1092

AD-A

RD&E CENTER

Technical Report

No. 13233

THEORY OF OPERATION FOR TIRE QUALITY MONITOR

MAY 1987

By Irvin R. Kraska &
Thomas A. Mathieson
GARD Division
7449 North Natchez Avenue
Niles, IL 60648

APPROVED FOR PUBLIC RELEASE:
DISTRIBUTION IS UNLIMITED

20030113134

U.S. ARMY TANK-AUTOMOTIVE COMMAND
RESEARCH, DEVELOPMENT & ENGINEERING CENTER
Warren, Michigan 48397-5000

AI83611

REPRODUCTION QUALITY NOTICE

This document is the best quality available. The copy furnished to DTIC contained pages that may have the following quality problems:

- Pages smaller or larger than normal.
- Pages with background color or light colored printing.
- Pages with small type or poor printing; and or
- Pages with continuous tone material or color photographs.

Due to various output media available these conditions may or may not cause poor legibility in the microfiche or hardcopy output you receive.

☐ If this block is checked, the copy furnished to DTIC contained pages with color printing, that when reproduced in Black and White, may change detail of the original copy.

NOTICES

This report is not to be construed as an official Department of the Army position.

Mention of any trade names or manufacturers in this report shall not be construed as an official endorsement or approval of such products or companies by the U.S. Government.

Destroy this report when it is no longer needed. Do not return it to the originator.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188
Exp. Date: Jun 30, 1986

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for Public Release: Distribution is Unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S) 13233
6a. NAME OF PERFORMING ORGANIZATION Chamberlain Nat'l Gard Division 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION U.S. Army Tank-Automotive Command
6c. ADDRESS (City, State, and ZIP Code) 7449 North Natchez Avenue Niles, IL 60648	7b. ADDRESS (City, State, and ZIP Code) Warren, MI 48397-5000
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
Theory of Operation for Tire Quality Monitor (U)

12. PERSONAL AUTHOR(S)
Kraska, Irvin R. (Gard Division); Mathieson, Thomas A. (Gard Division)

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM 1983 TO 1986Aug	1987 May	134

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Tire, Quality, Retread, Nondestructive, Testing

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The Tire Quality Monitor (TQM) is a microcomputer-controlled, ultrasonic tire inspector. It not only performs the computations required to classify and analyze ultrasonic signals reflected from tire structures, it also formats and controls the displays, intercepts and interprets the operator's pressing of the front panel keyboard switches, controls the inspection rate and the characteristics of the signal reception hardware, and provides a reprogramming capability to modify tire classification and analysis parameters. This report describes the software used to perform these functions, provides information to a software engineer on how the TQM supports itself and performs its programmed functions, and contains information on how the computer recognizes and analyzes tire structures. This document is addressed to tire engineers or nondestructive evaluation personnel responsible for the TQM's implementation/modification.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified	
22a. NAME OF RESPONSIBLE INDIVIDUAL Larry McNamara	22b. TELEPHONE (Include Area Code) (313) 574-8038	22c. OFFICE SYMBOL AMSTA-OAT

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Continued)

LIST OF TABLES

1.0. INTRODUCTION

1.1. Background

This is the final technical report on the theory of operation for the Tire Quality Monitor (TQM) prepared by Chamberlain National, GARD Division, for the U.S. Army Tank-Automotive Command (TACOM) under Contract DAAE07-83-C-R088.

The TQM is an ultrasonic testing device that uses a microprocessor to analyze data from a tire to test its suitability for retreading. The TQM has the ability to detect and analyze defects which cannnot be determined by current visual inspection methods. The TQM can detect tire degradation, bond and ply separation, bond line defects, and porosity in the rubber.

1.2. Scope

This report is a detailed technical description of the processes that the TQM goes through to inspect tires. The report describes the software used to perform the inspection, provides information to a software engineer on how the TQM supports itself and performs its programmed functions, and contains information on how the computer recognizes and analyzes the internal structure of the tires.

1.3. Purpose

The purpose of the TQM is to supplement the visual inspection of tires. The use of the TQM greatly improves the efficiency of the retreading process and quality of the retreaded tires by decreasing the number of bad tire carcasses entering the process.

2.0. OBJECTIVES

The primary goal of this report is to provide the software engineer for the TQM a detailed description of the processes that the TQM goes through in collecting and analyzing data during the inspection of tires.

3.0. CONCLUSIONS

The TQM, when used as a supplement to the visual inspection of tires, greatly increases the level of quality of the retreaded tires, as well as decreases the in-process failures by reducing the number of bad tire carcasses entering the process.

4.0. RECOMMENDATIONS

4.1. Tire Carcass Shipment

Tire carcasses should be inspected by the TQM before shipping to retreaders to eliminate the cost associated with the shipment of bad tire carcasses.

4.2. Depot Use

The TQM should be used at depot tire retreading operations to screen out defective tire carcasses to reduce the process costs by reducing the number of carcasses that fail during retreading.

4.3. Checking Retreaded Tires

The TQM should be used to check retreaded tires returning from contractor retreading facilities to determine if the same quality carcasses supplied to the contractor have been returned to the government.

5.0. DISCUSSION

5.1. Operating System

The TQM software "Operating System" is extremely primitive, consisting of a cold-start initialization sequence and two hardware interrupt handlers. The cold-start sequence (Figures 5-1 and 5-2) tests the TQM workspace random access memory (RAM) (F000 through FFFF). If there is any test failure, the sequence branches to a routine which presents a flashing "E 0" message to the displays in an infinite loop. Otherwise, if the RAM test is passed, the RAM is cleared and the program continues to:

- Copy receiver section control voltages from Programmable Read-Only Memory (EEPROM) into RAM and then out to the hardware interface

- Transmit display blanking codes to the hardware interface

- Initialize all nonzero indices and pointers held in RAM to their respective starting values.

- Call routines that set the TQM into:
  - Glass-Reinforced Plastic (GRP) maintenance mode
  - TEMP display
  - PRE retreat mode
  - MIDLINE test location

- Reset the display refresh clocks in RAM

```
                    Cold Start
                        :
                        V
              Initilize Stack Pointer
                        V
          Process Walking Bit Test of RAM
                  (Flowchart 1.1a)
                        V
                    Clear RAM
                        V
          Initialize Receiver Hardware
               agc(1)   <- [RAM_TMP_INGAIN]   <- [ROM_INGAIN]
              agc(2,c)  <- [RAM_TMP_FN_GAIN]  <- [ROM_FN_GAIN]
              agc(2,a)  <- [RAM_TMP_PK_GAIN]  <- [ROM_PK_GAIN]
              agc(2,b)  <- [RAM_TMP_SLOPE]    <- [ROM_SLOPE]
               agc(3)   <- [RAM_TMP_OUTGAIN]  <- [ROM_OUTGAIN]
                        V
          Initialize Displays Hardware
               disp <- DSPLY0 Array <- Blanking codes
               disp <- DSPLY1 Array <- Blanking codes
                        V
         Initialize Update Mode Indices
         UPDATESTATUS <- 0
         TEMPINDEX    <- 8
         THICKINDEX   <- 4
         ADDRESS      <- FF00H
                        V
         Initialize Temperature Indices
           CALIB_TEMP <- 70-30
    Array "OOT" Flags <- 0
           TEMPDIVBY5 <- [CALIB_TEMP]/5
           TEMPREMAIN <- Modulo([CALIB_TEMP],5)
                        V
     Initialize Temperature Averaging Pointer
         TEMP_POINTER <- #TEMP_ARR
                        V
Initialize TQM State to TEMP Display, PRE Retread Mode,
        MIDLINE Test Location, and GRP Type
                        V
                 Initialize Clocks
            TIMERDSP <- 100/6   (1/6 second timer)
            TIMEREO  <- 1       (1/3 second timer)
                        V
           Enable RST 5.5 and RST 7.5
              Enable Interrupts
                        :
                        V
                         <-----.
                        :      :
                         ------'
```

Figure 5-1. Powerup Initialization Sequence

```
                 Process Walking Bit Test of RAM
                                :
                                V
               Set bit b0 into Reference Pattern
                                V
.------------------------------>
:                               V
:                  Pattern <- Reference Pattern
:                               V
:                         m <- F000 (Start of RAM)
:                               V
:        .--------------------->
:        :                      V
:        :               [m] <- Pattern
:        :                      V               no
:        :                 m = Pattern? ---------------.
:        :                 yes  :                       :
:        :                      V                       :
:        :           Rotate Pattern Left                :
:        :                 m <- m + 1                   :
:        :                      V                       :
:        ---------------- m=0?                          :
:                          yes  :                       :
:                               V                       :
:                  Pattern <- Pattern                   :
:                          m <- F000                    :
:                               V                       :
:        .--------------------->                        :
:        :                      V               no      V
:        :                 [m] = Pattern? --------------> <------------------.
:        :                 yes  :                       :                    :
:        :                      V                       :                    :
:        :             Rotate Pattern Left              :                    :
:        :                 m <- m + 1                   :                    :
:        :                      :                       V                    :
:        :               no     V         Display Flashing "E  0" Message    :
:        ---------------- m=0?                          :                    :
:                          yes  :                        --------------------'
:                               V
:             Rotate Reference Pattern Left
:                               :
:  no                           V
----- Has Bit Walked Through Entire Pattern?
                          yes  :
                               V
                              Exit
```

Figure 5-2. RAM Test

At this point, the TQM is initialized. The 8085 Central Processing Unit (CPU) interrupts Recovery Sequence Tester (RST) 5.5 and RST 7.5 are then enabled, and the program sits in an infinite wait loop for interrupt-driven processes.

The highest priority interrupt handler (RST 7.5) is assigned the tasks of pulsing the TQM ultrasonic transducer and of scheduling the reception and processing of ultrasonic reflections. This interrupt is driven by a 100-hertz (Hz) hardware clock. Figures 5-3 through 5-7 outline the steps executed by this handler. Note that the receiver automatic gain control (AGC) section is triggered and the transducer pulsed at every service of the interrupt, but the return signal is digitized only when no processing of a previously digitized signal is in progress. This is done to maintain the oscilloscope display as described in par. 5.6. One of the software clocks serviced by this handler then schedules, at a 6-Hz rate, the processing of digitized data if a gain calibration is active and such processing is not already in progress. This clock also updates receiver hardware parameters, controls requests for listing (as described in par. 5.6.), and alternates displays and task groups.

