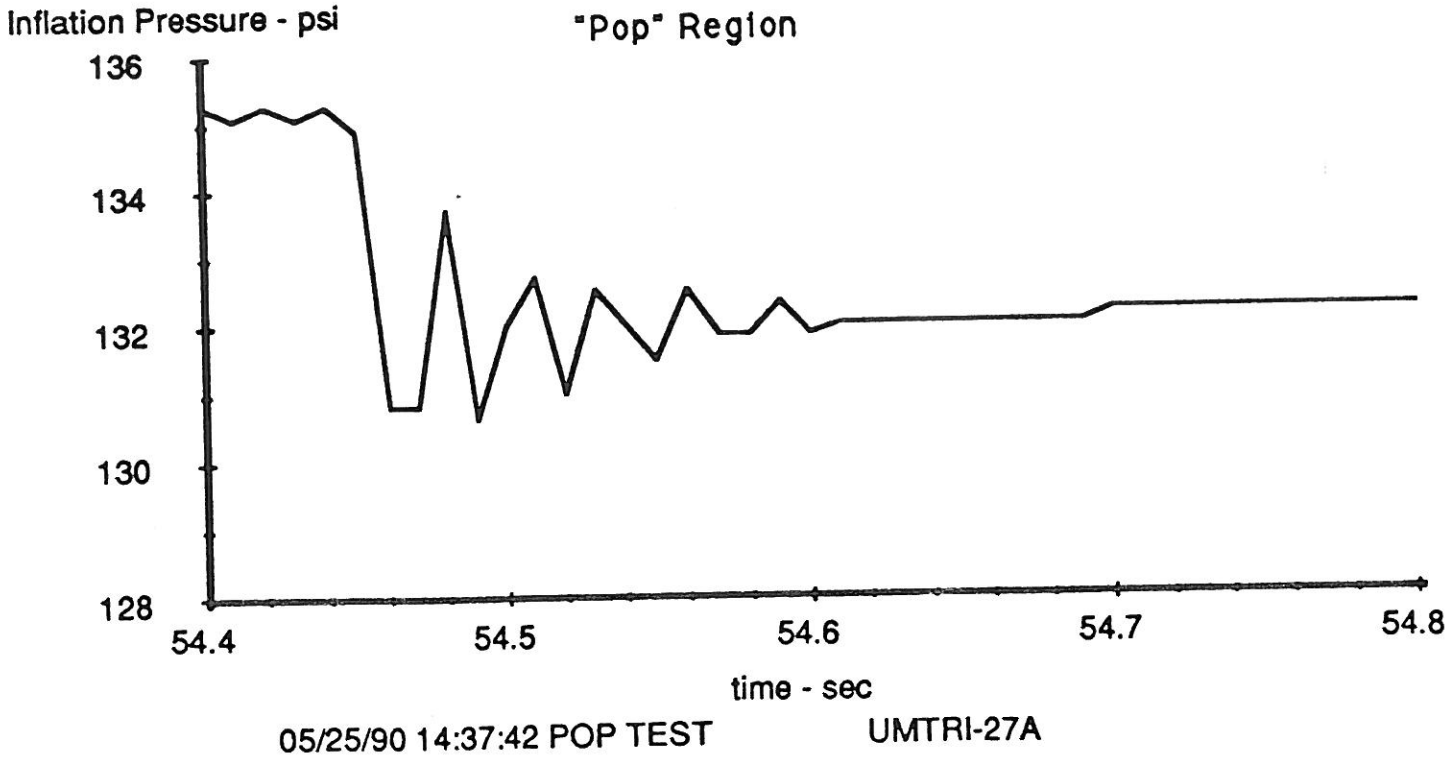
Dunlop A/P Radial Rover LT215/85 Rib



