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DOT HS-820 228

# AN INFRARED EXPERIMENT ON A ROAD WHEEL DURING AN FMVSS 109 TYPE COMPLIANCE TEST

Contract No. DOT-TSC-NHTSA-72-3

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Interim Report

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WASHINGTON, D.C. 20590

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the National Highway Traffic Safety Administration.

## PREFACE

The work described in this report was performed to determine the relationship between an automobile tires thermal performance and tire failure. This work was coordinated by the Transportation Systems Center, Electromechanical Branch as a part of the non-destructive Automobile Tire Testing Program sponsored by the National Highway Traffic Safety Administration, Research Institute.

The experiment was conducted at Ogden Technology, a compliance center testing retread tires in Long Island, New York. TSC designed the experiment provided coordination, technical assistance, data analysis and evaluation during the experiment.

The purpose of this report is to describe the instrumentation and the data collection techniques used rather than to cite results of the first experiments although some preliminary thermal data proved to be interesting.



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## 1.0 INTRODUCTION

Clearly, one of the more important elements of the relationship between compliance tests and the road failure of tires deals with the tire's thermal performance during compliance tests. In an effort to gain more knowledge about failures during compliance testing, an experiment was conducted at Ogden Technology, a compliance center testing retread tires in Long Island, New York. The experiment's purpose was to determine whether monitoring the thermal performance of tires would permit observation of the growth of flaw areas and predict the occurrence and cause substantially in advance of failure. Therefore, it was necessary to identify the location of any changes and to establish their magnitude with time in compliance testing. The continuing thermal profile of all parts of the tire should be recorded throughout the entire test. For a high speed test, this means obtaining data over a period of three and a half hours. For an endurance test, data must be collected continuously over a period of thirty-four hours.

Of singular importance is the ability to relate areas having flaws identified by other non-destructive means to thermal anomalies, and hopefully to failed areas. In order to accomplish this, it is necessary to rigorously scrutinize the data taken before compliance testing and compare it with later identical tests made after compliance testing. All tires sent to the compliance center were inspected using techniques at the current level of the art of ultrasonics, holography, IR imaging and X-Ray. After return from compliance testing, they were similarly inspected. Data obtained from the four inspection modes is available in a computerized data storage system from which plots of the location of anomalous areas can be obtained. It is therefore quite easy to perform a first level correlation review on tires which have been run at compliance centers.

At the compliance center, a system of radiometers was set up which could simultaneously monitor temperature excursions of 1/2" segments of tire approximately 2.5" wide at each shoulder. In

addition, the absolute tread temperature was continuously monitored. The sensors had a temperature precision of approximately 0.1°F with accuracy of overall temperature measurement of approximately two degrees. The complete system is outlined in Section 2.0.

## 2.0 INSTRUMENTATION

The system consisted of one Barnes IT4 infrared thermometer, two transient radiometers, a sync pickup with a binary spacing counter and a readout package. Figure 1 is a block diagram of the complete instrumentation package used in the experiment.

The readout package was made up of a Tektronics dual channel oscilloscope, Model 516, onto which a modified Beatty Coleman K-D-5 strip film oscilloscope camera is mounted.

Figure 2 is a photograph of one transient radiometer and the readout equipment. Figure 3 is a photograph of the radiometers set up on a standard DOT test wheel at the compliance center. Optical and response data for the transient radiometer may be found in Appendix A.

Appendix B contains data about the IT4; its accompanying recorder and the calibration thereof.

The photo-optic pickup was used for locating an identifying mark on the tire with respect to its rotational coordinates. It is a standard Dolan Jenner Model 500 specially modified at TSC to provide binary spaced output as described elsewhere.

The following sections provide a brief description of the various system components.

### 2.1 TRANSIENT RADIOMETERS

These are near-IR sensors, whose liquid nitrogen cooled detectors are designed to subtend an angle of approximately  $2.2^\circ \times .1^\circ$  with a temperature sensitivity at  $100^\circ\text{F}$  of better than  $.1^\circ\text{F}$ . They are set up to sweep a 2.5" annulus around the tire with one sensor at each tread-shoulder intersection. The projected coverage for each radiometer is approximately 4 1/2" on the tire. The sensors have a 5 - 3000 Hz bandwidth and the output signal is 0-9V at 1K impedance.

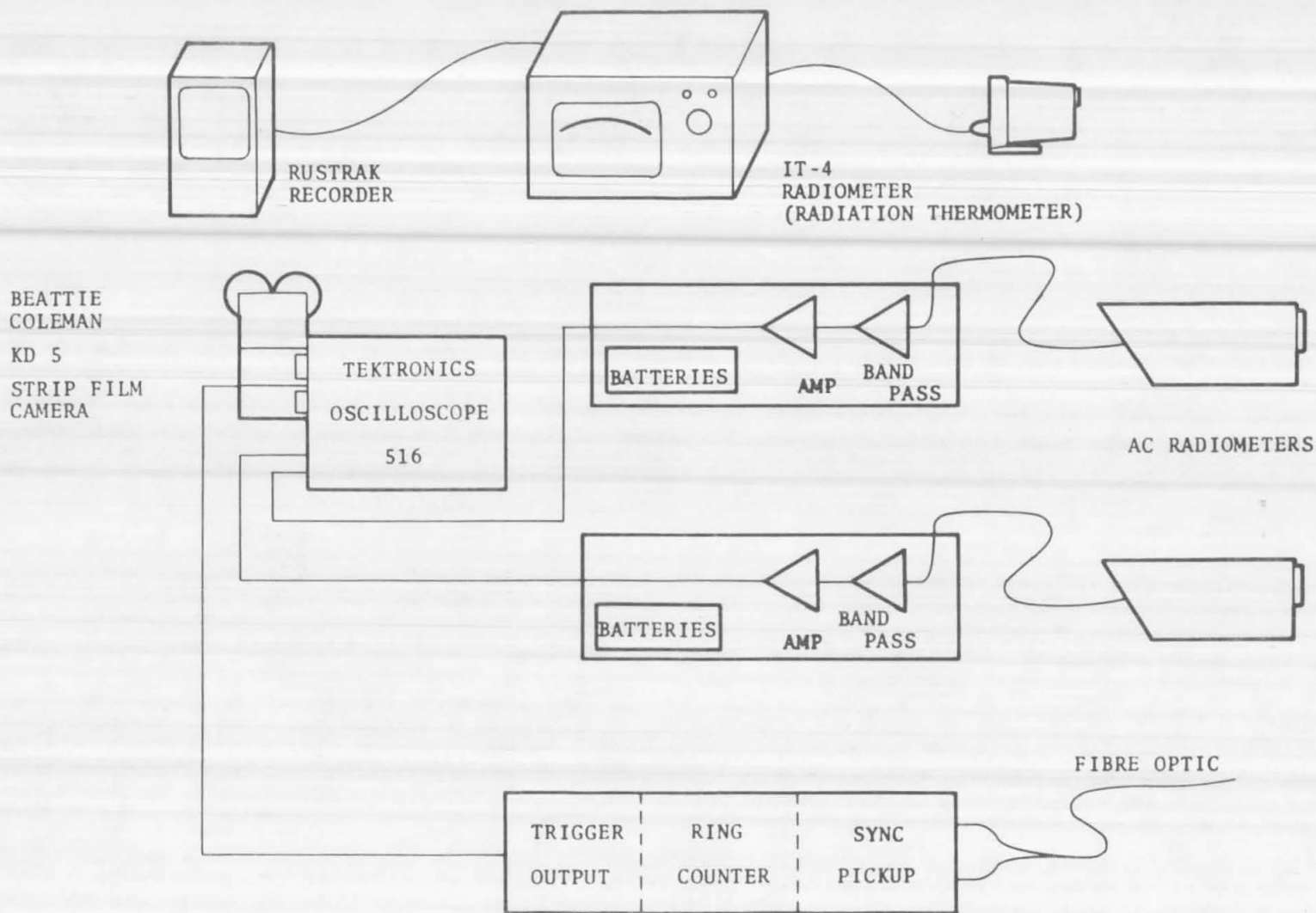


Figure 1. Field Infrared Tire Inspection System



Figure 2. Field Infrared Tire Inspection System (FITIS) Mounted on Scope Cart

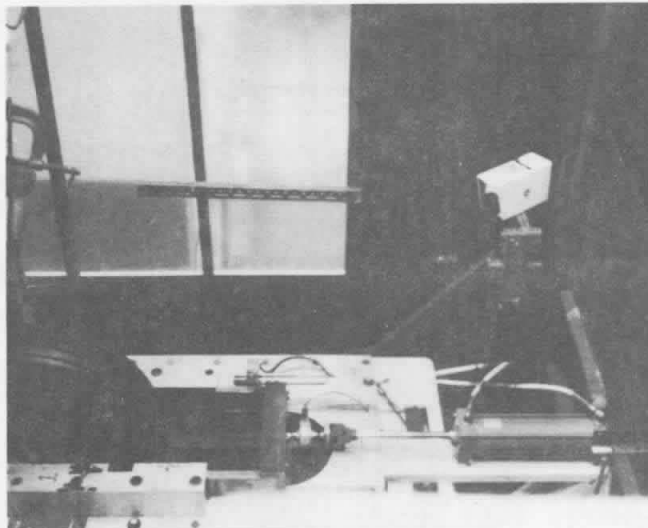


Figure 3. FITIS Mounted on Test Wheel

## 2.2 ABSOLUTE TEMPERATURE SENSOR

A temperature-sensing radiometer, the IT4, was used; its 2° field of view is focused on a 1.5-inch circle at the center of the tread. Output from this unit is fed to a conventional Rustrack recorder with a chart speed of approximately 1" per hour and an accuracy of ~ 2°F. No provision is made for emissivity compensation on tires since they are assumed to be uniform and almost black. A recorder temperature curve is given in Figure 4.

## 2.3 SYNC PICKUP

Sync pickup is a photo optic pickup in the form of a bifurcated fibre bundle with a light at the end of one arm and a silicon detector at the other. A reflecting surface moving in front of the single end of the bundle causes a triggering pulse to be generated. This pulse corresponding to a single tire rotation is then run through a binary divider controlled by a selector switch to give an output pulse for every 2, 4, 8, 16, 32, 64 rotations with provision for increasing to 128, 256, 512 or 1024 input pulses. This output is then fed to the trigger circuit of the oscilloscope. Table 1 gives the approximate timing interval for various rotational speeds.

## 2.4 READOUT

Readout is accomplished by feeding the output of each transient radiometer to one channel of the scope. Scope timing is then adjusted, using the uncalibrated vernier, until output from two complete tire rotations may be viewed on the scope face. Next, a mask is placed over the scope face in the manner shown in Figure 5. Then this display represents temperature excursions in the Y direction versus rotational position around the tire. The left trace is the inside tire shoulder and the right trace is the outside or whitewall shoulder.

The scope's data is presented at intervals dependent upon the binary divider's setting on the sync trigger. It has been found convenient to take a piece of data every fifteen to thirty seconds.