Specifically, the "odd" task group will process the calibration period clocks always, execute temperature calibration when active, and send to the hardware interface those codes formatting the "odd" display (i.e., the dark half of a flashing pattern). If the update mode is disabled, the "even" task group will process the STORE and CLEAR switch light-emitting diode (LED) clocks, process the information necessary to refresh the enabled display if not already being processed, and send to the hardware interface those codes formatting the "even" display (i.e., the lit half of a flashing pattern). If the update mode is enabled, the "even" task group does not process any information and updates the "even" display according to the latest sequence of update commands as derived from servicing the RST 5.5 interrupt.

The lowest priority interrupt handler (RST 5.5) is assigned the tasks of receiving, interpreting, and executing commands from the operator's pressing of keyboard switches. This interrupt is driven by a common trigger line from the front panel keyboard array. Figures 5-8 through 5-10 outline the execution of this handler. All mode change, inspection and update commands to the TQM are serviced by this handler. Figures 5-11 through 5-13 and Table 5-1 summarize the manner in which TQM mode changes and inspection states are handled.

5.2 Signal Acquisition

5.2.1. General. The transducer pulse timing, signal reception parameters, and signal capture and digitization are under computer control in the TQM. This chapter describes the software which controls the computer and the parameters which control the hardware.

5.2.2. Pulse Generation. The high-voltage electrical pulse which drives the ultrasonic transducer is generated by circuitry which is

```
                RST 7.5 Interrupt
         (100 Hz Hardware Clock Service)
                        :
                        V                    yes
        Ultrasonic Data Processing Active? ----.
                   no :                        :
                        V                      :
               Trigger TDR                     :
                        :                      :
                        V                      :
                         <---------------------'
                        :
                        V
               Trigger AGC
              Trigger Pulse
                        :
                        V              no
          Has 1/6 second passed? -------------.
                   yes :                       :
                        V                      :
          Process Even/Odd Tasks               :
            (Flowchart 1.2a)                   :
                        :                      :
                        V                      :
                         <---------------------'
                        :
                        V
             Enable RST 7.5
            Enable Interrupts
                        :
                        V
                      Exit
```

Figure 5-3. Highest Priority Interrupt Service

```
                    Process Even/Odd Tasks
                              :
                              V
                    Reset 1/6 second timer
                              V                 no
                 Gain Calibration in Service? -------------.
                         yes  :                            :
                              V                      yes   V
                 Ultrasonic Data Processing Active? ------>
                          no  :                            :
                              V                            :
                        Set Semaphore                      :
                       Enable RST 7.5                      :
                      Enable Interrupts                    :
                              V                            :
                   Retard 1/6 second timer                 :
                              V                            :
                  Process Gain Calibration                 :
                      (Flowchart 4.5)                      :
                              V                            :
                      Disable Interrupts                   :
                       Clear Semaphore                     :
                              V                            :
                  Advance 1/6 second timer                 :
                              V                            :
                               <---------------------------'
            yes               V              no
   .------------- Has 1/3 second passed? -------------.
   V                                                  V
Process Even Tasks                          Process Odd Tasks
 (Flowchart 1.2c)                            (Flowchart 1.2b)
   :                                                  :
    -----------------------> <-----------------------'
                              V
   Send Vectored Display Codes to Hardware Interface
                 Update Receiver Hardware
                              V              no
                  STORE listing enabled? ----.
                         yes  :                   :
                              V                   :
                  Process STORE listing           :
                     (Flowchart 3-10)             :
                              V                   :
                               <-----------------'
                              V              no
                 ANALYZE listing enabled? ----.
                         yes  :                   :
                              V                   :
                 Process ANALYZE listing          :
                     (Flowchart 3-11)             :
                              V                   :
                               <-----------------'
                              V
                             Exit
```

Figure 5-4. Even/Odd Task Allocation

```
                Process Odd Tasks
                        :
                        V               yes
          Update Mode Enabled? -----------.
                        V           yes       :
            TEMP CAL Time Up? -------.       :
                     no :                :       :
                        V                :       :
          Process TEMP CAL Timer        :       :
            (Flowchart 1.2d)            :       :
                        V                :       :
                         <---------------'       :
                        V           yes           :
            TEST CAL Time Up? -------.       :
                     no :                :       :
                        V                :       :
          Process TEST CAL Timer        :       :
            (Flowchart 1.2d)            :       :
                        V                :       :
                         <---------------'       :
                        V          no            :
            TEMP CAL Active? --------.       :
                    yes :                :       :
                        V                :       :
             Process TEMP CAL           :       :
             (Flowchart 4.4)            :       :
                        V                :       :
                         <---------------'       :
                        V           no            :
            TEMP CAL Time Up? -------.       :
                    yes :                :       :
                        V                :       :
          Turn Even TEMP led On         :       :
          Turn  Odd TEMP led Off        :       :
                        V                :       :
                         <---------------'       :
                        V           no            :
            TEST CAL Time Up? -------.       :
                    yes :                :       :
                        V                :       :
          Turn Even TEST led On         :       :
          Turn  Odd TEST led Off        :       :
                        V                :       :
                         <---------------'       :
                        V           yes           :
             Any CAL Time Up? -------.       :
                     no :                :       :
                        V                :       :
          Set Even Seven-Segment        :       :
           Codes into Odd Array         :       :
                        V               V       :
                         <---------------  <---'
                        V
         Point to Odd Display Array
                        V           yes
                      Exit
```

Figure 5-5. Odd Tasks

```
                            Process Even Tasks
                                    :
                                    V
                          Reset 1/3 Second Timer
                                    V
                     STORELEDCLOCK <- STORELEDCLOCK - 1
                                    V            no
                             STORELEDCLOCK = 0? ----------.
                                yes :                     :
                                    V                     :
                     Turn Off Even and Odd STORE leds     :
                                    V                     :
                                     <--------------------'
                                    V
                     CLEARLEDCLOCK <- CLEARLEDCLOCK - 1
                                    V            no
                             CLEARLEDCLOCK = 0? ----------.
                                yes :                     :
                                    V                     :
                     Turn Off Even and Odd CLEAR leds     :
                                    V                     :
                                     <--------------------'
                                    V            yes
                          Update Mode Enabled? ------------------------.
                                 no :                                   :
                                    V              yes                  V
                          Calibration in Service? -------------------->
                                 no :                                   :
                 no                 V              yes                  :
               .----- Calibration Error Condition? -----.               :
               V                 yes         *          :               :
Ultrasonic Data Processing Active? -----> Exit          :               :
            no :                                        :               :
               V                                        :               :
         Set Semaphore                                  :               :
        Enable RST 7.5                                  :               :
       Enable Interrupts                                :               :
               V                                        V               :
     Process Enabled Display                Point to "-CAL" Display     :
   (Flowchart 3.1,3.2, or 3.3)                          :               :
               :                                        :               :
                ------------------> <-------------------'               :
                                    V                                   :
                            Disable Interrupts                          :
                             Clear Semaphore                            :
                                    V        yes                        :
                              KEY_INPUT = 0? ---------------.           :
                                 no :                        :           :
                                    V                        :           :
                Process Command Translation And Execution    :           :
                            (Flowchart 1.3c)                 :           :
                                    V                        V           :
                                     <---------------------- <---------'
                                    V
                           Point to Even Display
                                    :
                                    V
                                   Exit
```

Figure 5-6. Even Tasks

```
Process TEMP CAL Timer
            :
            V
[TEMTIM]  <- [TEMTIM] - 1
            :
            V
      TEMTIM = 0? -----> Exit
       yes :
            V
       Set FLAGS(b6)      ["timed-out" true]
     Clear FLAGS(b4,b2) ["hold","in-service" false]
            :
            V
            Exit


Process TEST CAL Timer
            :
            V
[CALTIM]  <- [CALTIM] - 1
            :
            V
      CALTIM = 0? -----> Exit
       yes :
            V
       Set FLAGS(b7)      ["timed-out" true]
     Clear FLAGS(b5,b3) ["hold","in-service" false]
            :
            V
            Exit
```

Figure 5-7. Calibration Period Timers

```
          RST 5.5 Interrupt
     (Keyboard Switch Service)
                  :
                  V
          Disable RST 7.5
          Disable RST 5.5
                  :
                  V                   no
    Calibration In Service? ----.
           yes  :                    :
                  V                   :
      Process Keyboard Switch         :
          (Flowchart 1.3b)            :
                  :                   :
                  V                   :
                  <-----------------'
                  :
                  V
          Enable RST 5.5
          Enable RST 7.5
        Enable Interrupts
                  :
                  V
                Exit
```

Figure 5-8. Lowest Priority Interrupt Service

```
                Process Keyboard Switch
                          :
                          V
                  Enable Interrupts
                          :
                          V                            no
    Has Switch Been Pressed for 5 Consecutive Reads? -----.
                      yes :                               :
                          V                               :
                  Disable Interrupts                      :
               Read Input into KEY_INPUT                  :
                          :                               :
                          V                   yes         :
          Ultrasonic Data Processing Active? -------.     :
                       no :                         :     :
                          V                         :     :
        Process Command Translation and Execution   :     :
                   (Flowchart 1.3c)                 :     :
                          :                         :     :
                          V                         :     :
                           <------------------------'     :
                          :                               :
                          V                               :
                  Enable Interrupts                       :
                          :                               :
                          V                               :
                           <---------------------------.  :
                          :                            :  :
                          V                         no :  :
     Has Switch Been Open for 5 Consecutive Reads? ----'  :
                      yes :                               :
                          V                               :
                           <------------------------------'
                          :
                          V
                  Disable Interrupts
                          :
                          V
                        Exit
```

Figure 5-9. Front Panel Keyboard Services

```
                 Process Command Translation and Execution
                                   :
             yes                   V                  no
          .--------- Update Mode Enabled? ---------.
          :                                        :
          V                                        V
Point to Update Vector Table            Point to Operations Vector Table
          :                                        :
          ------------------> <-------------------'
                                   :
                                   V
      Read Execution Address from Vector Table + KEY_INPUT
                                   :
                                   V
                         KEY_INPUT <- Ø
                                   :
                                   V           no
                         Error Condition? ------.
                             yes :              :
                  no             V              :
        Exit <----- Is command a CLEAR?         :
                             yes :              :
                                 V              :
                                  <-------------'
                                 :
                                 V
                         Execute Procedure
                            (Table 1.1)
                                 :
                                 V
                                Exit
```