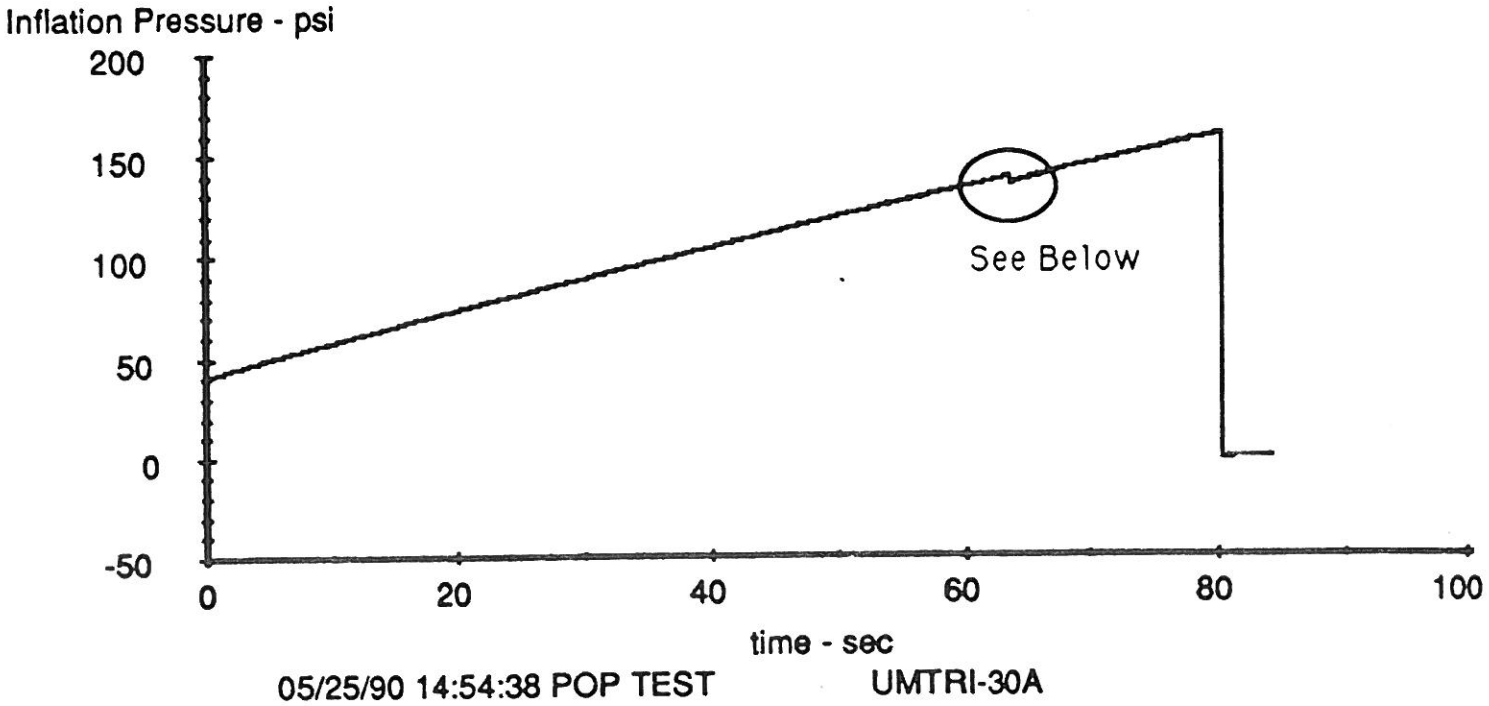
05/25/90 POP TEST UMTRI

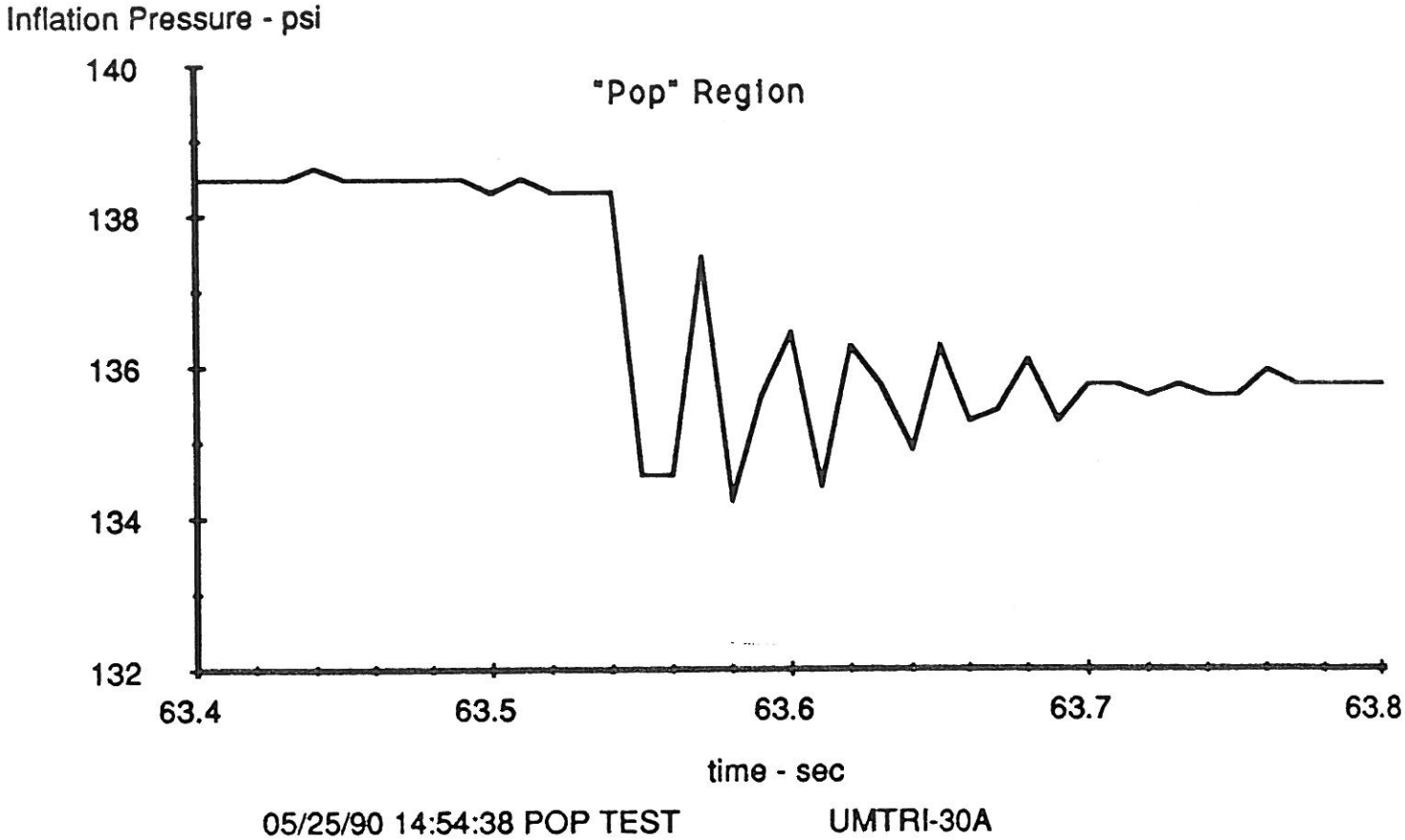
Dunlop A/P Radial Rover LT215/85 Rib
Peak Pressure = 181.02 psi
Popped Pressure = 135.41 psi
Test ID 18