IT4 - TEMP. VS RECORDER CHART DIVISIONS  
DEPT. OF TRANSPORTATION TIRE TESTING PROGRAM

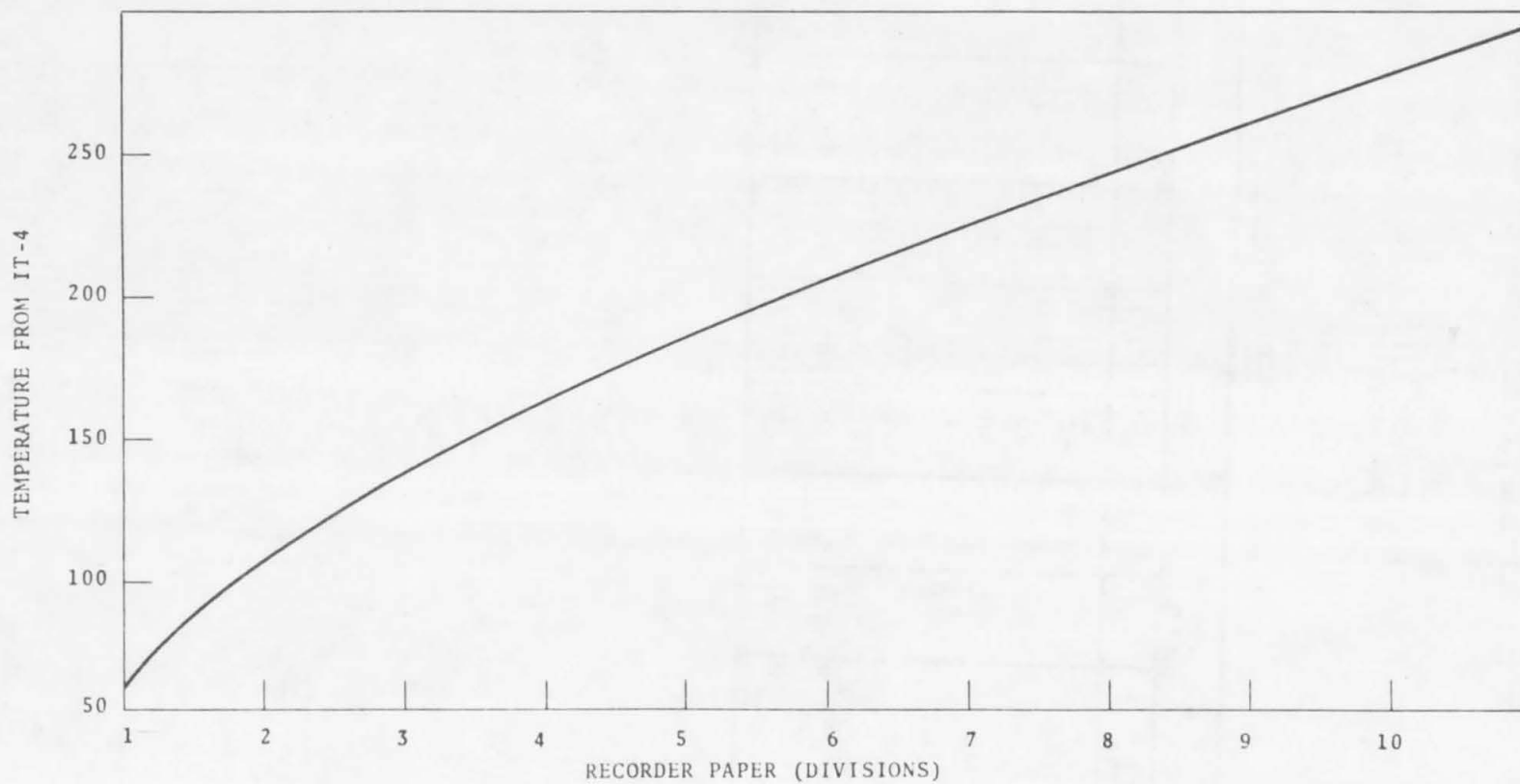


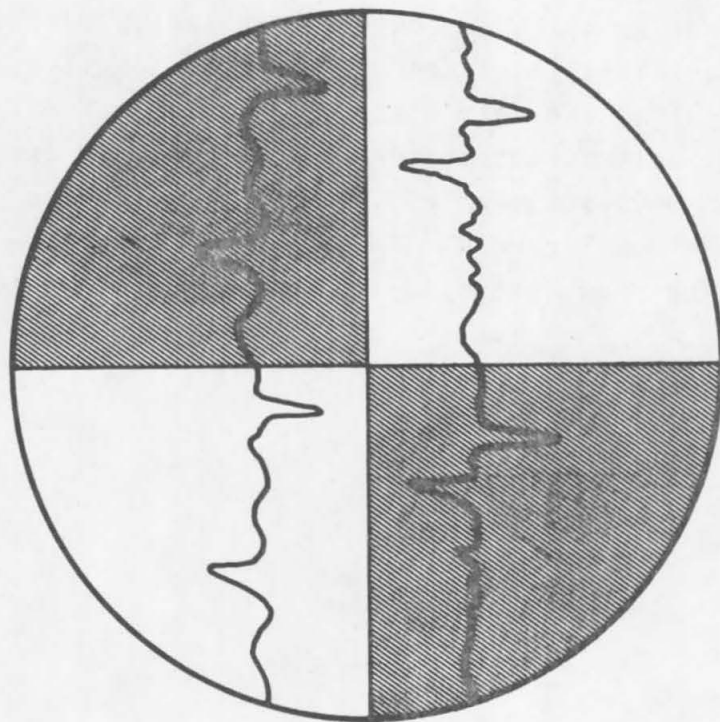
Figure 4. IT-4 Temperature Vs Recorder Chart Division

TABLE 1. COUNTER SETTING VS OSCILLOSCOPE TRACE SPEED

Department of Transportation Tire Test Program  
 Contract TME-0049-MC

Records/Minute

		Counter Setting						
RPS	Scope Setting	*1	2	4	8	16	32	64
4	50 msec/cm	240	120	60	30	15	7.5	3.75
5	40 msec/cm	300	150	95	37.5	18.8	9.4	4.7
6	33.3 msec/cm	360	180	90	45	22.5	11.25	6.62
8	25 msec/cm	480	240	120	60	30	15	7.5
10	20 msec/cm	600	300	150	75	37.5	18.8	9.4
12	16.7 msec/cm	720	360	180	90	45	22.5	11.25
14	14 msec/cm	804	420	210	105	52.5	26.25	13.12
15	13 msec/cm	900	450	225	112	56	28	14



LEFT  
SHOULDER

CHANNEL 1

RIGHT  
SHOULDER

CHANNEL 2

Figure 5. Display (FITIS)

## 2.5 DATA RECORDING

This is done on film using a Beattie Coleman camera with a continuous strip film transport; its direction of motion is normal to the X direction of the scope face. Film travel is matched to the frequency of data taking and about four inches of 35mm film moves across an image of the scope face every hour giving a packing density on film of between fifty and one hundred lines of data per inch. This format is called a contourgraph and is described in Reference 2. Electrical gains are set up on the oscilloscope to represent an output of one volt for .080" of vertical film excursion or 5°F per volt output at 140°F or 8°F per .1" excursion on the 35mm film. A more accurate transfer function may be obtained from the curves on Figure 6. Appendix D is a summary of the complete operating procedure used at the compliance center.

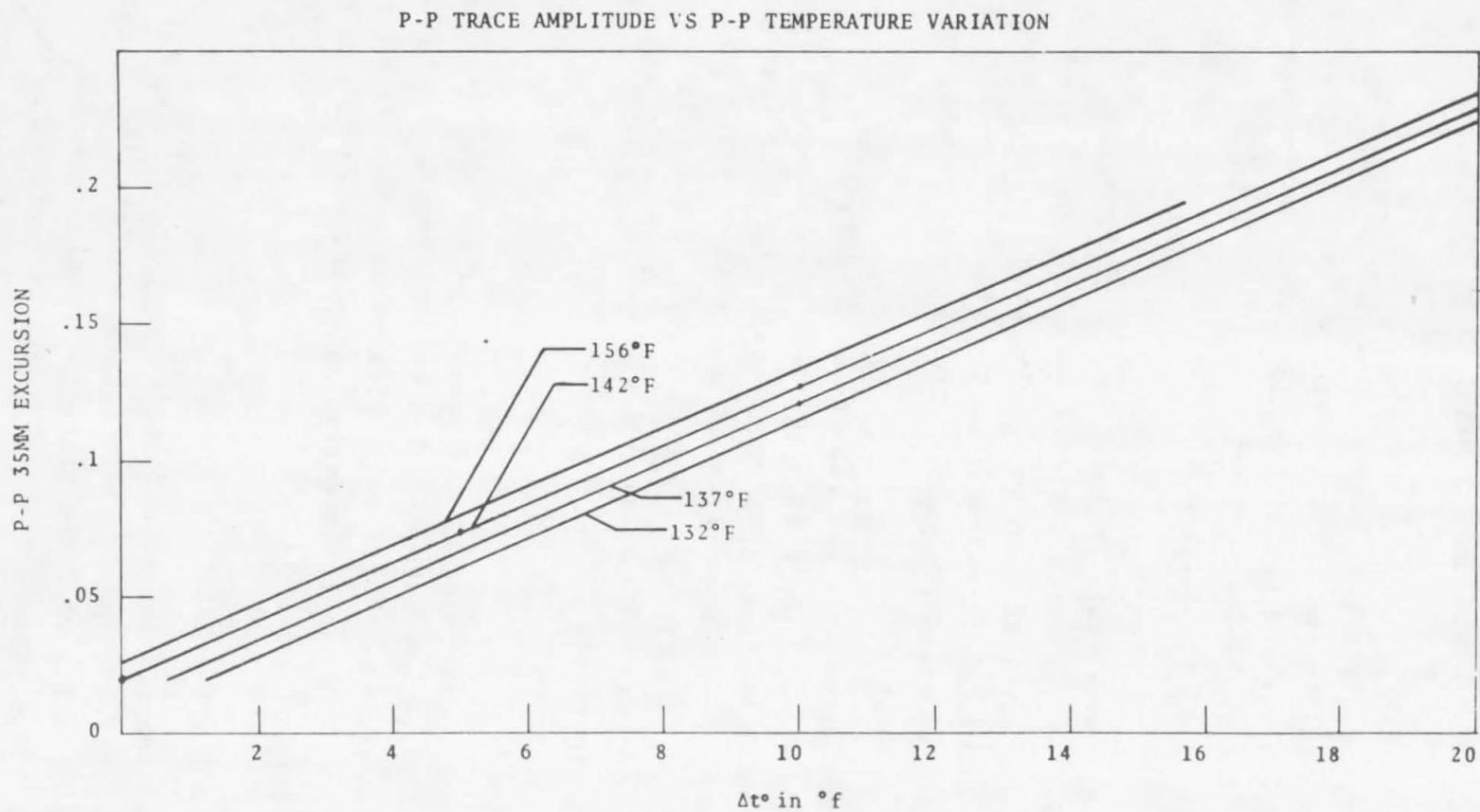


Figure 6. P-P Trace Amplitude Vs P-P Temperature Variation

### 3.0 COMPLIANCE TESTING EXPERIMENT

Six retread tires were investigated at the compliance center. Prior to shipment to the center, a standard set on non-destructive inspections was carried out at the Transportation Systems Center in Cambridge. The following sections review the non-destructive test data and copies of the failure analysis reviews are included in Appendix D.

The compliance tests included both high speed and endurance tests. Three of the tires reviewed survived high speed and two of the balance survived endurance. One tire failed its endurance tests (approximately 29 hours after the start). One tire that passed displayed excessive groove cracking and probably should have been considered defective.

The compliance test was the standard FMVSS 109 test on a DOT approved 67" wheel. The high speed test consisted of a two hour break-in, a two hour wait, and successive half-hour runs at 75, 80 and 85 mph. Endurance was a 34-hour test in which load was adjusted to values empirically established to give tire pressure of 24 psi for four hours, then increased to 28 psi for six hours, and finally increased to 32 psi for 24 hours.

#### 3.1 MEASUREMENTS

There are five special measurement parameters for this experiment. Three are taken for the entire duration of the compliance run and can therefore be plotted conveniently as a function of time; two are taken periodically and used to adjust the scale factors of other data.