Figure 5-10. Switch Command Translation and Execution

```
                                       Process Tire Type Selection
                                                   :
                                                   V
 .---------------.---------------.- Turn Off All TIRE TYPE leds -.---------------.---------------.---------------.
 :               :               :               :               :               :               :               :
 V               V               V               V               V               V               V               V
TRUCK/S 1 Entry TRUCK/T 1 Entry PASS/S 1 Entry  TRUCK/S 2 Entry TRUCK/T 2 Entry PASS/S 2 Entry  R/N Entry      GRP Entry
 :               :               :               :               :               :               :               :
 V               V               V               V               V               V               V               V
 Turn On         Turn On         Turn On         Turn On         Turn On         Turn On         Turn On         Turn On
TRUCK/T 1 led   TRUCK/T 1 led   PASS/S 1 led    TRUCK/T 2 led   TRUCK/T 2 led   PASS/S 2 led    R/N led         GRP led
 :               :               :               :               :               :               :               :
 V               V               V               V               V               V               V               V
Set FSELECT(b2) Set FSELECT(b1) Set FSELECT(b0) Set FSELECT(b5) Set FSELECT(b4) Set FSELECT(b3) Set FSELECT(b7) Set FSELECT(b6)
 :               V               V               V               V               V               :               :
 ---------------) ---------------) ---------------) (--------------- (--------------- (---------------'             :
                                                 V                                                               V
                                       agc(3) (- [ROM_OUTGAIN]                                    agc(3) (- [GRP_OUTGAIN]
                                                 V                                                               :
                                                 (---------------------------------------------------------------'
                                                 :
                                                 V
                                        SETPOINT (- Gain calibration setpoint
                                        ALTPOINT (- Saturation case gain calibration setpoint
                                         TABBASE (- Temperature/Thickness Table Address
                                    PULSERINGOUT (- Pulser Ringout Mask Length
TEXTNULLGAP,MINIMUMWIDTH,ENVELOPEWIDTH,ENVELOPEGAP (- Envelope Feature Extraction Parameters
                                    FARCLEANTIME (- Tread inspection "garbage" limit
                          NEARPOROTIME,FARPOROTIME (- Porosity window
                          NEARSTRUTIME,FARSTRUTIME (- Structure window
                           B2,B3,B4,B5,B6,B7,B8,B9 (- Steel-Belted Tire Accept/Reject Parameters
                                              C1 (- Steel-Belted Tire Classification Parameter
                 LOWGAPLIMIT,MIDGAPLIMIT,HIGHGAPLIMIT (- Textile-Plied Tire Classification Parameters
                             P3P5_DT_N,P3P5_DT_F (- Liner accept/reject parameter
                                                 :
                                                 V
                                        NOISEAMP (- Noise Amplitude and Width Thresholds
                                              A1 (- Absolute Degradation Threshold (xSR)
                                              A2 (- Absolute Separation Threshold (xSR)
                                             A11 (- Absolute Porosity Threshold
                                      LOWERLIMIT (- Absolute Degradation Threshold (TTX)
                                      UPPERLIMIT (- Absolute Separation Threshold (TTX)
                                             A18 (- Absolute Bondline Threshold
                      LOWSHOPLIMIT,HIGHSHOPLIMIT (- Time Limits for TTX Single Peak Classification
                                                 :
                                                 V
                                       Disable "-CAL" Message
                                         Reset ANALYSTATUS
                                          CALTIM (- 1
                                          TEMTIM (- 1
                                                 :
                                                 V
                                                Exit
```

Figure 5-11. Tire Type Selection

```
                    Process Retread Mode Selection
           :                                              :
           :                                              :
           :                                              :
           V                                              V
       PRE Entry                                     POST Entry
           :                                              :
           V                                              V
    Turn On PRE led                               Turn On POST led
   Turn Off POST led                              Turn Off PRE led
           :                                              :
           V                                              V
   Set FSELECT+1(b0)                           Clear FSELECT+1(b0)
           :                                              :
           V                                              V
  Point to PRE-Retread                          Point to POST-Retread
 Parameters Appropriate                        Parameters Appropriate
  to TIRE TYPE Selected                         to TIRE TYPE Selected
           :                                              :
            --------------> <--------------'
                           :
                           V
                NOISEAMP <- Noise Amplitude and Width Thresholds
                      A1 <- Absolute Degradation Threshold
                      A2 <- Absolute Separation Threshold
                     A11 <- Absolute Porosity Threshold
              LOWERLIMIT <- Absolute Degradation Threshold (TTX)
              UPPERLIMIT <- Absolute Separation Threshold (TTX)
                     A18 <- Absolute Bondline Threshold
LOWSHOPLIMIT,HIGHSHOPLIMIT <- Time Limits for TTX Single Peak Classificati
                           :
                           V
                          Exit
```

Figure 5-12. Retread Mode Selection

```
             Process Test Location Selection
             :                                     :
             :                                     :
             :                                     :
             V                                     V
     MIDLINE Entry                         SHOULDER Entry
             :                                     :
             V                                     V
   Turn On MIDLINE led                 Turn On SHOULDER led
  Turn Off SHOULDER led                Turn Off MIDLINE led
             :                                     :
             V                                     V
     Set FSELECT+1(b1)                   Clear FSELECT+1(b1)
             :                                     :
              --------------> <--------------
                              :
                              V
                             Exit
```

Figure 5-13. Test Location Selection

Table 5-1. Switch Commands and Executing Routines

SWITCH COMMAND	OPERATIONS FLOWCHART	OPERATIONS ROUTINE	UPDATE ROUTINE
THICK	Flowchart 3.2	DEPTH	
TEMP	Flowchart 3.3	TEMPERATURE	
QUALITY	Flowchart 3.1	QUALITY	
TEMP CAL	Flowchart 4.1	TEMP_CAL_START	
TEST CAL	Flowchart 4.2	GAIN_CAL_START	
TRUCK/S 1	Flowchart 1.4	OTSR_I	
TRUCK/T 1	Flowchart 1.4	OTTX_I	
PASS/S 1	Flowchart 1.4	OPSR_I	
TRUCK/S 2	Flowchart 1.4	OTSR_II	
TRUCK/T 2	Flowchart 1.4	OTTX_II	
PASS/S 2	Flowchart 1.4	OPSR_II	
R/N	Flowchart 1.4		
GRP	Flowchart 1.4		
PRE	Flowchart 1.5	OPRE	
POST	Flowchart 1.5	OPOST	
MIDLINE	Flowchart 1.6	OMID	
SHOULDER	Flowchart 1.6	OSHLDR	
STORE	Flowchart 3.10	STORE	
ANALYZE	Flowchart 3.11	ANALYZE	

triggered by CPU control at a 100-Hz rate. Normally, an AGC trigger (discussed in par. 5.2.3.) starts the gain variation in the receiver's depth compensation circuit and a pulse trigger follows 16.0 microseconds later. However, if the CPU is not actively processing a digitized ultrasonic signal, this normal sequence will be immediately preceeded by a Transient Data Recorder (TDR) trigger to start the acquisition and digitization of the next signal. The resultant acquisition, therefore, contains coupled AGC trigger noise sampled along with the transducer's "main-bang" and the returning tire structure reflections. Figure 5-14 illustrates the relationship of these pulses.

As discussed in par. 5.1., the CPU control of this 100-Hz pulse generation sequence comes from the execution of the highest priority interrupt service in the software. It was designed this way to provide a stable oscilloscope display (described in par. 5.6.) of the ultrasonic signals detected by the transducer. The actual processing of the digitized signals is done at a nominal 3-Hz rate. The 100-Hz interrupt service has been designed to allow the CPU to perform multiple tasks between the pulse generation task and the signal-processing task so that neither task is significantly impeded by the execution of the other. Those branches in Figures 5-3 through 5-7 which act on the presence of ultrasonic data processing assure this.

5.2.3. Signal Reception. The receiver section amplifies the incoming signal by two constant factors and by a factor which monotonically increases with time. This increasing factor is required to compensate the received signal for the attenuation caused by passage through tread rubber. The compensation factor value is controlled by a section of the receiver's AGC circuit known as the Distance-Amplitude Compensator (DAC) and designated as AGC_2 since it is the second gain stage in the receiver. This ACC_2 stage is configured by the CPU via three voltages. The ways the AGC_2 is configured are listed in Table 5-2 and illustrated in Figure 5-14.

Table 5-2 and Figure 5-14 also refer to three other voltages. One controls the constant gain of the first amplifier stage (AGC_1) and two control alternate gains of the third amplifier stage (AGC_3). At any time, the total gain of the receiver section is a composite of the constant AGC_1 and AGC_3 gains and the varying AGC_2 gain.

The initial gains are imposed on the hardware before the time of the TDR or AGC trigger pulse. The AGC trigger pulse preceeds the high-voltage pulse generation trigger by 16.0 microseconds to allow the receiver AGC circuits time to settle before digitizing ultrasonic reflections.