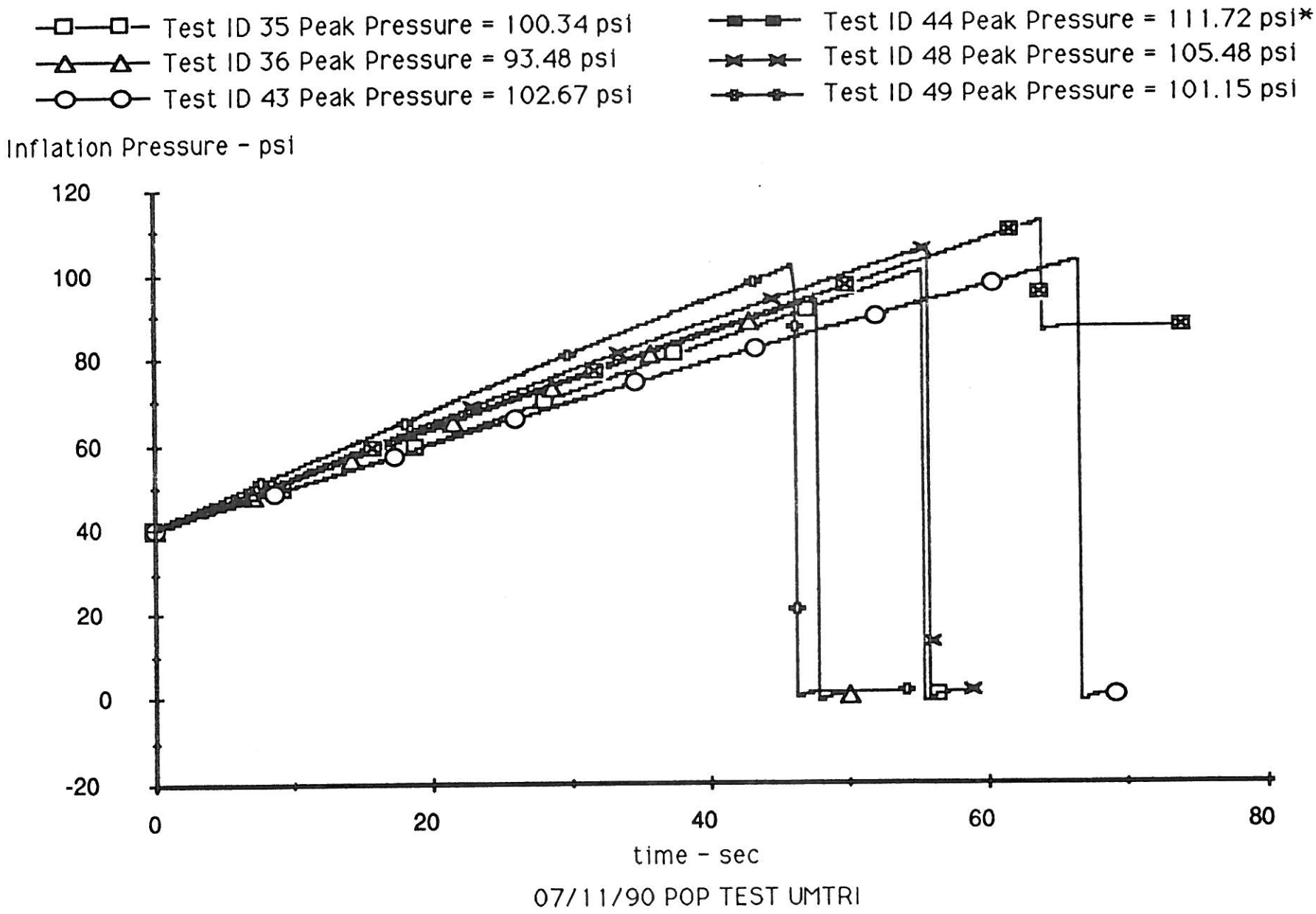


Dunlop A/P Radial Rover LT215/85 Rib
Peak Pressure = 159.92 psi
Popped Pressure = 138.64 psi
Test ID 20