#### 3.2 TREAD TEMPERATURE

Tread temperature as a function of time is shown for all six tires in Figures 7 and 8. Some elements of the data should be explained. In Figure 7 the sharp increments correspond to speed changes. These represent increasing differentials of roughly 5°F.

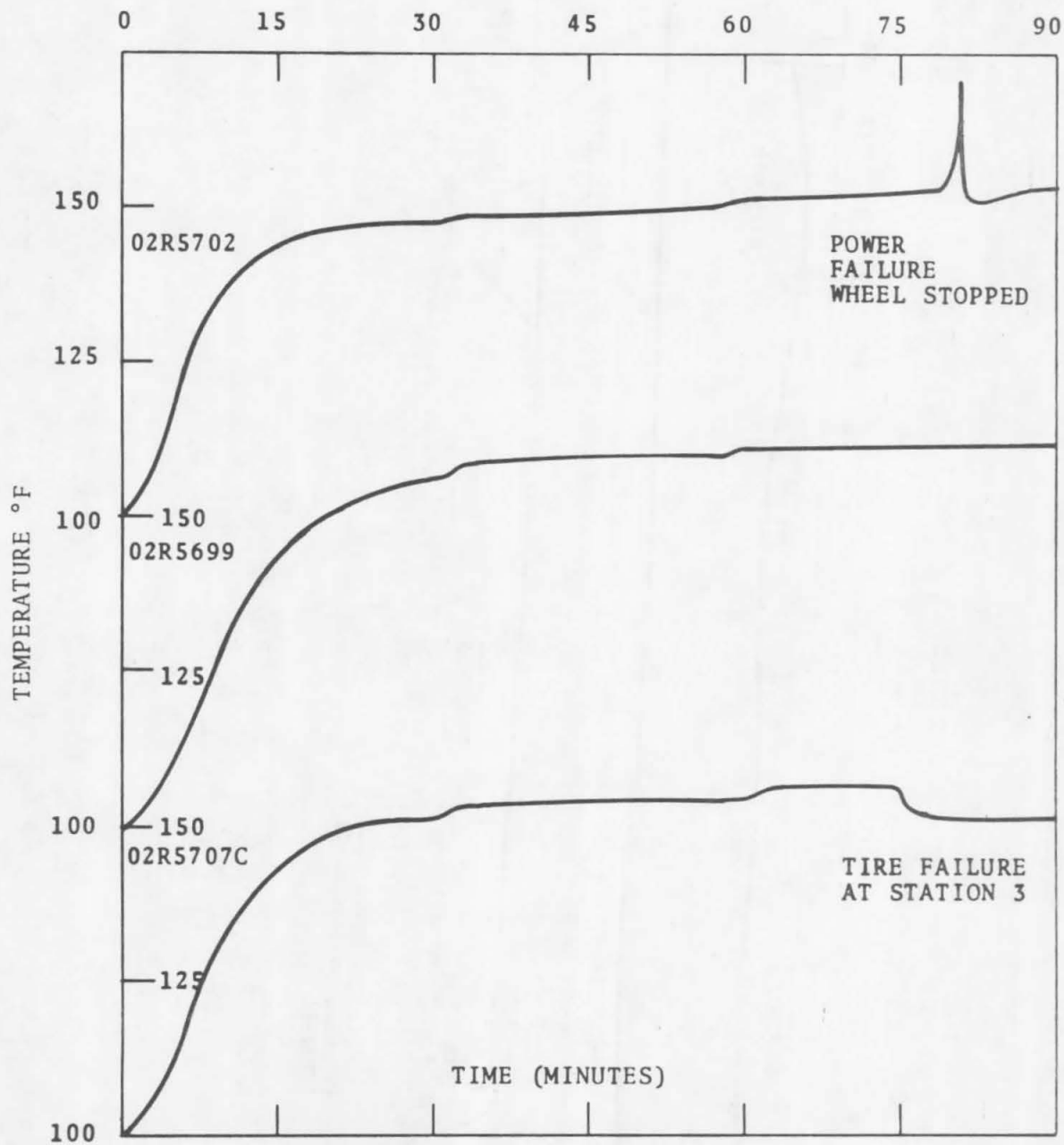


Figure 7. Temperature Vs Run Time High Speed Test

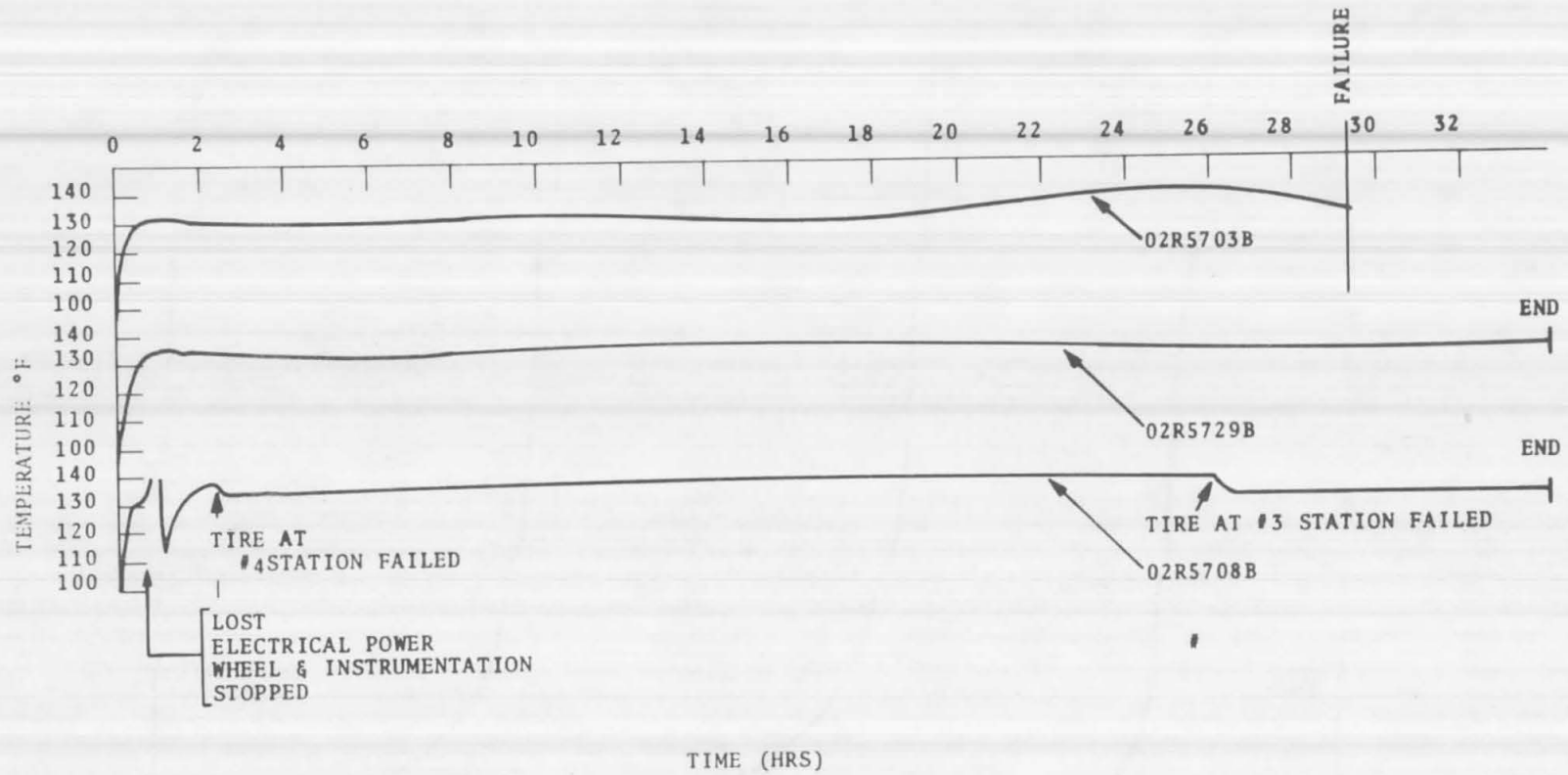


Figure 8. Temperature Vs Run Time Endurance Test



Wheel stoppage at any time during the test results in a very rapid rise in temperature probably caused by the removal of the cooling effects of the draft of air across the tire during rotation, combined with diffusion of the tire inner temperature to the surface. On the other hand, failure of one of the other three tires being run had the effect of reducing the tire temperature seven degrees. Figure 9 is a schematic showing the approximate location of the various stations around the road wheel.

### 3.3 DIFFERENTIAL ABSOLUTE SHOULDER TEMPERATURE

This measurement was made after the tire stabilized at its running temperature (Table 2). Little change in this differential was observed over the life of the test being run; therefore only one value was recorded. The main reason for taking the shoulder temperature was to use it in connection with the data on Figure 6 to determine temperature excursions from the transient radiometer data shown in Figure 16. It is interesting to note that shoulder temperature data taken for most of the tires observed did not result in the establishment of a systematic method for determining whether the outside whitewall or the inside of the tire would run hotter.

### 3.4 TEMPERATURE EXCURSIONS AROUND THE TIRE

Temperature excursions around the tire shoulder are shown in Figures 10 through 15. Explanations are required concerning the data as follows:

- a. The abscissa is time in hours for endurance and minutes for high speed with the ordinate as peak-to-peak temperature difference obtained by dimension measurements by an optical comparator from the data contourograph (Figure 16) converted to degrees F by data in Figure 6.
- b. The thermal time constant for a tire under change of wheel conditions (i.e., force, inflation pressure, or speed changes) is less than 15 minutes and could not be observed readily in the contourograms from which the graphs were taken. Instantaneous changes may therefore

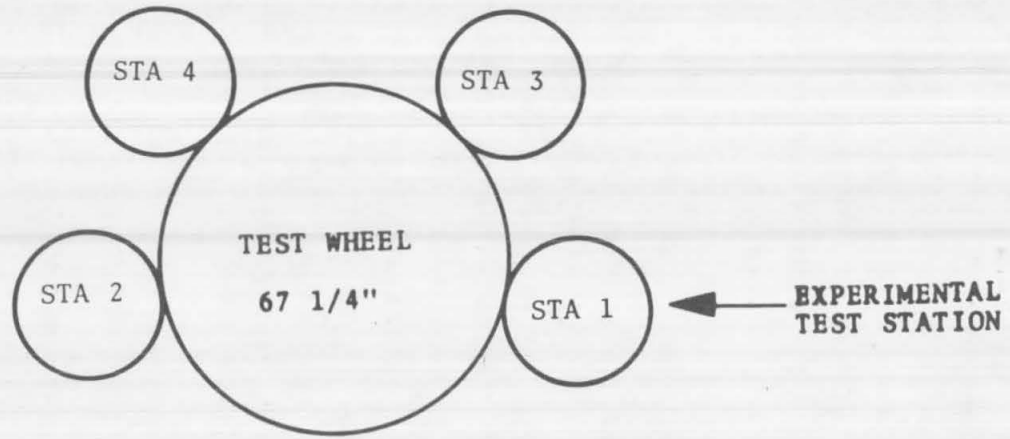


Figure 9. Tire Location on Test Wheel

TABLE 2. DIFFERENTIAL ABSOLUTE SHOULDER TEMPERATURE

	INSIDE SHOULDER	OUTSIDE SHOULDER	DIFFERENCE
02R5702C	156	150	6°
02R5699CC	175	148	27°
02R5707C	178	157	21°
02R5703B	156	146	10°
02R5729B	140	139	1°
02R5708B	135	135	0°