The rate of gain change is imposed to control how rapidly the gain compensation factor increases with time from its initial set value. The rate is factory preset to 1.25 decibels (dB) per one-sixteenth inch to compensate for the average depth attenuation in tread rubber. The largest AGC_2 gain is imposed to limit post-signal noise amplification. The value required depends on amplifier or TDR input capacity, the maxi-

Table 5-2. Receiver Section Control Voltages

LABEL	ADDRESS	DESCRIPTION
ROM_INGAIN	E780	Gain control for agc(1)
ROM_FN_GAIN	E782	Gain control for agc(2,c)
ROM_PK_GAIN	E784	Gain control for agc(2,a)
ROM_SLOPE	E786	Slope control for agc(2,b)
ROM_OUTGAIN	E788	Gain control for agc(3) when CRP not active
CRP_OUTGAIN	E78A	Gain control for agc(3) when CRP active

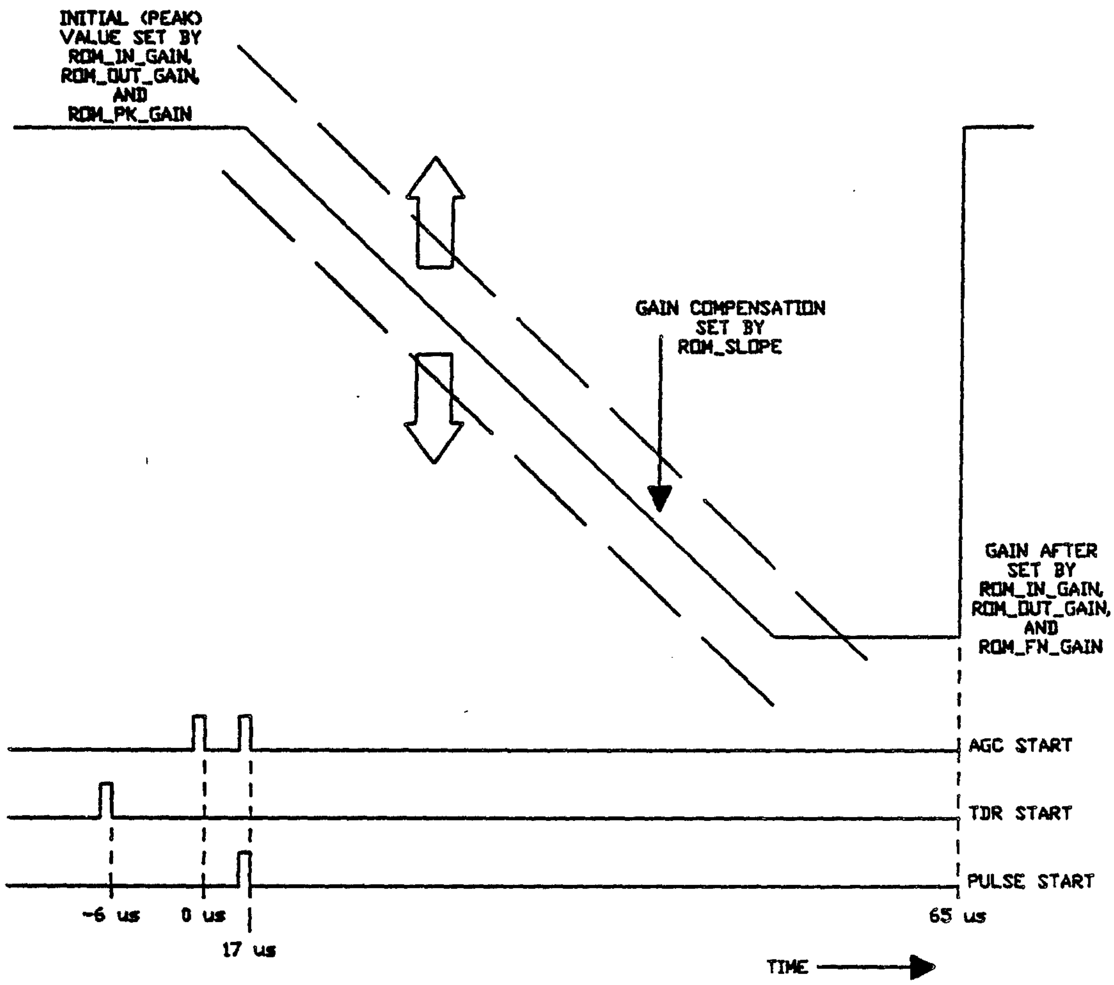


Figure 5-14. AGC Ramp Signal

mum depth of tire to be inspected by the TQM, and the rate of gain change. For these reasons, the settings of largest gain and rate of gain change are interactive. The largest gain is factory preset to be imposed at approximately twenty-sixteenths inch of tread depth.

The only parameter the CPU uses to control the AGC circuit during normal TQM operation is the AGC_1 gain. Because each of the three amplifiers in the AGC circuit acts independently, variation of the AGC_1 gain will not alter the rate of gain change or the value of the largest gain. Note in Figure 5-14 that the time when largest gain is imposed can be altered, but not its value. As a consequence, CPU control of the AGC_1 gain effectively yields proportional CPU control of any gain throughout the sampled signal domain.

The CPU exerts its control of the AGC at a 3-Hz rate, but it varies the value of the AGC_1 gain control parameter only during TEST calibrations. This value is altered by a hardware/software servosystem to compensate the TQM for variations in the material being inspected or monitored. As can be inferred from Figure 5-14 adjustment of the value of the initial gain will alter the gain compensation factor throughout the signal period in a linear and predictable manner.

By monitoring a precisely machined reference block of material whose acoustic attenuation is invariant with temperature, a known and universally invariant ultrasonic reflection amplitude can be received and compared to a setpoint amplitude for the purpose of automatically adjusting the value of the initial gain. A reference block of GRP meets all requirements of invariance, and two are supplied with each TQM. The TQM holds eight setpoint amplitude values in EEPROM, one for each of six inspectable tire types and two for reference or calibration blocks. Table 5-3 lists these setpoints. Table 5-3(a) lists the primary gain calibration setpoints and Table 5-3(b) lists the secondary gain calibration setpoints (described in more detail in par. 5.3.5.).

The appropriate setpoint is selected from the front panel setting of TIRE TYPE as it exists at the time calibration. The calibration proceeds in a manner outlined in Figure 5-15. The second AGC_3 voltage listed in Table 5-2 acts as an attenuation during such calibration to compensate for the extreme reflectivity of the GRP block. As long as the average received reflection amplitude differs from the setpoint, the CPU will increase or decrease the value of the AGC_1 gain so as to drive the reflection amplitude toward equaling the setpoint.

As this process proceeds, the amplitude of the received reflection is displayed on the two left-most digits of the front panel. If the expected reflection occurring between eleven-sixteenths and thirteen-sixteeths inches time equivalent is not detected, the CPU will issue a "-CAL" display message to indicate an improperly received calibration signal. The TQM will request such gain calibration for any of the following conditions:

Table 5-3. Gain Calibration Setpoint Values*

	TIRE TYPE	ADDRESS	DESCRIPTION
AMPTABLE	PSR_I	E790	Passenger Steel-Belted 1
	TTX_I	E792	Truck Textile-Plied 1
	TSR_I	E794	Truck Steel-Belted 1
	GRP_	E796	Glass-Reinforced Plastic Block
	RN	E798	Rubber/Nylon Block
	PSR_II	E79A	Passenger Steel-Belted 2
	TTX_II	E79C	Truck Textile-Plied 2
	TSR_II	E79E	Truck Steel-Belted 2

(a) Primary Gain Calibration Setpoints

	TIRE TYPE	ADDRESS	DESCRIPTION
ALTTABLE	PSR_I	E7A0	Passenger Steel-Belted 1
	TTX_I	E7A2	Truck Textile-Plied 1
	TSR_I	E7A4	Truck Steel-Belted 1
	GRP_	E7A6	Glass-Reinforced Plastic Block
	RN	E7A8	Rubber/Nylon Block
	PSR_II	E7AA	Passenger Steel-Belted 2
	TTX_II	E7AC	Truck Textile-plied 2
	TSR_II	E7AE	Truck Steel-Belted 2

(b) Secondary Gain Calibration Setpoints

*TQM Reading of Setpoints = Setpoint/4.23
Example for GRP (refer to listing in Appendix):
15 = 63/4.23 where $63_{10} = 3F_{16}$

```
              Process Gain Calibration
                         V
      Process Reflection Feature Extraction
                 (Flowchart 3.4)
                         V                 yes
       Automatic DAC Adjustment Enabled? ----------------------.
                     no :                                       :
                        V                                       V
      Process Maximum Amplitude Search Between       Process DAC Adjustment
        CAL_LOW_WINDOW and CAL_HIGH_WINDOW             (Flowchart 4.6)
                        :
                        V                  no
       Does Peak Amplitude pa(Max) Exist? ---------------------------.
                    yes :                                             :
                        V                                             :
        CALTOTALPEAKS  <-  [CALTOTALPEAKS]+pa(Max)                    :
        CALAVERAGECNT  <-  [CALAVERAGECNT] - 1                        :
         no             V                                             :
Exit  <------- CALAVERAGECNT = 0?                                     :
                    yes :                                             :
                        V                                             :
              Average  <-  [CALTOTALPEAKS]/4                          :
                        V                                             :
      Process Preparation of Amplitude Display                        :
                        :                                             :
                        V                                             :
              CALAVERAGECNT  <- 4                                     :
              CALTOTALPEAKS  <- 0                                     :
                        V              yes                            :
            Average > [SETPOINT]+1? -----------------------.          :
                     no :                                   :         :
                        V              yes                  :         :
            Average < [SETPOINT]-1? ---------.              :         :
                     no :                     V             :         :
                        V                  Increase       Reduce      :
            CALENDCNT  <-  [CALENDCNT] - 1   Gain           Gain      :
               no       V                     :               :       :
Exit  <----------- CALENDCNT = 0?             -----> <-----'          :
                    yes :                            :                :
                        V      yes                   V                :
                    GRP Type? ---------------.     Gain      yes      V
                     no :                    :   Control at -------->
                        V                    :    Limits?             :
             Restore original NOISEWIDTH     :    no :                V
               agc(3)  <- [ROM_OUTGAIN]      :       :    CALTRYCNT  <- [CALTRYCNT] - 1
                        V                    :       :                V          no
                    <-----------------'      :             CALTRYCNT = 0? -----> Exit
                        V                            V          yes :
               agc(1)  <- Gain             agc(1)  <- New Gain      :
                        V                            :              :
               CALTIM  <- 3*60*15                    :              :
             Turn Off TEST CAL led                   :              V
                        V                            :        Set FSELECT+1(b6)
                 Set FLAGS(b5)                       :          Set FLAGS(b7)
               Clear FLAGS(b7,b3)                    :        Clear FLAGS(b5,b3)
                        V                            V              V
                       Exit                        Exit            Exit
```

Figure 5-15. Gain Calibration

- selection of new tire type,
- 15 minutes elapsed time from prior calibrating, or
- initial TQM turn on.

5.2.4. Signal Capture. The received and amplified signal is digitized by a very fast analog-to-digital converter and RAM system. This is the TQM's TDR and it is initialized and triggered by the CPU detection of a software grant to do so. Triggering occurs at the TDR trigger time of the next 100-Hz pulse service request. Software grants are issued at a 3-Hz rate so that the TDR captures only 3 of 100 signals returned each second.