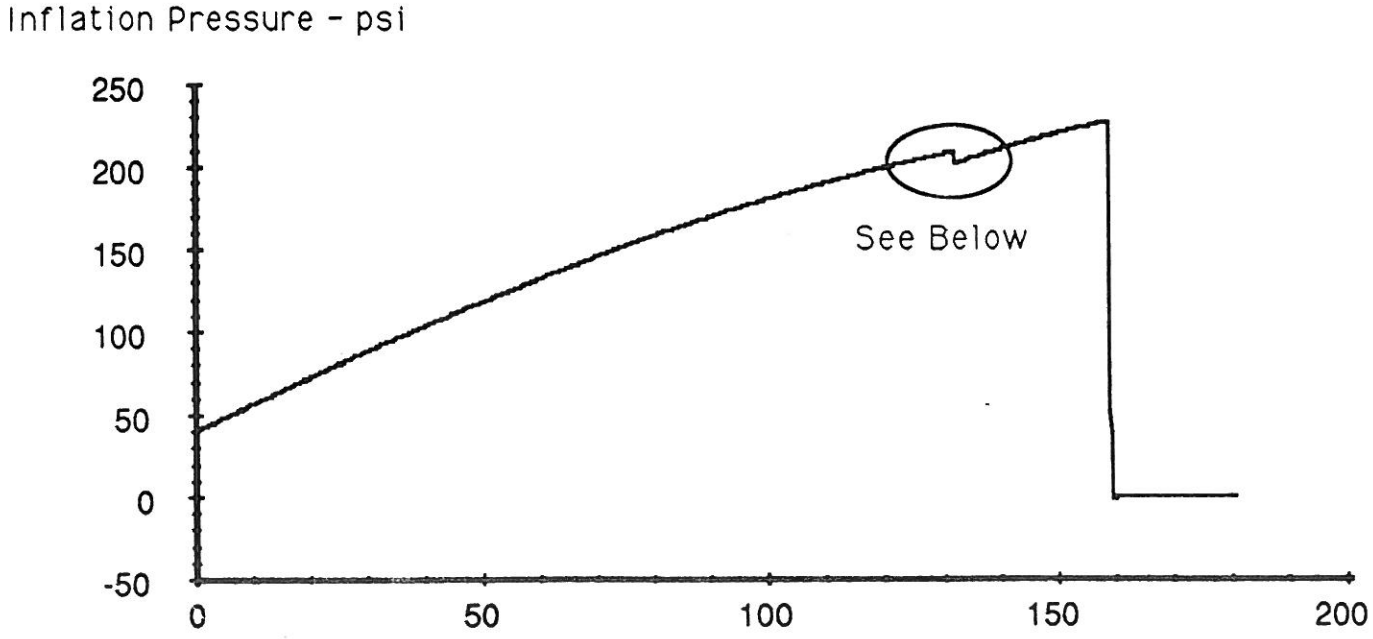


Cooper Discoverer LT 215/85 Rib

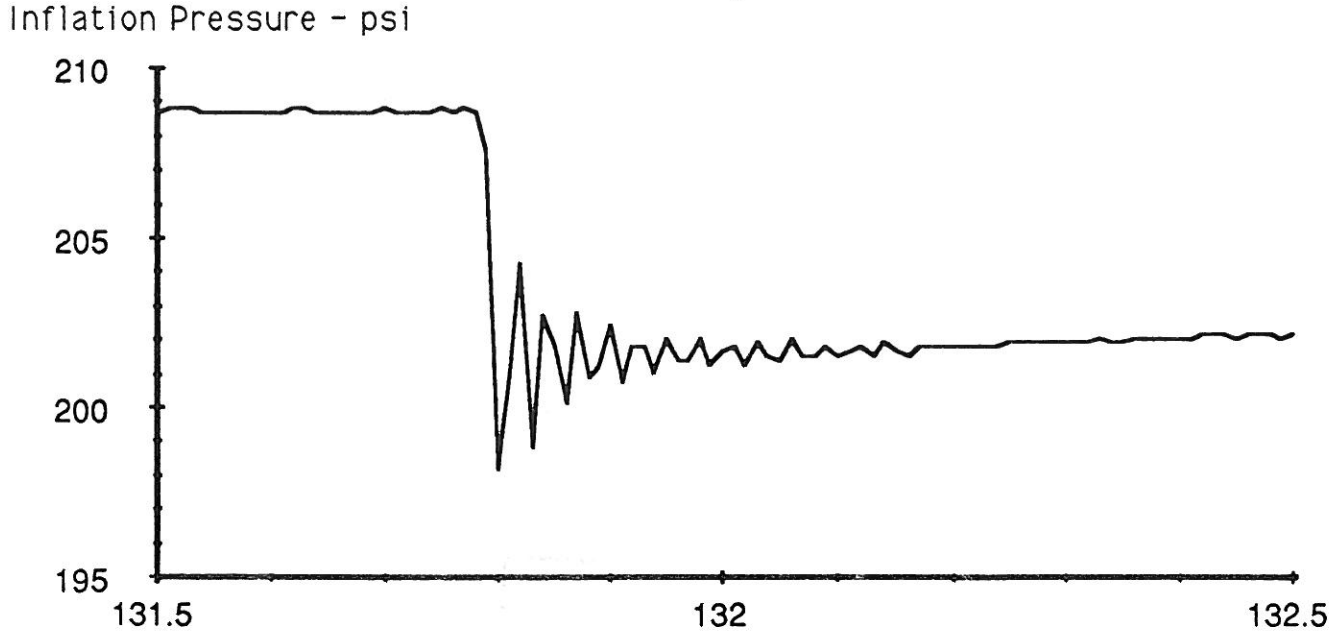


* See report for an explanation of why this did not return to zero.

General Ameri Steel LT 215/85 Rib
Peak Pressure = 227.51 psi
Popped Pressure = 208.83 psi
Test ID 40



"Pop" Region



General Ameri Steel LT215/85 Rib