DIFFERENTIAL ABSOLUTE SHOULDER  
TEMPERATURE

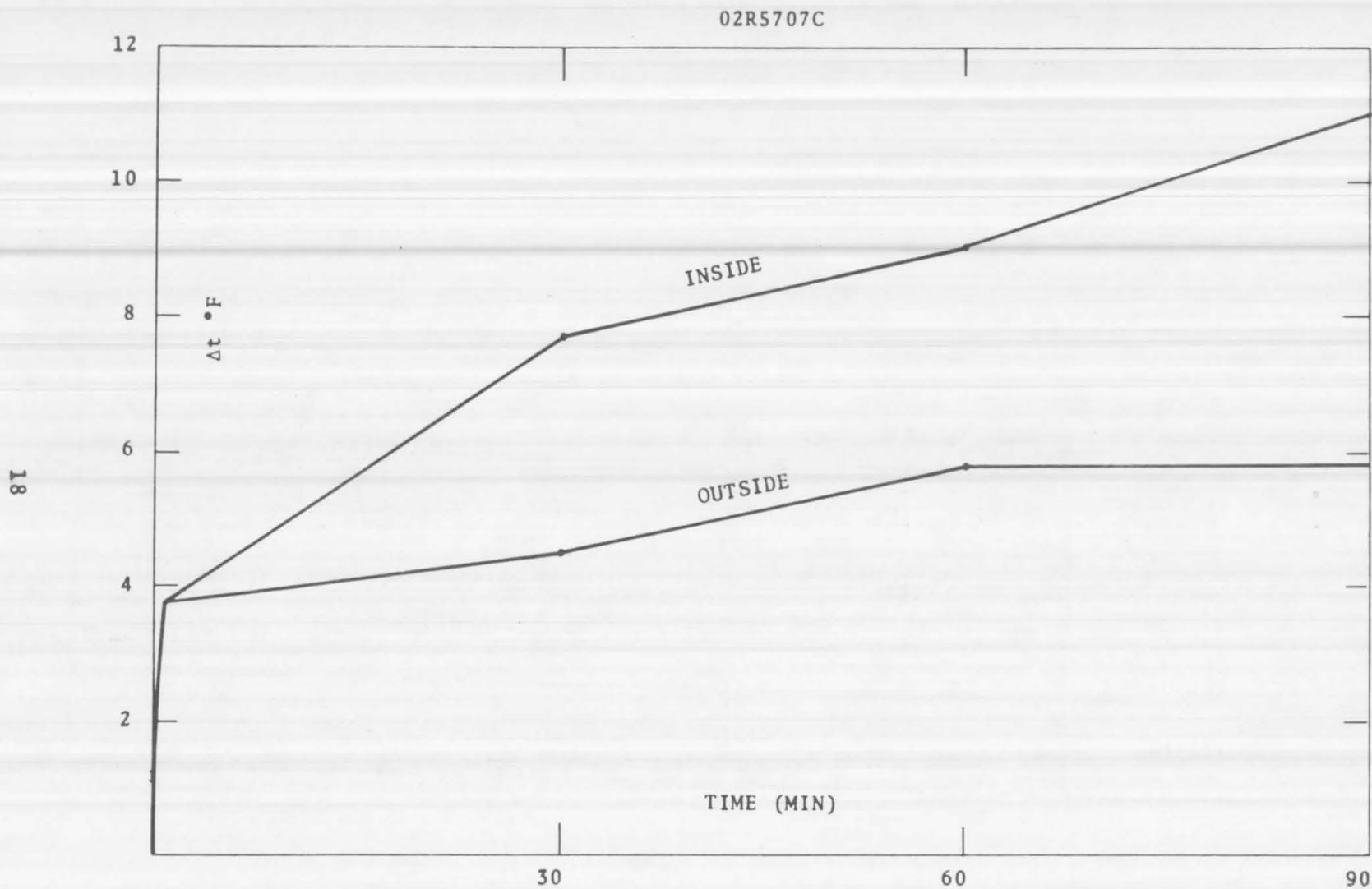


Figure 10. Tire Temperature Differential Vs Runtime  
Tire #02R5207

02R5699C

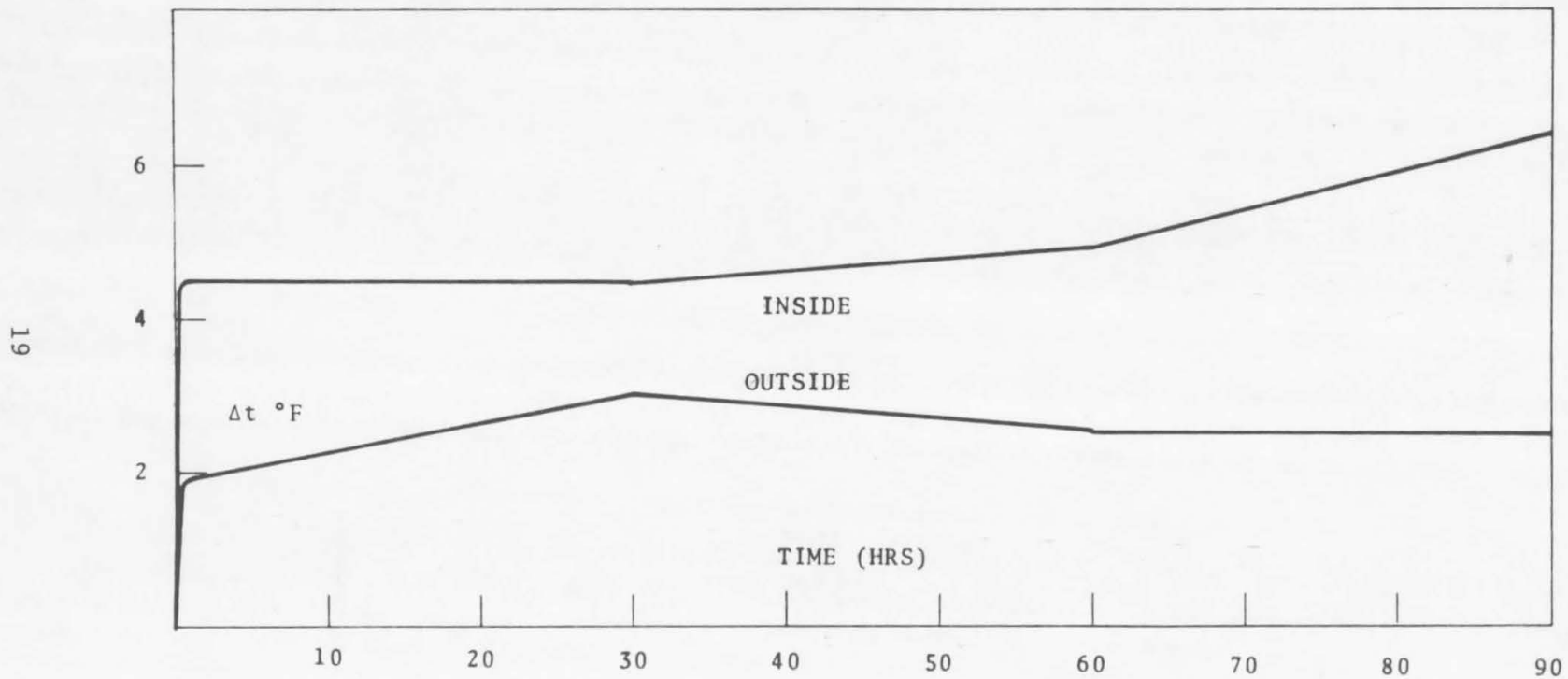


Figure 11. Tire Temperature Differential Vs Runtime  
Tire #02R5699C

02R5720C

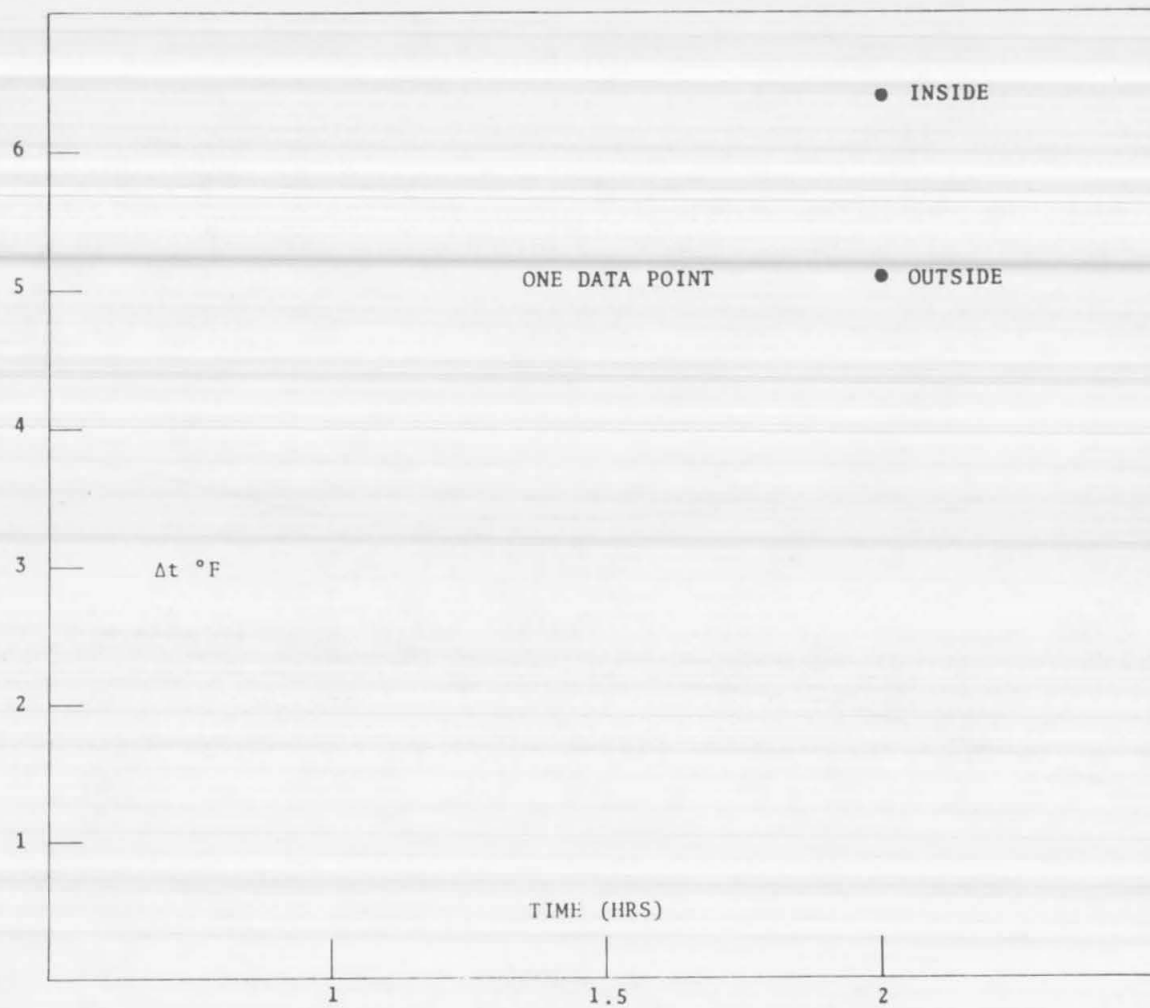


Figure 12. Tire Temperature Differential Vs Runtime  
Tire #02R5720C

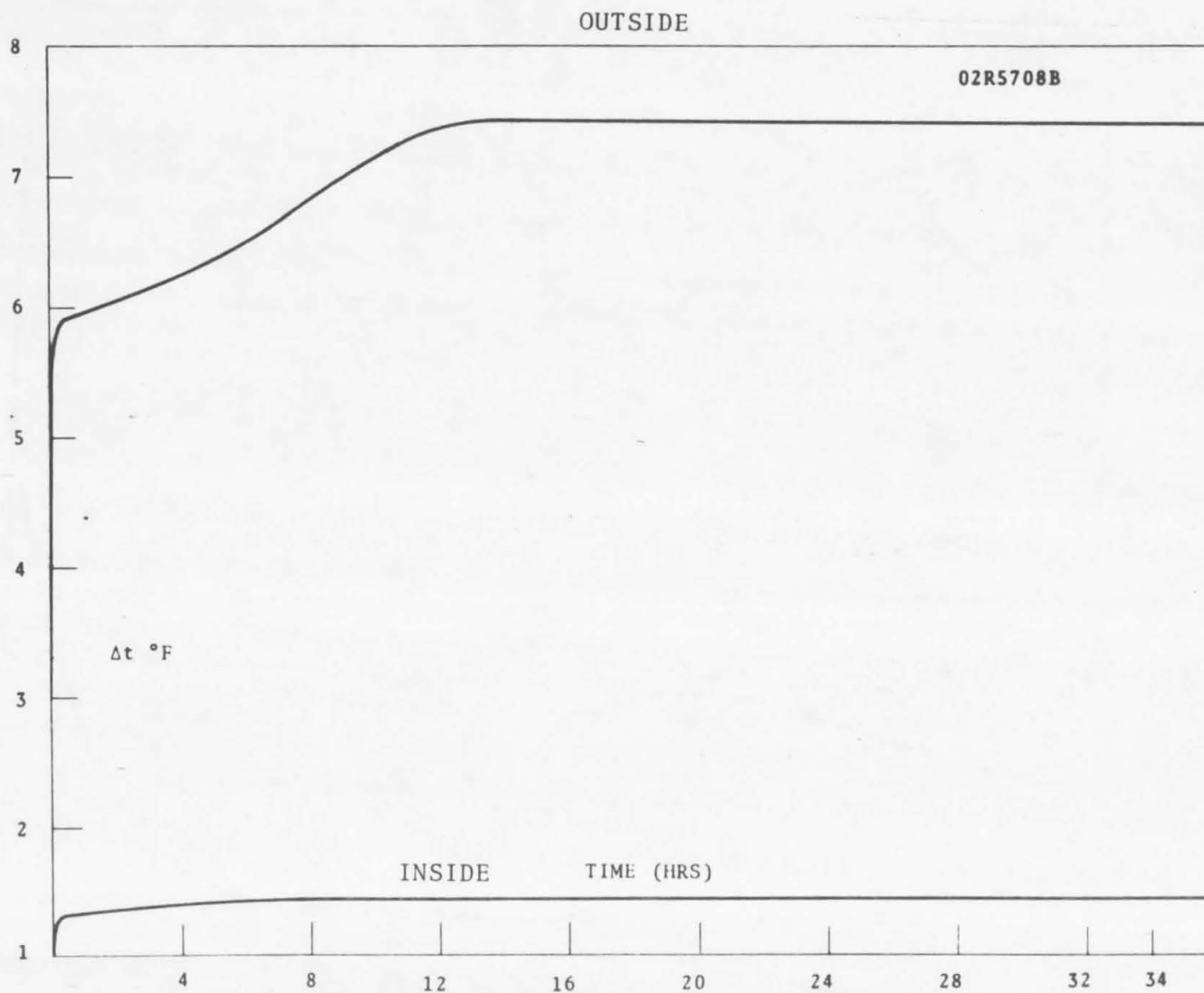


Figure 13. Tire Temperature Differential Vs Runtime  
Tire #02R5708B

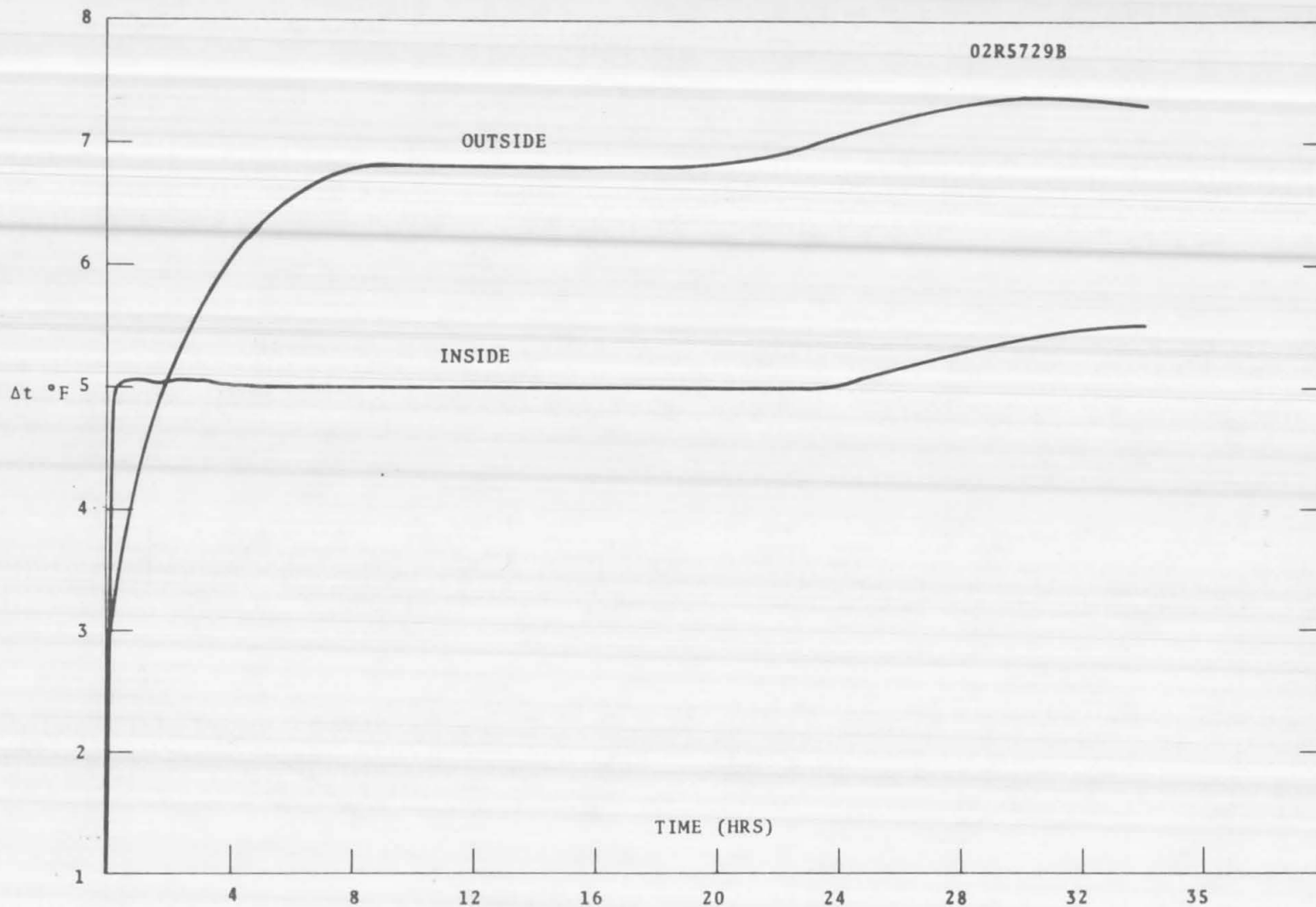