While the signal is being captured, the TDR hardware issues a busy signal to inform the CPU that the capture process is underway. Signals are sampled at a 20-Megahertz (MHz) rate and, since the ultrasonic information being acquired has very little spectral content in excess of 1 MHz, this rate is sufficient to obtain an amplitude sample of the signal accurate to ± 1.2 percent of the actual amplitude. The use of a high sampling rate for capture also increases the accuracy of time measurements within the signal. The CPU software eventually uses time measurements to identify tire structures from their reflections and to measure tread depth.

5.3. Signal Processing

5.3.1. General. The sampled and digitized ultrasonic signal can now be processed to extract displayable information about the tire being inspected. If the selected display is QUALITY or THICK, the sampled signal is generally subjected to two stages of data reduction and feature extraction, a stage of saturation detection and disposition, stages of time compensation for temperature and amplitude compensation for depth, isolation of significant features, and classification of remaining features according to structural characteristics appropriate to the TIRE TYPE selected. Finally, the relevant information is measured from the set of features of relevant classification and is displayed. This process, which runs at a 3-Hz rate, is summarized in Figures 5-16 through 5-18.

If the selected display is TEMP, the sampled ultrasonic signal is not processed. Instead, the thermocouple is read and an averaged temperature is processed for display. This process, also running at a 3-Hz rate, is summarized in Figure 5-19.

5.3.2. Reflection Feature Extraction. Software processing of the digitized signal starts with the transfer of a selected window of the captured signal from the TDR memory to a workspace memory. The transferable portion of the captured signal is selected in the two-step process illustrated in Figures 5-20 through 5-23. First, the CPU is directed to begin examining the TDR memory out to an address offset of

```
                 Process QUALITY Display
                           :
                           V                    yes
                 Holding ANALYZE Display? ----------------> Exit
                       no  :
                           V
          Process Reflection Feature Extraction
                    (Flowchart 3.4)
                           V
        Process Search for Reflection Saturation
                    (Flowchart 3.5)
                           V
           Process Envelope Feature Extraction
                    (Flowchart 3.6)
                           V
                          GRP         yes
                      "Tire Type"   -----------------.
                           ?                         V
                       no  :                pa(a)  <- Pmax
                           V                tp(a)  <- Tmax
                          R/N         yes            V
                      "Tire Type"   ---------------->
                           ?                         :
                       no  :                         :
                           V                         :
            Process Saturation Disposition           :
                   (Flowchart 3.2a)                  :
                           V                         :
       Process Amplitude and Time Compensation       :
                    (Flowchart 3.7)                  :
                           V                         :
                   Process Windowing                 :
                    (Flowchart 3.8)                  :
                           V                         V
                 Process Classification        P3  <- Pa
                    (Flowchart 3.9)            P2  <- P3
                           V                         :
                            <------------------------'
                           V
                 Process Depth Computation
                   (Flowchart 3.2b)
                           V
          Process Preparation of P3 Amplitude Display
                           :
                           V
                          Exit
```

Figure 5-16. Quality Display Processing

```
                  Process DEPTH Display
                            :
                            V
             Holding ANALYZE Display? ---------------) Exit
                         no :
                            V
      Process Reflection Feature Extraction
                  (Flowchart 3.4)
                            V
    Process Search for Reflection Saturation
                  (Flowchart 3.5)
                            V
       Process Envelope Feature Extraction
                  (Flowchart 3.6)
                            V
                           GRP        yes
                      "Tire Type"   ---------------.
                            ?                      V
                         no :              pa(a) <- Pmax
                            V              tp(a) <- Tmax
                           R/N        yes          V
                      "Tire Type"   ---------------)
                            ?                      :
                         no :                      :
                            V                      :
        Process Saturation Disposition             :
                  (Flowchart 3.2a)                 :
                            V                      :
     Process Amplitude and Time Compensation       :
                  (Flowchart 3.7)                  :
                            V                      :
                 Process Windowing                 :
                  (Flowchart 3.8)                  :
                            V                      V
             Process Classification           P3 <- Pa
                  (Flowchart 3.9)             P2 <- P3
                            V                      :
                            (----------------------'
                            V
              Process Depth Computation
                  (Flowchart 3.2b)
                            V
     Process Preparation of D Depth Display
                            :
                            V
                          Exit
```

Figure 5-17. Thickness Display Processing

```
             Process Saturation Disposition
                              :
                              V                          yes
      Saturation Already Acknowledged as Detected? -------> Exit
                           no :
                              V
            Acknowledge Detection of Saturation
                              :
                              V                            yes
    Has an ANALYZE Occurred Since Last Calibration? ------> Exit
                           no :
                              V                   yes
             Has Gain Already Been Reduced? -------------> Exit
                           no :
                              V
                           Flag lower gain
                  SETPOINT <- ALTPOINT Prepare new setpoint
             FSELECT+1(b6) <- 1        Set calibration error condition
                    CALTIM <- 1        Force calibration timeout
                              :
                              V
                            Exit
```

```
Flowchart 3.2a    REFLECTION SATURATION DISPOSITION
```

```
                Process Depth Computation
                             :
         yes                 V             no
       .------ Textile Tire Type? -----.
       :                               :
       V                               V
    D <- tp(3)                      D <- tp(2)
       :                               :
        --------------> <--------------'
                             :
                             V
                        D <- D/2.125
                             :
                             V
                           Exit
```

Figure 5-18. Thickness Display Computation

```
                Process TEMP Display
                        :
                        V
                    Delay 480 us
               Turn off "Out-of-Temp" led
                        V                 yes
              Temperature Circuit Busy? -----------> Start Next Conversion
                     no :                                                :
                        V        yes                                     V
                   Open Probe? ------------------------------.     Exit
                     no :                                    :
                        V                                    :
                 Read Temperature                            :
                        V        yes                         V
                   Overrange? ------------------------------>
                     no :                                    :
                        V               yes                  :
                Polarity Positive? -----.                    :
                     no :               :                    :
                        V               :                    V
           Negate Temperature Reading   :               Prepare "----" message
                        V               :                    :
                        <---------------'                    V
                        V                               Turn on "Out-of-Temp" led
             Start Next Conversion                       Start Next Conversion
      Insert Latest Temperature Reading into Array               :
        Compute Average of Arrayed Readings                      V
   T   <- (9/5)*[([TEMP_SLOPE]/4095)*(Average)]                 Exit
                        :                 +32+[TEMP_OFFSET]
                        V                     yes
           Was Polarity Read Positive? ----------.
                     no :                        :
                        V                        :
                     Negate T                    V
              Prepare Displayable "-"  Prepare Displayable " "
                        V                        :
                        <------------------------'
                        V
         LAST_TEMP_READ <- T-30
                        V          yes
                 115 > T >= 30? ----------------.
                     no :                        :
                        V                        :
            Turn on "Out-of-Temp" led            :
                        V                        :
                        <------------------------'
                        V
      Process Preparation of Temperature Display
                        :
                        V
                      Exit
```

Figure 5-19. Temperature Display Processing

```
                     Process Reflection Feature Extraction
                                     :
                                     V
                                      <-------------.
                                     V          no  :
                           Signal captured? -----'
DTAB is Transient Data            yes :
 Recorder (TDR) memory                :
 where signal is captured             V                 AGC_TRIG_OFFSET is EEPROM
 and digitized.                   i <- MASDAT            memory holding 50 ns
                                  j <- DTAB + 0          offset of agc noise after
MASDAT is random-access           A <- 0                 TDR trigger.
 memory (RAM) where               k <- 1
 rectified and smoothed               :                 MAINBANG_OFFSET is EEPROM
 data is transferred.                 :                  memory holding 50 ns
                                      V                  offset of transducer pulse
                          .---------->                   after TDR trigger.
                          :           V            no
                          :   112 < d(j) < 144? ----.
                          :       yes :             :
                          :           V             :
                          :       A <- A + d(j)     :
                          :       k <- k + 1        :
                          :           V             :
                          :            <------------'
                          :           V
                          :       j <- j + 1
                          :   no      V
                           ------- j = DTAB + [AGC_TRIG_OFFSET]?
                                  yes :
                                      V
                                  j <- DTAB + [MAINBANG_OFFSET]
                                      V
                 .------------------->
                 :        no          V
                 :        .---- d(j) < 0?
                 :        :     yes :
                 :        :           V
                 :        :   d(j) <- |d(j)|
                 :        :           V
                 :         --------->
                 :                    V
                 :            d(j) <- d(j) + A/k - 127
                 :            d(i) <- [d(i) + d(j)]/2
                 :                    V
                 :                i <- i + 1
                 :                j <- j + 1
                 :            no      V
                  ---------------- i = MASDAT + 1280?
                                  yes :
                                      V
```

Figure 5-20. Data Selection, Rectification, and Smoothing

```
                     Process Reflection Feature Extraction (Cont.)
                                            :
PULSERINGOUT,                               :                 PEAKTBL is memory where
NOISEAMP, &                                 V                     reflection features
NOISEWIDTH selected from         C  <- 63                         are held.
 EEPROM at time of tire          i  <- 1 (PEAKTBL index)
 type selection.                 t  <- [PULSERINGOUT]
  See Table 3.1                  K  <- 1280 - t
                                 j  <- MASDAT + t
                                    V
.------------------------------->
:                                   V                   no
:                          d(j) >= [NOISEAMP]? -------.
:                              yes :                      :
:                    no            V                      V
:                 .------ ts(i) = 0?                 t  <- t - 1
:                 :          yes :                        V
:                 :              V                 Close Peak (threshold)
:                 :        ts(i) <- t                 (Flowchart 3.4c)
:                 :        pa(i) <- d(j)                  V
:                 :        tp(i) <- t                 t  <- t + 1
:                 :              V                        V
:                  ------------> <--------------- C = 0? -------.
:                                V          yes                   :
:                      d(j+1) < d(j)? -------------.              :
:                             no :                  :             :
:                   yes          V                  :             :
:            .----------- d(j+1) > d(j)?            :             :
:            V                no :                  V             :
:          Sign    no            V            no   Sign           :
:        Change? --------------> <--------------- Change?         :
:       yes :                    :               yes :            :
:           V                    :                   V            :
:   Multiple Lookahead           :           Multiple Lookahead   :
:    (Flowchart 3.4d)            :            (Flowchart 3.4d)    :
:           V                    :                   V            :
:         Sign     no            V            no   Sign           :
:       Change? --------------> <--------------- Change?          :
:       yes :                    :               yes :            :
:           V                    :                   V            :
:  Close Peak (contour)          :           pa(i) <- d(j-1)      :
:   (Flowchart 3.4c)             :           tp(i) <- t           :
:           V    no              V                   :            :
:         C = 0? --------------> <-------------------'            :
:       yes :                    V                                :
:           :              t  <- t + 1                            :
:           :              K  <- K - 1                            :
:           :          no        V                                :
-----------/:/---------------- K = 0?                             :
            :               yes  V                                :
            ----------> Set EOD markers <-------------------------'
                                 :
                                 V
                                Exit
```