Figure 14. Tire Temperature Differential Vs Runtime  
Tire #02R5729B



02R5703C

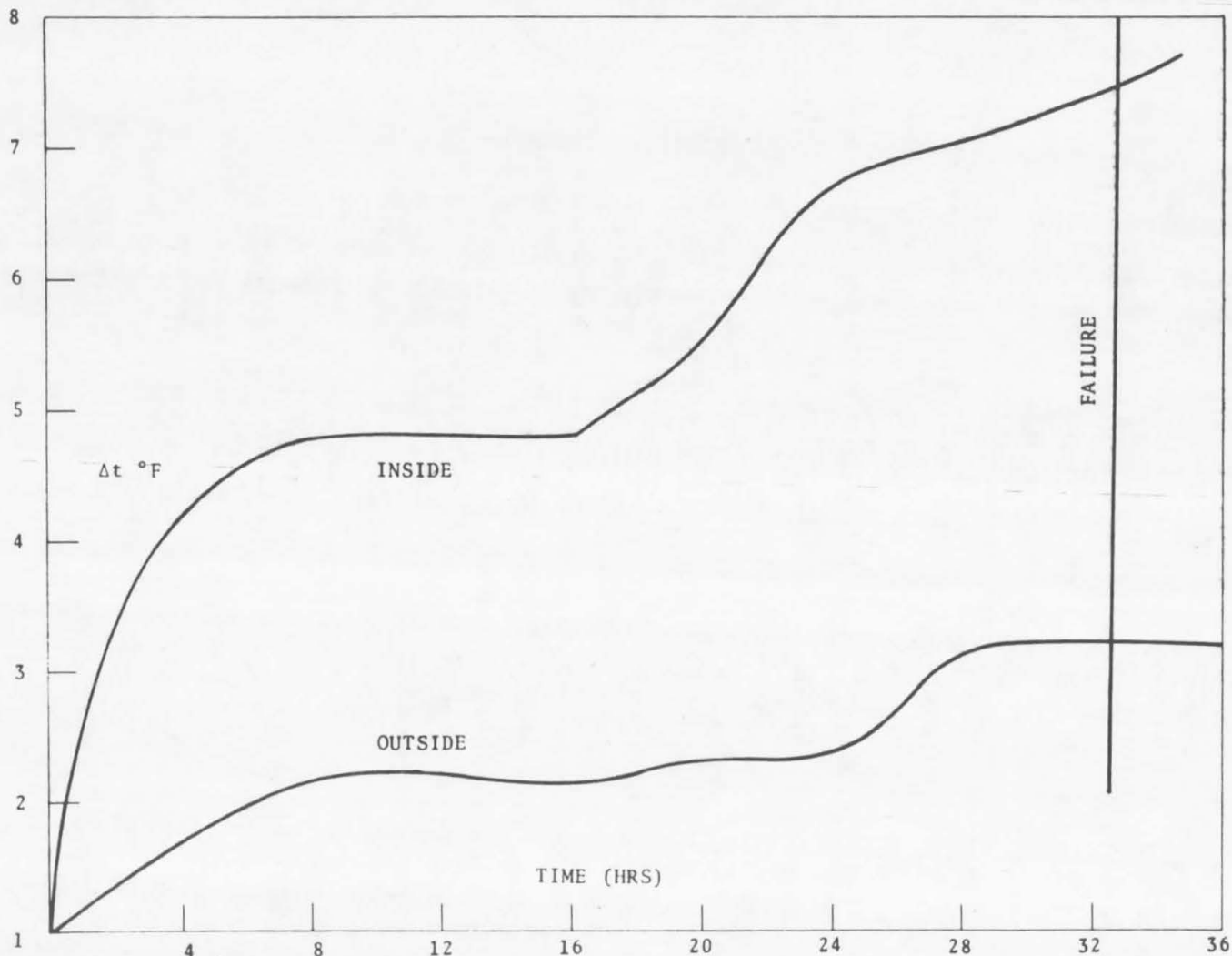


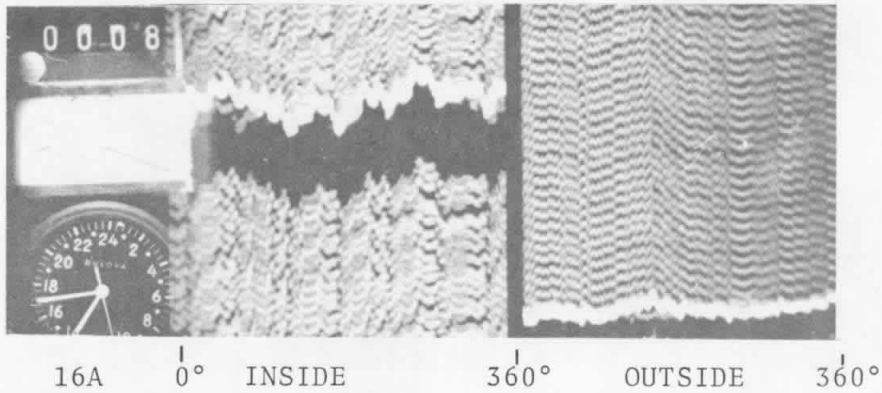
Figure 15. Tire Temperature Differential Vs Runtime  
Tire #02R5703C

have been plotted as flattened trend lines. A more careful review of the data would probably identify these step functions as is done in the absolute temperature data. This suggests a peak to peak differentiation circuit for recording on a slow recorder as a function of time rather than a contourograph of the entire trace.

- c. On tire #02R5720C an equipment failure resulted in the accumulation of about 15 minutes of data at the end of the run. No changes were observed.

It is interesting to note that the only tire which exhibited radical variations > 50% in the latter part of its run did fail.

An examination of the specific contourographs is appropriate. In certain instances, however, the data obtained is in poor condition because it is sometimes difficult to read. The set up was taken to the field without any real means of setting parameters, gain stages etc. Since there is very little data in the literature about tire surface temperatures<sup>3</sup>, temperature ranges were set excessively wide with the result that signal fluctuations were rather small. Moreover, the early data contained a variety of film exposure and trace isometry experiments which tend to obscure the primary information. Figure 16 shows the contourograph for the failed tire 02R5703B which started at 0811 on April 17, 1972. It failed at 1353 the following day. The tire constantly ran with the inside shoulder about five degrees hotter than the outside. At about midnight, the inside shoulder developed a hot spot about a third of the way from the left edge of the inside trace. Figure 16C shows this at time 0336 AM. The left edge is obscured by the identification tab but superposition of trace 16C with trace 16A or 16B shows a definite rise of about 3°F at the arrow. By the time of failure both traces had shown radical excursions (about 2° outside, 5° inside) and failure occurred immediately thereafter.

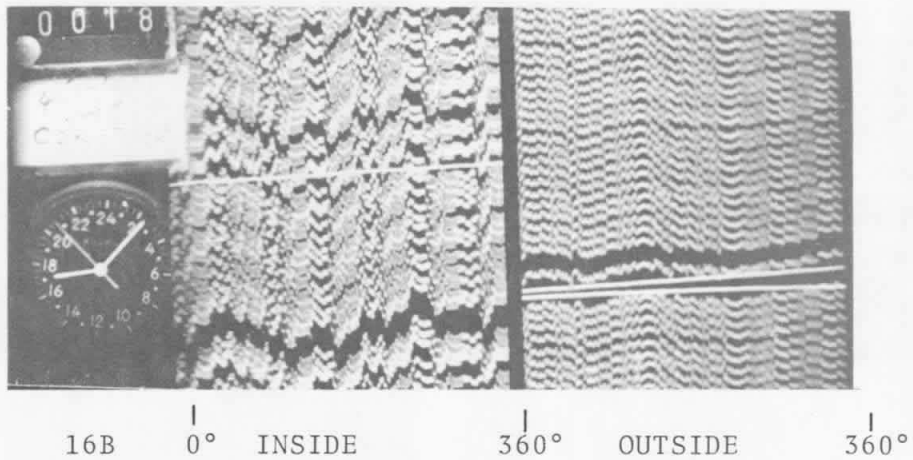


TIME 1343

INSIDE P-P  $\Delta t = 0.070'' = 4.4^\circ$

OUTSIDE  $\Delta t = .03 = 1.9^\circ$

TIME BETWEEN TRACES 12 SEC

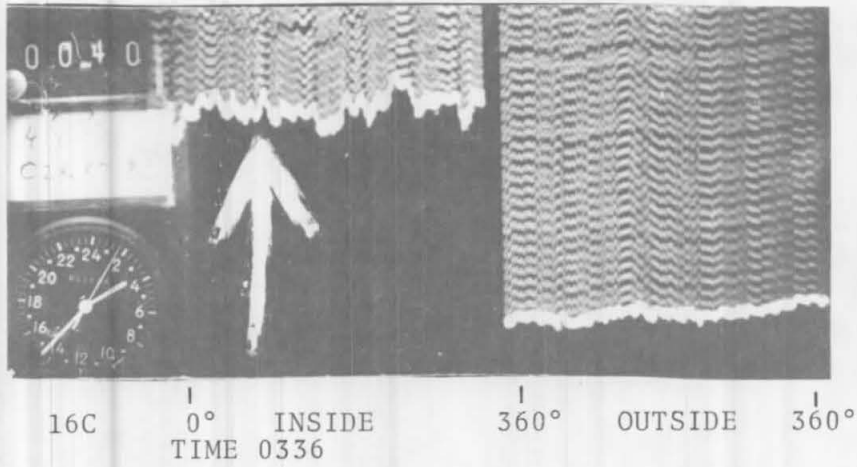


TIME 1706

INSIDE = .075 = 4.5

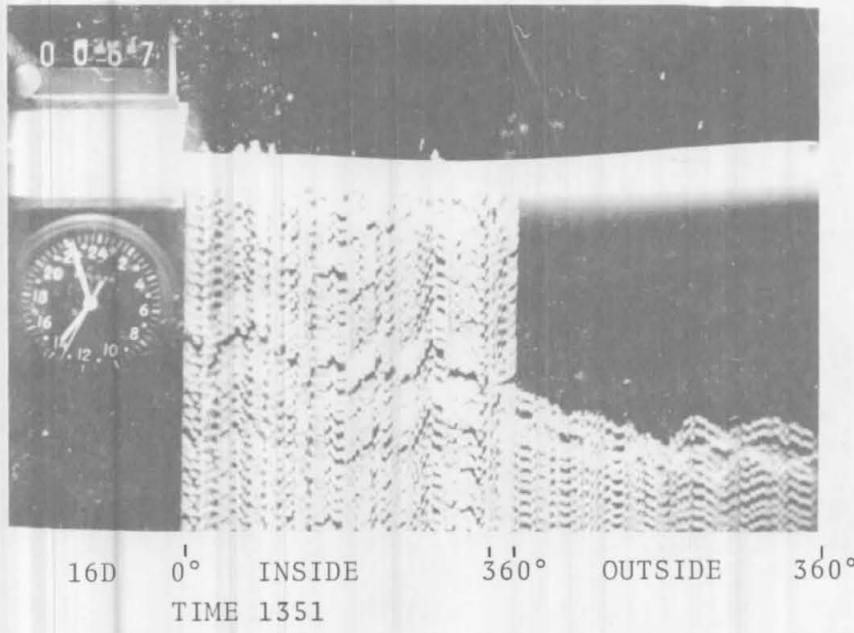
OUTSIDE = .03'' = 1.9

Figure 16. Contourographs of Tire Temperature



INSIDE .09" = 5.8

OUTSIDE .03" = 1.9



INSIDE .1" = 6.4°f

OUTSIDE .05" = 2.2°

FAILURE OCCURRED AT 1353

TIME BETWEEN TRACES 9.5 SEC

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Figure 16. Contourographs of Tire Temperature (Cont.)

## 4.0 SUMMARY AND CONCLUSIONS

The data presented indicate that tires follow a fairly predictable thermal pattern during compliance tests and that departures from this pattern may be precursors of failure. Examination of the one failed tire indicated that the cause of failure was a fabric rupture in the plies that was not observed prior to re-treading. Reversion occurred in the rubber around this area which was adjacent to the hottest tread location; consequently conditions were conducive to failure.

Specific conclusions follow:

1. Two or three tire failures on a 4 tire test wheel change the temperature so radically that the test for the remaining tires may be worthless.
2. Temperature spread of a few degrees may be indicative of numerous structural changes within the tire.
3. Wheel stoppages impose questionable thermal stresses on the tire during test.
4. Tire #02R5708 might well have failed had tires on other stations of the test wheel not failed, thereby reducing the overall temperature of the subsequent experiment.
5. There is no reason to believe that a tire is thermally symmetrical any more than it is geometrically symmetrical; therefore, if one wall has a different stiffness or thickness due to, for example, the placement of whitewall rubber or chafing ribs, it will show thermal assymetry.
6. Anomalies in flawed areas cannot be depended upon to be greater in magnitude than other heat sources in the tire.

It is recommended that further experiments be performed to confirm the findings in this report.

## REFERENCES

1. Non-destructive Tire Inspection Studies at the Transportation Systems Center, Lavery, A. L., NHTSA, February 1972.
2. Webb, George and Rogers, Richard, The Contourograph, IEEE Spectrum, June 1966, p. 77.
3. Conant, F. S., Tire Temperatures, Rubber Chemistry and Technology, April 1971, Vol. 44, No. 2, p. 397.

APPENDIX A

PERFORMANCE DATA, TRANSIENT RADIOMETER

TABLE A-1. TARGET SIZE VS WORKING DISTANCE

Department of Transportation Tire Test Program

Contract DOT-TSC-360

Working Distance Feet	Width Inches	Height Inches	$\frac{A\Omega (Dw)}{A\Omega (5 Ft)}$
5	2.34	0.117	1.0
6	2.81	0.14	1.0
7	3.28	0.164	1.0
8	3.75	0.187	1.0
9	4.21	0.216	0.945
10	4.68	0.234	1.0
11	5.15	0.258	1.0
12	5.61	0.281	1.0
13	6.08	0.304	0.925