Figure 5-21. Reflection Feature Extraction

```
NOISEAMP & NOISEWIDTH
 selected from EEPROM          Close Peak
 at time of tire type               V
 selection.                  ts(i) = 0? ------------------.
 See Table 3.1                   no V                      :
                           te(i) <- t                      :
                                    V             no       :
            te(i) - ts(i) >= [NOISEWIDTH]? -.              :
                               yes V          no V         :
                           pa(i) >= [NOISEAMP]? -->        :
                               yes V             :         :
                                 i <- i + 1      V         :
                           ts(i) <- t      ts(i) <- 0      :
                                 C <- C - 1      :         :
                           ts(i) <- 0     <---------'      :
                                    V                      :
                                     <---------------------'
                                    V
                                  Exit
```

Figure 5-22. Peak Closure

```
                    Multiple Lookahead
                           :
                           V
                    jj <- j+1
                           :
                           V
                            <---------------.
                           :                :
       yes                 V                :
Exit <------ |d(jj) - d(jj+1)| >= 32 ?      :
                      no   :                :
                           V                :
                    jj <- jj+1              :
                           :                :
                           V      yes       :
             (jj - j+1) = 5 ?   -----------'
                      no   :
                           V
                         Exit
```

Figure 5-23. Trend Lookahead

value stored in EEPROM address E7D2 (AGC_TRIG_OFFSET). During this examination of the time after the TDR start and before the AGC trigger (approximately 6 microseconds), the CPU accumulates all captured values lying within a ±10-percent band around the TDR centroid value of 128. It then computes the measured analog ground (g) of the receiver section by dividing the accumulation by the number of values accumulated. This ground value is stored in RAM memory FAD6 (GROUND).

The CPU then begins to transfer data to the workspace memory MASDAT from a TDR memory address offset by the value stored in EEPROM address E7D4 (MAINBANG OFFSET). This represents a point sampled at the start of the "main bang" reflection of the transducer.

The ensuing transfer of data is itself a triple process as illustrated in Figure 5-20. Starting from that point in TDR memory which corresponds to the acquisition time of the "main bang" and continuing for the next 1,280 bytes (representing 64 microseconds of acquisition time), the CPU subjects each sampled value (d_j) to the following three steps in sequence:

(1) sampled value (d_j) is normalized to measured analog ground value (g=A/K) and then converted to an absolute positive number. This is rectification.

(2) Rectified value $|d_j - g|$ is added to the time correspondent value (di) in the workspace memory and then divided by 2. This is dynamic averaging, or smoothing.

(3) Dynamically averaged value $\frac{|d_j - g| + d_i}{2}$ is then stored in memory where d_i was accessed in step (2) and the data acquired at the next sample times j+1, i+1 are treated similarly.

After 64 microseconds of acquired samples have been dynamically averaged, the CPU proceeds to reduce the amount of data it is required to process by extracting the features of the captured ultrasonic reflections according to logic outlined in Figure 5-21. The point in the data at which it begins the reduction is determined by a time offset used to bypass the captured transducer ringout signal. The size of this ringout "mask" depends on the tire type selected at the TQM front panel and its value is held in RAM memory PULSERINGOUT (FA90). The values held in EEPROM are listed in Table 5-4(a).

The reduction occurs by characterizing each rectified reflection (describable by approximately 40 numbers) with a set of 4 numbers: reflection maximum amplitude $p_a^{\Sigma}(j)$, the time of its occurrence $t_p^{\Sigma}(j)$, the reflection start time $t_s^{\Sigma}(j)$, and its end time $t_e^{\Sigma}(j)$. All these times are referenced from the acquisition time of the start of the "main bang." Each reflection of amplitude greater than a characteristic threshold, and of width greater than a characteristic time, is characterized this way. The characteristic thresholds and times used depend

Table 5-4. Reflection Feature Extraction Parameters

LABEL	ADDRESS	DESCRIPTION
PSR_I_RINGOUT	E804	Passenger Steel-Belted 1
TTX_I_RINGOUT	E844	Truck Textile-Plied 1
TSR_I_RINGOUT	E884	Truck Steel-Belted 1
PSR_II_RINGOUT	E8C4	Passenger Steel-Belted 2
TTX_II_RINGOUT	E904	Truck Textile-Plied 2
TSR_II_RINGOUT	E944	Truck Steel-Belted 2
GRP_RINGOUT	E984	Glass-Reinforced Plastic Block
RN_RINGOUT	E9C4	Rubber/Nylon Block

(a) Main Bang Ringout Mask

LABEL	ADDRESS	DESCRIPTION
PSR_I_PRE_NAMP	E800	Passenger Steel-Belted 1 Pre-Retread
PSR_I_PST_NAMP	E802	Passenger Steel-Belted 1 Post-Retread
TTX_I_PRE_NAMP	E840	Truck Textile-Plied 1 Pre-Retread
TTX_I_PST_NAMP	E842	Truck Textile-Plied 1 Post Retread
TSR_I_PRE_NAMP	E880	Truck Steel-Belted 1 Pre-Retread
TSR_I_PST_NAMP	E882	Truck Steel-Belted 1 Post-Retread
PSR_II_PRE_NAMP	E8C0	Passenger Steel-Belted 2 Pre-Retread
PSR_II_PST_NAMP	E8C2	Passenger Steel-Belted 2 Post-Retread
TTX_II_PRE_NAMP	E900	Truck Textile-Plied 2 Pre-Retread
TTX_II_PST_NAMP	E902	Truck Textile-Plied 2 Post-Retread
TSR_II_PRE_NAMP	E940	Truck Steel-Belted 2 Pre-Retread
TSR_II_PST_NAMP	E942	Truck Steel-Belted 2 Post-Retread
GRP_PRE_NAMP	E980	Glass-Reinforced Plastic Block
RN_PRE_NAMP	E9C0	Rubber/Nylon Block

(b) Maximum Noise Amplitude from Ground

LABEL	ADDRESS	DESCRIPTION
PSR_I_PRE_NWID	E801	Passenger Steel-Belted 1 Pre-Retread
PSR_I_PST_NWID	E803	Passsnger Steel-Belted 1 Post-Retread
TTX_I_PRE_NWID	E841	Truck Textile-Plied 1 Pre-Retread
TTX_I_PST_NWID	E843	Truck Textile Plied 1 Post-Retread
TSR_I_PRE_NWID	E881	Truck Steel-Belted 1 Pre-Retread
TSR_I_PST_NWID	E883	Truck Steel-Belted 1 Post-Retread
PSR_II_PRE_NWID	E8C1	Passenger Steel-Belted 2 Pre-Retread
PSR_II_PST_NWID	E8C3	Passenger Steel-Belted 2 Post-Retread
TTX_II_PRE_NWID	E901	Truck Textile-Plied 2 Pre-Retread
TTX_II_PST_NWID	E903	Truck Textile-Plied 2 Post-Retread
TSR_II_PRE_NWID	E941	Truck Steel-Belted 2 Pre-Retread
TSR_II_PRE_NWID	E943	Truck Steel-Belted 2 Pre-Retread
GRP_PRE_NWID	E981	Glass-Reinforced Plastic Block
RN_PRE_NWID	E9C1	Rubber/Nylon Block

(c) Maximum Noise Width

on the TIRE TYPE selected at the TQM front panel and are held in EEPROM with the characteristics shown in Tables 5-4(b) and (c).

The product of signal rectification is held in memory as a tabular array of the extracted features of the reflections. This is accessible to observation on a printer by procedures discussed in par. 5.6. From this array, the reflection data is transferred to further stages of signal processing.

5.3.3. Automatic Saturation Detection. The reflection features extracted by procedures described in the preceeding section are next searched for evidence of potential signal saturation. This search, outlined in Figure 5-24, is performed at this late processing stage for reasons of efficiency. The data population has been substantially reduced, the pertinent data (i.e., peak amplitudes) isolated, and sources of unavoidable system saturation (i.e., main bang pulse, AGC, and TDR triggers) removed. Using terminology introduced in the preceding section, the test for saturation is:

$$|\varepsilon| + d_i \geq 127 \text{ Saturation}$$

$$|\varepsilon| + d_i < 127 \text{ No Saturation}$$

Detection of no saturation allows monitoring to proceed normally. Detection of saturation sets a condition flag which has consequences described in par. 5.3.5.

5.3.4. Peak Envelope Feature Extraction. Ultrasonic reflection data which has been rectified and smoothed contains more information than is necessary or practical for the CPU to make real-time classifications. Therefore, the first stage of the TQM pattern processing is the reduction of the captured data to a series of descriptive features. This stage has been discussed in par. 5.3.2. and it creates, for ultrasonic reflection, a set of four numbers describing that reflection. These numbers, or features, are:

- $t_s^r(j)$ the time at which reflection j rises above noise threshold
- $p_a^r(j)$ the peak amplitude of reflection j
- $t_p^r(J)$ the time at which reflection j peaks
- $t_e^r(j)$ the time at which reflection j falls below noise threshold

A further reduction of the processing data base occurs in a second stage, that of extracting the features of reflection envelopes from the features of reflections. This second stage proceeds as illustrated in Figure 5-25 and is controlled by the number of reflections, the capacity of envelope feature memory, the reflection peak amplitude (p_a^r) contours,

```
          Process Search for Saturation
                        :
                        V
                     j <- 1
                        :
                        V
.---------------------->
:                       :
:                       V          yes
:                 End-of-Data?   ----------> Exit
:                    no :
:                       V          no
:           pa(j)+|A/k| < 127?  -----------.
:                   yes :                  :
:                       V                  :
:           Mark Saturation as Detected    :
:                       :                  :
:                       V                  :
:                        <------------------
:                       :
:                       V
:                    j <- j+1
:                       :
 ------------------------
```

Figure 5-24. Saturation Monitoring

and by three time limits defining the minimum interenvelope gap and the minimum and maximum envelope width.