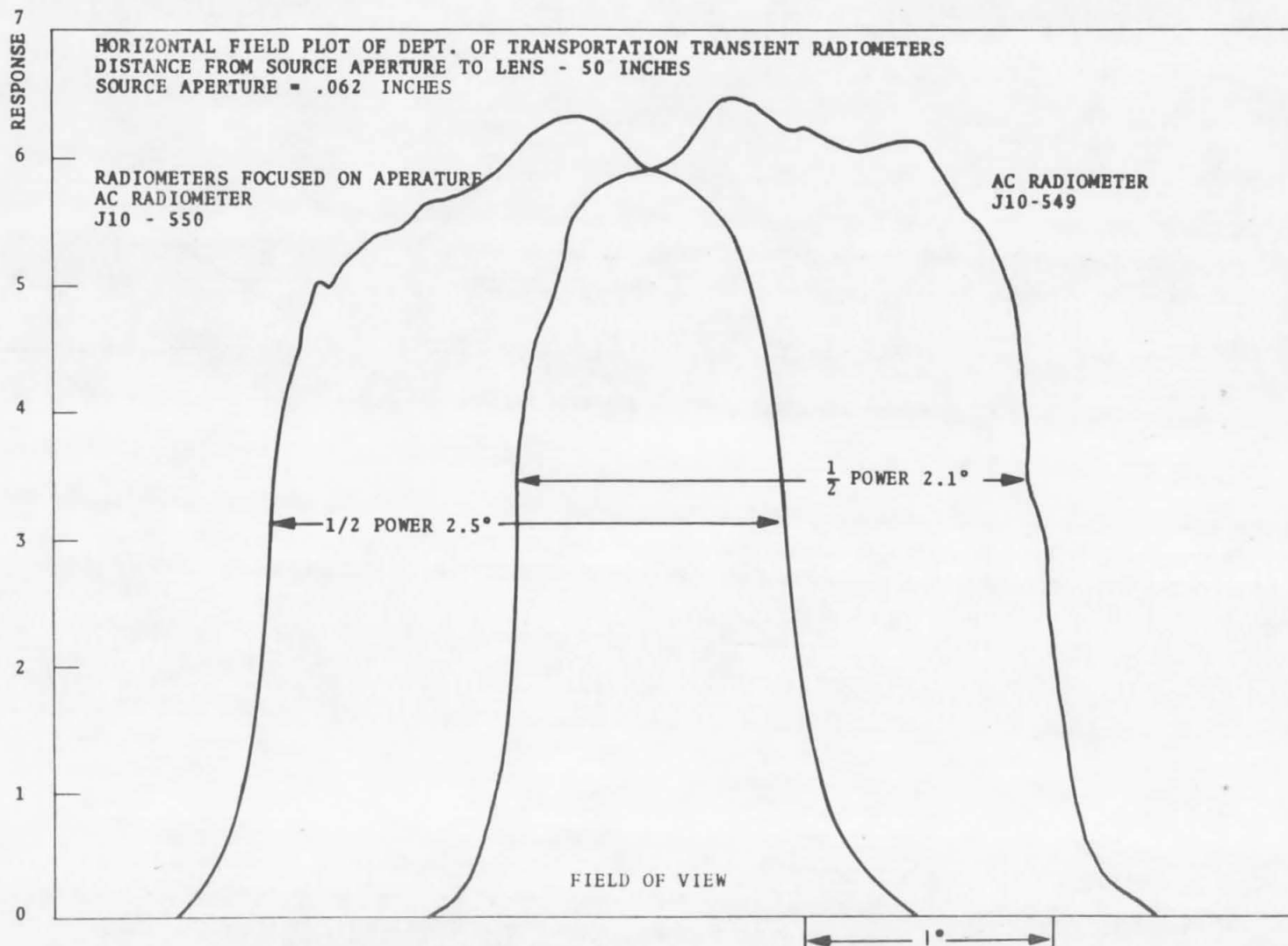


Figure A-1. Field of View Plot

A-4

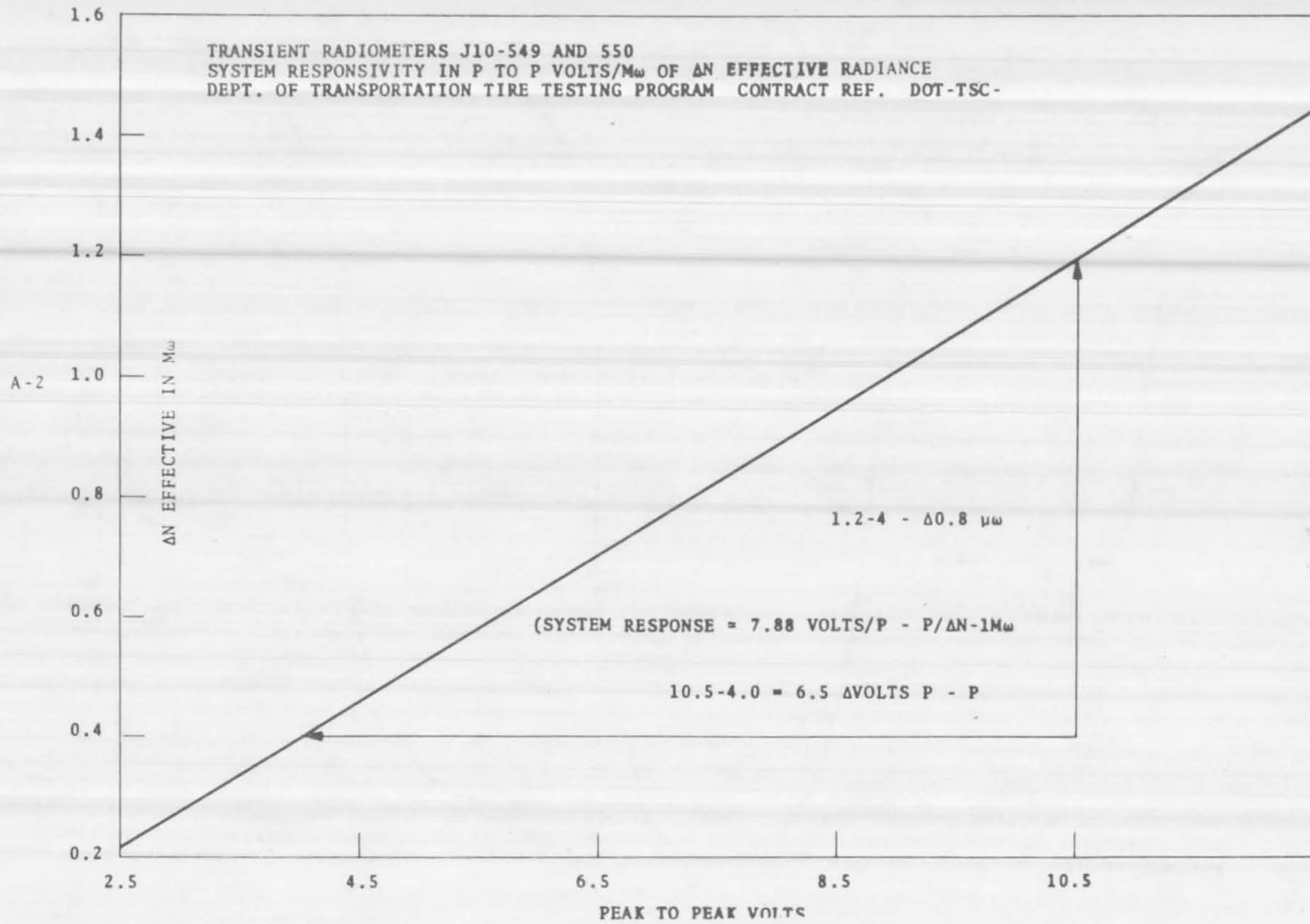
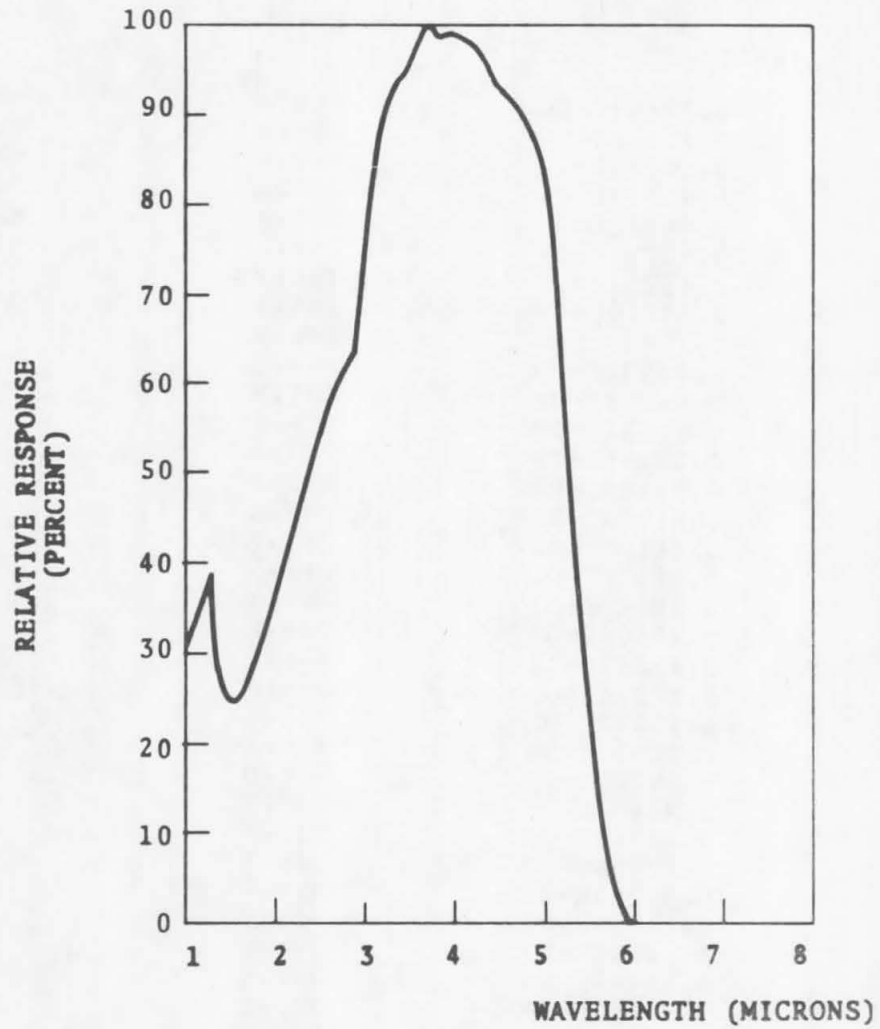


Figure A-2. Response to Radiant Energy



Spectral Composite of InSb  
 Detector (77°K) As<sub>2</sub> As<sub>3</sub>  
 objective lens, Silicon

Figure A-3. Spectral Response

TABLE A-2. NORMALIZED RADIANCE TABLE FOR VARIOUS  
VALUES OF OBSERVED TEMPERATURE

BEC Project 3228

INITIAL LAMBDA (MICRONS) = 1.000  
FINAL LAMBDA (MICRONS) = 6.000  
DELTA LAMBDA (MICRONS) = 0.100

Contract DOT-TSC-360

Neff Data

Page 1

TEMP F	N (WATTS/CM2-STER)	TEMP K	TEMP C
-20.	0.27543E-04	244.1	-28.9
-15.	0.31592E-04	246.8	-26.2
-10.	0.36135E-04	249.6	-23.4
-5.	0.41218E-04	252.4	-20.6
0.	0.46892E-04	255.2	-17.8
5.	0.53211E-04	258.0	-15.0
10.	0.60231E-04	260.7	-12.3
15.	0.68015E-04	263.5	-9.5
20.	0.76625E-04	266.3	-6.7
25.	0.86131E-04	269.1	-3.9
30.	0.96603E-04	271.8	-1.2
35.	0.10811E-03	274.6	1.6
40.	0.12075E-03	277.4	4.4
45.	0.13460E-03	280.2	7.2
50.	0.14974E-03	283.0	10.0
55.	0.16626E-03	285.7	12.7
60.	0.18428E-03	288.5	15.5
65.	0.20387E-03	291.3	18.3
70.	0.22516E-03	294.1	21.1
75.	0.24825E-03	296.8	23.8
80.	0.27326E-03	299.6	26.6
85.	0.30030E-03	302.4	29.4
90.	0.32951E-03	305.2	32.2
95.	0.36100E-03	308.0	35.0
100.	0.39492E-03	310.7	37.7
105.	0.43140E-03	313.5	40.5
110.	0.47059E-03	316.3	43.3
115.	0.51264E-03	319.1	46.1
120.	0.55769E-03	321.8	48.8
125.	0.60591E-03	324.6	51.6
130.	0.65747E-03	327.4	54.4
135.	0.71252E-03	330.2	57.2
140.	0.77125E-03	333.0	59.9
145.	0.83384E-03	335.7	62.7
150.	0.90046E-03	338.5	65.5
155.	0.97130E-03	341.3	68.3
160.	0.10465E-02	344.1	71.1
165.	0.11264E-02	346.8	73.8
170.	0.12111E-02	349.6	76.6
175.	0.13009E-02	352.4	79.4
180.	0.13958E-02	355.2	82.2
185.	0.14963E-02	358.0	85.0
190.	0.16024E-02	360.7	87.7
195.	0.17145E-02	363.5	90.5
200.	0.18327E-02	366.3	93.3

TABLE A-2 NORMALIZED RADIANCE TABLE FOR VARIOUS VALUES  
OF OBSERVED TEMPERATURE (Continued)

BEC Project 3228 Contract DOT-TSC-360			Page 2
205.	0.19573E-02	369.1	96.1
210.	0.20885E-02	371.8	98.8
215.	0.22266E-02	374.6	101.6
220.	0.23719E-02	377.4	104.4
225.	0.25245E-02	380.2	107.2
230.	0.26848E-02	383.0	109.9
235.	0.28530E-02	385.7	112.7
240.	0.30294E-02	388.5	115.5
245.	0.32143E-02	391.3	118.3
250.	0.34079E-02	394.1	121.1
255.	0.36105E-02	396.8	123.8
260.	0.38224E-02	399.6	126.6
265.	0.40440E-02	402.4	129.4
270.	0.42755E-02	405.2	132.2
275.	0.45171E-02	408.0	135.0
280.	0.47693E-02	410.7	137.7
285.	0.50323E-02	413.5	140.5
290.	0.53065E-02	416.3	143.3
295.	0.55920E-02	419.1	146.1
300.	0.58894E-02	421.8	148.8
305.	0.61989E-02	424.6	151.6
310.	0.65207E-02	427.4	154.4
315.	0.68553E-02	430.2	157.2
320.	0.72031E-02	433.0	160.0
325.	0.75642E-02	435.7	162.7
330.	0.79391E-02	438.5	165.5
335.	0.83281E-02	441.3	168.3
340.	0.87316E-02	444.1	171.1
345.	0.91498E-02	446.8	173.8
350.	0.95833E-02	449.6	176.6



APPENDIX B

IT-4B

GENERAL DESCRIPTION

## 1.1 INTRODUCTION

The IT-4 Non-contact Thermometer has been specifically designed for industrial process control and measurement. The instrument can be connected to most recorder and controller systems for a permanent record of temperature variations or to regulate the manufacturing process.

The system consists of a sensing head and an electronic control unit. The two units are connected by a single cable. The sensing head can be hand-held, mounted on a tripod or fixed in a permanent installation overlooking the target. The control unit may be shelf-mounted or installed in single or dual rack mounting at a reasonable long distance from the sensing head.

## 1.2 DESCRIPTION

The sensing head contains the Immersed Thermistor Detector, a Spectral Filter, and Objective lens - all located in a temperature-stabilized cavity. A mechanical chopper system allows the detector to alternately view target energy and the internal reference energy.

Detector signals created by differences in energy levels are amplified in the sensing head and sent to the electronics processing module for further amplification, calibration, demodulation, and filtering.

## 1.3 SPECIFICATIONS

### 1.3.1 Mechanical

	Weight	Size
Sensing Head	3.75 lbs.	5.125" diameter, 8" length
Electronics Module	8.75 lbs.	5.15" H x 10.25 W x 9.50" D





1.3.2 General Specifications

MODEL NO.	APPLICATION	SPECTRAL REGION	
		$\lambda_o$	width
IT-4A	General Purpose	11 $\mu$	55%
IT-4B	General Purpose-narrow band; gives freedom from effects of water vapor	10.5 $\mu$	20%
IT-4C	Specialized for materials with CH band such as polyethylene	3.45 $\mu$	3%
IT-4D	Specialized for materials such as mylar	7.9 $\mu$	6%
IT-4E	Specialized for glass	5.1 $\mu$	1%

Field-of-view (1/2 power) 2° FOV.

SPOT SIZE-INCHES

DISTANCE	2° FOV
1 inch	0.5
4 inches	0.6
10 inches	0.8
30 inches	1.3
100 inches	4.0
300 inches	12.0
1000 inches	40.0

Ambient Temperature Range - 0°C to 40°C

Recorder Outputs - J202, 0 to 5 volts at 10 MA; J203, 0 to 100 mv (adjustable at 100 ohms).

Output Response - (10-90%) 50 milliseconds; 15 or 500 milliseconds optional.

Power Requirements - 115/230 VAC, 50-400 Hz. 40 watts

Accuracy - IT-4A, D. E = 1% of meter span; IT-4C - 2% of span, 5% below 60°C.

APPENDIX C

COMPLIANCE CENTER OPERATING PROCEDURE

## OPERATING PROCEDURE FOR IR TESTS

- I. AT START OF TEST RUN
  - A. TURN ON MASTER "ON" SWITCH
  - B. TURN SWITCH ON SYNC BOX ALL THE WAY TO THE LEFT CCW (BOX WITH BLUE TOP) (POSITION MARKED SU)
  - C. OPEN THE BOX AND WITH THE SYNC HOOKED UP TO THE SCOPE: DETERMINE WHETHER THE SYNC BOX IS GIVING AN OUTPUT (20V PULSES) (RED LIGHT OFF)
  - D. SET UP SYNC PULSE SO THAT IT DRIVES EXTERNAL SCOPE TRIGGER; REMOVE SYNC LINE TO DISPLAY AND PLUG IN SENSOR
  - E. FOCUS RADIOMETER FOR PEAK RESPONSE (KNOB AT REAR OF WHITE BOX)
  - F. WITH A RADIOMETER (WHITE BOX) OUTPUT INTO BOTH CHANNELS ADJUST SCOPE TIME BASE UNTIL ONE COMPLETE TRACE APPEARS IN THE LOWER LEFT WINDOW
  - G. TURN SWITCH ON SYNC BOX TO EN (FOR ENDURANCE) OR HS (FOR HIGH SPEED)
  - H. LOAD FILM CASSETTE
  - I. CLOSE VIEWING WINDOW IN CAMERA
  - J. OPEN RED FILM BLOCKING SLIDE
  - K. TURN CAMERA ON WITH SWITCH IN HANDLE
- II. PREPARATION PRIOR TO START OF RUN
  - A. OPEN CAMERA MARKER COMPARTMENT AND CHANGE TIRE LABEL (WRITE OUT TIRE NUMBER OF PAPER TOGETHER WITH DATE)
  - B. MARK TIRE AND DATE AND TIME ON RUSTRAK PAPER
  - C. WINDHACK WATCH IN MARKER COMPARTMENT
  - D. PLACE REFLECTING TAPE NEAR DOT LABEL ON RIM
  - E. FILL SENSORS (WHITE BOX) WITH LIQUID NITROGEN
- III. DAILY ROUTINE
  - A. CHANGE FILM CASSETTE
  - B. LEAVE ONE CASSETTE AT PHOTOLAB AND PICK UP OTHER

## TROUBLE SHOOTING

- IV. TURN SYNC BOX ROTARY SWITCH TO SU POSITION FOR FOLLOWING TESTS' PROCEDURE TO SET EXTERNAL SCOPE TRIGGER
- A. FOLLOW TEK INSTRUCTIONS OR DO AS FOLLOWS:
1. SET BOTH STABILITY AND TRIGGERING LEVEL ALL THE WAY TO THE RIGHT, EXTERNAL SYNC WILL START TO TRIGGER
  2. MOVE RED KNOB TO LEFT UNTIL TRIGGER GOES AWAY AND SCOPE TRACE DISAPPEARS
  3. MOVE BLACK KNOB CCW UNTIL TRIGGER PULSE REAPPEARS AND IS STABLE. DO SLOWLY SO THAT YOU DO NOT GO BEYOND PROPER SETTING.
- B. IF SYNC BOX GIVES NO OUTPUT (RED LIGHT ON) DO THE FOLLOWING:
1. CHECK FOR LIGHT SHINING AT RIM AND REFLECTOR ON RIM
  2. OPEN BLUE BOX AND FIND LEVEL OR GAIN CONTROL. ADJUST UNTIL LIGHT GOES OUT
  3. CHECK TO SEE IF LIGHT GOES ON WHEN SIGNAL FROM TIRE IS INTERRUPTED BY A PIECE OF FILM.
- C. NO OUTPUT FROM RADIOMETER
1. CHECK NITROGEN
  2. CHECK SCOPE SETTINGS
  3. CHECK OFF ON SWITCH ON POWER SUPPLY (GRAY BOX)
  4. CHECK BATTERIES WITH MULTIMETER SHOULD READ 10V OR BETTER
- V. EVERY HOUR FOR ENDURANCE EVERY HALF HOUR FOR HIGH SPEED
- A. CHECK TO SEE SYNC PRESENCE LIGHT IS OUT
- B. CHECK NITROGEN AND REFILL (EVERY HOUR MAX!)
- C. CHECK FOR PRESENCE OF A TRACE AS FOLLOWS:
1. PUSH IN RED FILM SLIDE
  2. OPEN VIEW WINDOW
  3. WAIT 30 SECONDS IF YOU SEE A TRACE, OK
  4. CLOSE WINDOW
  5. PULL OUT FILM SLIDE
- D. FLASH ON MARKER BY CLICKING SWITCH ON HAND HELD ACTUATOR OFF THEN ON. LEAVE SWITCH IN "ON" POSITION!



APPENDIX D

TIRE FAILURE ANALYSIS SUMMARY  
6 TIRES

DATE: 5/11/72

SERIAL NO: T2X0203R - B -

COMPLIANCE HISTORY: Failed Endurance Test

VISUAL: Inside liner and #1 & #2 plies completely shattered  
0400 and in most areas from head to head. At 0090/φ270 a "blow  
out" or rupture 2" x 2" through the white wall.

COMMENTS:



DATE: 5/8/72

SERIAL NO: T2X0199R (C)

COMPLIANCE HISTORY: Passed high speed

VISUAL: A ØK

COMMENTS: A separation between 4th ply and rubber running 7" in the Ø310/Ø135 area. This was picked up by I.R., U.S. and Holography.

Another separation again at 4th ply/rubber interface, 1 1/4" dia. and again picked up by all three NDT methods.

Holography: at Ø100/140 1" sepn at 4th ply/rubber junction at Ø100/240 small void in carcass rubber 1/8" dia. ply/rubber sep'n @ 200/140 - 1/4" Recap.carcass sep'ns at Ø 230 & Ø235/Ø130 - ply/rubber sep'n 1" dia.

@ Ø260/140 - ply/rubber sep'n 1" dia.

@ Ø275/160 - ply/rubber sep'n 1/4" dia

@ Ø350/140 - Recap/carcass - passes junction

DATE: 5/8/72

SERIAL NO: T2X0208R  
(02R5708B)

COMPLIANCE HISTORY: Passed Endurance Test

VISUAL: Groove cracking - #3 groove @400

COMMENTS: Severe groove cracking in #3 groove all the way around tire. Sectioning showed cracking down to the #2 glass belt. Also initial deterioration of glass cord can be seen, a condition that leads in to belt/belt separation as has been seen in the past. Holography/U.S., I.R. all indicated defects in this one area.

DATE: 5/8/72

SERIAL NO: T2X0202R

COMPLIANCE HISTORY: Passed high speed

VISUAL: AØK

COMMENTS: I.R. indicated 2 areas;  $\phi$ 350/090 - an excessively large splice was found. The other was  $\theta$ 210/180; - nothing was seen:

Holography: A suspicious area @  $\theta$ 310/ $\phi$ 220 (not entered into computer) was shown. A separation ~ 1 1/4" x 3/4", between #4 ply and rubber, this is not a Recap/carcass junction separation.

U.S.: Showed one area @268/211 in which nothing was found. Another possible suspicious area was groove #2. 2 areas of groove #2 was cut out; nothing seen.

X-Ray: S.A. @  $\theta$ 240/160 - nothing found.

DATE: 5/9/72

SERIAL NO: T2X0207R - (C)

COMPLIANCE HISTORY: Passed High Speed test

VISUAL: AOK

COMMENTS: U.S.            three possible SA

220/175 )  
135/185 }            nothing found  
170/185 )

No other NDT methods saw anything

DATE: 5/9/72

SERIAL NO: T2X0229R - B

COMPLIANCE HISTORY: Passed Endurance Test

VISUAL: AØK

COMMENTS:

U.S.

I.R.

Holography

} all indicated various defect  
areas, but F/A found none