Referring to Figure 5-25, a brief tracing of the process flow is as follows:

- During initialization, the structure envelope feature memory is cleared and the memory holding the largest peak amplitude (P_{max}) and its time of occurrence (T_{max}) is reset to zero.

- If the POST-RETREAD mode is enabled, processing of tread reflections is done according to the TEST LOCATION mode set. If the TEST LOCATION is that of MIDLINE inspection, the reflection features are ignored until a reflection with a peak time greater than or equal to a time threshold is detected. This time threshold for assuring cleanliness of the midline tread reflections is dependent on TIRE TYPE and is selected from the Table 5-5(a) parameters stored in EEPROM. If the POST-RETREAD mode and SHOULDER TEST LOCATION are enabled, the porosity envelope feature memory is cleared and, until either it is filled or there are no more reflections detected in the porosity time window, reflection features will be transferred from the reflection features memory to the porosity envelope feature memory. The width of the porosity time window is controlled by two parameters dependent on TIRE TYPE. These parameters are a minimum, or near porosity time and a maximum, or far porosity time and, depending on TIRE TYPE, and are selected from the parameters of Tables 5-5(b) and (c) stored in EEPROM. Figure 5-25 illustrates how these windows are used. If the RETREAD MODE set is PRE these windowing stages are passed by.

- A demarcation time t_2 is computed equal to 1.875 times the start time $t_s^r(1)$ of the first reflection. This is to eliminate from consideration for largest peak P_{max} any reflections occurring at times during which second reflections can occur. Then, until the structure envelope feature memory is filled or until there are no more reflections detected, reflection features will be processed into envelope features. The factor 1.875 is intrinsic to the TQM firmware and can not be altered.

- The details of the following process are illustrated in Figure 5-25. If any remaining reflections are detected, the features of the envelope to be characterized are initialized by a default transfer of the features of the next reflection j into the envelope i features memory. Until the envelope characterization process ends, the envelope start time $t_s^e(i)$ is held constant, the envelope end time $t_e^e(i)$ is updated using the latest $t_e^r(j)$, and the envelope

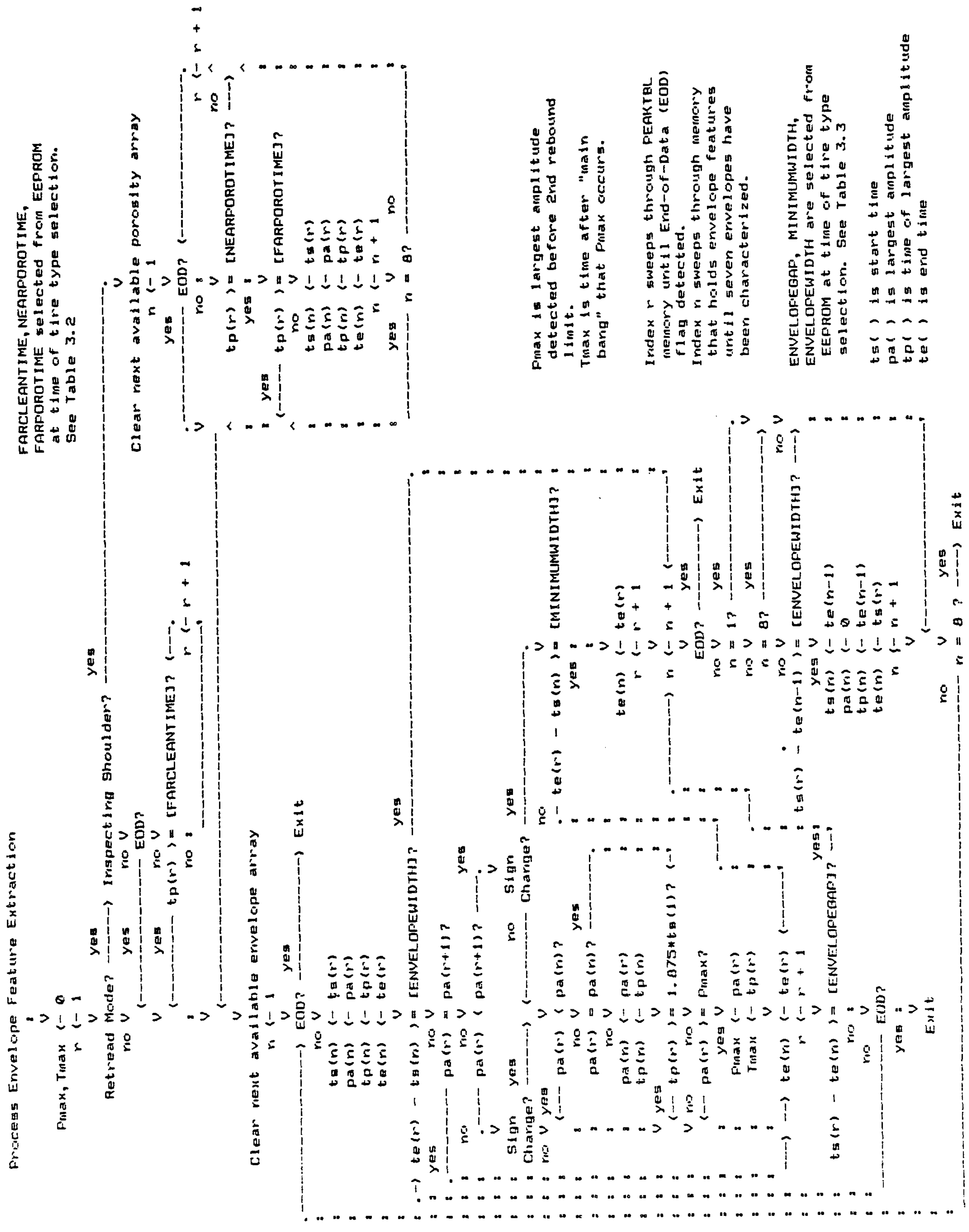


Figure 5-25. Envelope Feature Extraction Parameters

Table 5-5. Porosity Isolation Windows

LABEL	ADDRESS	DESCRIPTION
PSR-I-FCLNTIME	E80C	Passenger Steel-Belted 1
TTX-I-FCLNTIME	E84C	Truck Textile-Plied 1
TSR-I-FCLNTIME	E88C	Truck Steel-Belted 1
PSR-II-FCLNTIME	E8CC	Passenger Steel-Belted 2
TTX-II-FCLNTIME	E90C	Truck Textile-Plied 2
TSR-II-FCLNTIME	E94C	Truck Steel-Belted 2
GRP-FCLNTIME	E98C	Glass-Reinforced Plastic Block
RN-FCLNTIME	E9CC	Rubber/Nylon Block

(a) Maximum "Garbage" Time Limits

LABEL	ADDRESS	DESCRIPTION
PSR-I-NPORTIME	E80E	Passenger Steel-Belted 1
TTX-I-NPORTIME	E84E	Truck Textile-Plied 1
TSR-I-NPORTIME	E88E	Truck Steel-Belted 1
PSR-II-NPORTIME	E8CE	Passenger Steel-Belted 1
TTX-II-NPORTIME	E90E	Truck Textile-Plied 2
TSR-II-NPORTIME	E94E	Truck Steel-Belted 2
GRP-NPORTIME	E98E	Glass-Reinforced Plastic Block
RN-NPORTIME	E9CE	Rubber/Nylon Block

(b) Minimum Porosity Time Limits

LABEL	ADDRESS	DESCRIPTION
PSR-I-FPORTIME	E810	Passenger Steel-Belted 1
TTX-I-FPORTIME	E850	Truck Textile-Plied 1
TSR-I-FPORTIME	E890	Truck Steel-Belted 1
PSR-II-FPORTIME	E8D0	Passenger Steel-Belted 2
TTX-II-FPORTIME	E910	Truck Textile-Plied 2
TSR-II-FPORTIME	E950	Truck Steel-Belted 2
GRP-FPORTIME	E990	Glass-Reinforced Plastic Block
RN-FPORTIME	E9D0	Rubber/Nylon Block

(c) Maximum Porosity Time Limits

peak amplitude and peak time [$p_a^e(i)$, $t_p^e(i)$] are updated from [$p_a^r(j)$, $t_p^r(j)$] only if $p_a^r(j)$ is greater than any prior $p_a^r(j)$ since starting the envelope. During this search, P_{max} and T_{max} are also being updated if any $p_a^e(i)$ is found greater than P_{max}. This process stops once any $t_p^r(i)$ exceeds t_2, the second reflection limit. An envelope is closed by one of three conditions.

(1) if the difference between the latest $t_e^r(j)$ and $t_s^e(i)$ is greater than or equal to the maximum allowable width. This is closure by width.

(2) if the contour of peak reflection amplitudes inflects from negative slope to positive. This is closure by contour.

(3) if the difference between the next $t_s^r(j+i)$ and $r_e^r(j)$ is greater than or equal to the minimum allowable gap within an envelope. This is closure by gap.

Of course, closure will also occur preemptorily if no more reflections are detected. Closures by gap or width are controlled by parameters selected by tire type from EEPROM and listed in Table 5-6. Closure by contour is normally controlled by the profile of the data itself. However, in those unusual cases where the reflections from a single tire structure exhibit internal contours, a minimum envelope width threshold is invoked to assure that such odd tire structures are not represented by more than one envelope. In such cases, closure by contour will be disallowed if the resulting envelope width is less than the minimum width value. The active minimum width is selected by tire type from values stored in EEPROM and listed in Table 5-6(b).

At the termination of the envelope feature extraction process, a set of envelopes will each be characterized by $t_s^e(j)$, $p_a^e(j)$, $t_p^e(j)$, $t_e^e(j)$ such that $t_s^e(i) = t_s^r(j)$, $t_e^e(i) = t_e^r(j+k)$, $p_a^e(i)$ is the largest $p_a^r(m)$ in the interval $j \le m \le j+k$, and $t_p^e(i)$ is the corresponding $t_p^r(m)$.

The influence of the envelope width and the interenvelope gap time limits on the envelope closure process can be understood more easily by studying Figures 5-26 and 5-27. Both figures present a schematic representation of how reflection features (a) from a tire with two steel belts (A,B) and body plies (C) can be combined into envelopes (b, c, d). Figure 5-26(b) illustrates how the reduction of the width limit can close envelopes too soon, yielding erroneous time and peak amplitude values for this and subsequently closed envelopes. Similarly, making the width limit too large can combine reflections from distinct casing structures into one envelope (Figure 5-26(d)) yielding other errors in peak amplitude, times, and tabulation.

In the case illustrated, three casing structures (A, B, C) are transformed into three envelopes, but poor adjustment of the envelope width

Table 5-6. Envelope Feature Extraction Parameters

LABEL	ADDRESS	DESCRIPTION
PSR_I_ENVGAP	E806	Passenger Steel-Belted 1
TTX_I_ENVGAP	E846	Truck Textile-Plied 1
TSR_I_ENVGAP	E886	Truck Steel-Belted 1
PSR_II_ENVGAP	E8C6	Passenger Steel-Belted 2
TTX_II_ENVGAP	E906	Truck Textile-Plied 2
TSR_II_ENVGAP	E946	Truck Steel-Belted 2
GRP_ENVGAP	E986	Glass-Reinforced Plastic Block
RN_ENVGAP	E9C6	Rubber/Nylon Block

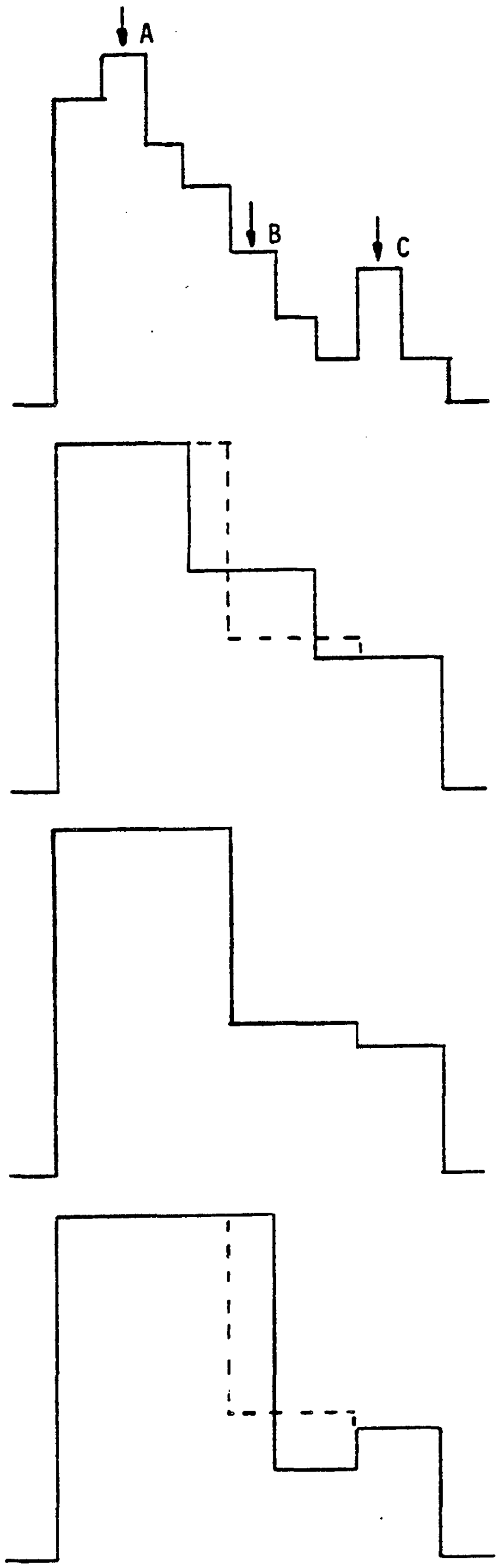
(a) Interenvelope Gap

LABEL	ADDRESS	DESCRIPTION
PSR_I_WIDTHMIN	E808	Passenger Steel-Belted 1
TTX_I_WIDTHMIN	E848	Truck Textile-Plied 1
TSR_I_WIDTHMIN	E888	Truck Steel-Belted 1
PSR_II_WIDTHMIN	E8C8	Passenger Steel-Belted 2
TTX_II_WIDTHMIN	E908	Truck Textile-Plied 2
TSR_II_WIDTHMIN	E948	Truck Steel-Belted 2
GRP_WIDTHMIN	E988	Glass-Reinforced Plastic Block
RN_WIDTHMIN	E9C8	Rubber/Nylon Block

(b) Narrow Envelope Limit

LABEL	ADDRESS	DESCRIPTION
PSR_I_ENVWIDTH	E80A	Passenger Steel-Belted 1
TTX_I_ENVWIDTH	E84A	Truck Textile-Plied 1
TSR_I_ENVWIDTH	E88A	Truck Steel-Belted 1
PSR_II_ENVWIDTH	E8CA	Passenger Steel-Belted 2
TTX_II_ENVWIDTH	E90A	Truck Textile-Plied 2
TSR_II_ENVWIDTH	E94A	Truck Steel-Belted 2
GRP_ENVWIDTH	E98A	Glass-Reinforced Plastic Block
RN_ENVWIDTH	E9CA	Rubber/Nylon Block

(c) Maximum Envelope Width



(a) Extracted Reflections

(b) xxxENVWIDTH too small

(c) xxxENVWIDTH properly adjusted

(d) xxxENVWIDTH too large

Figure 5-26. Envelope Feature Extraction Dependance on ENVELOPEWIDTH

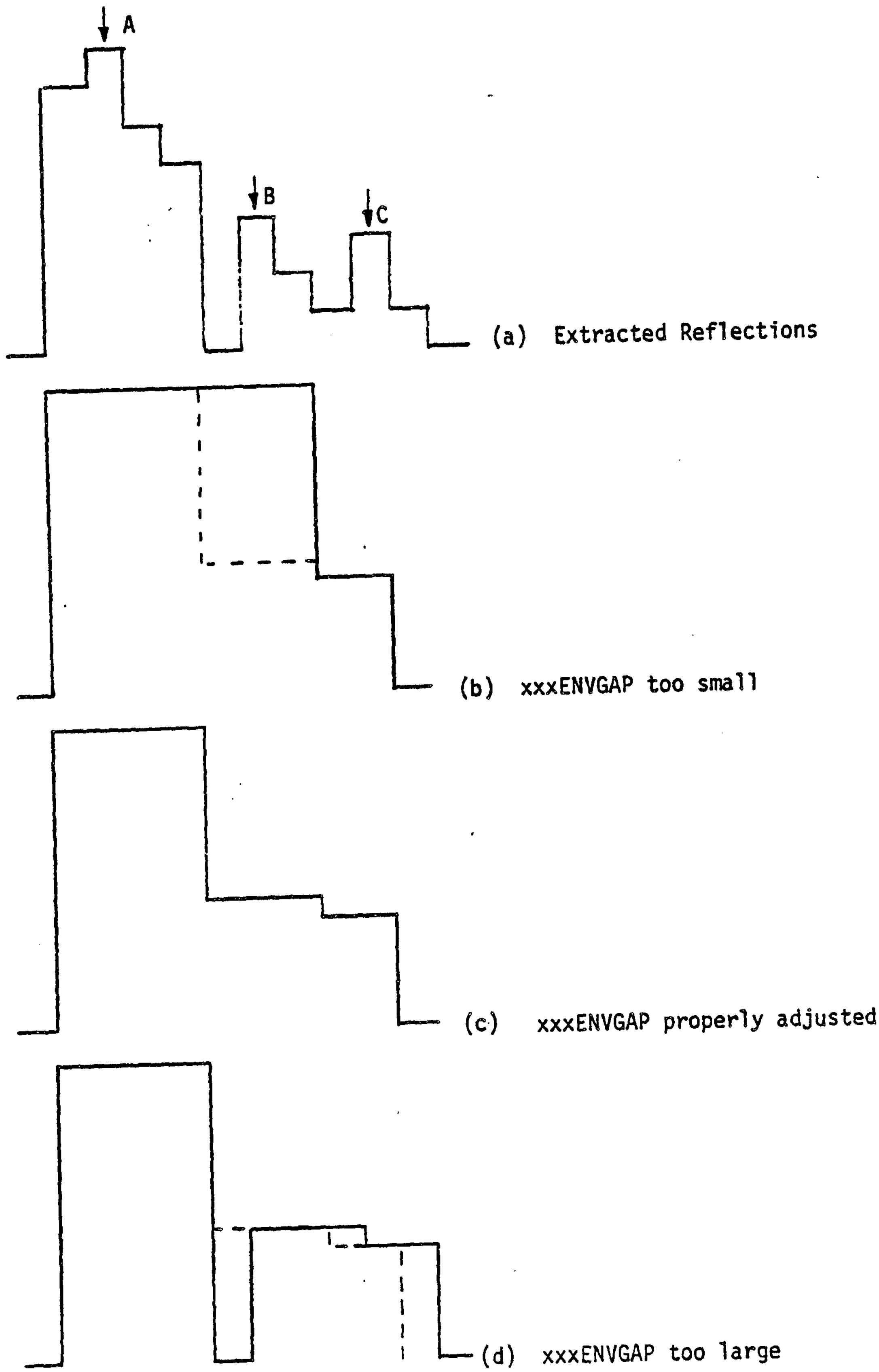


Figure 5-27. Envelope Feature Extraction Dependance on ENVELOPEGAP

parameter causes errors in the amplitude measure of the second steel belt. Figure 5-27 shows the errors that can result from improperly adjusted interenvelope gap time limits. Too small a time limit can cause the reflections from distinct casing structures to be combined into one envelope (Figure 5-27(b)). Similarly, too large a gap limit can engender the creation of unwarranted "null" envelopes which yield tabulation and amplitude errors (Figure 5-27(d)).

In the case illustrated, three casing structures (A, B, C) are transformed into two or four envelopes depending on how the interenvelope gap parameter is adjusted. In the two-envelope case, the second steel belt is completely merged into the first envelope along with the first steel belt. In the four-envelope case, a "null" envelope has been interposed between the first and second steel belt envelopes which will result in a serious misclassification by the CPU.

5.3.5. Saturation Disposition. If the TQM is in the GRP or B/M maintenance mode, the saturation condition flag is ignored and TQM operation continues normally. This is allowed because signal saturation is inherent in the materials monitored in these maintenance modes and such saturation in no way degrades the validity of the information processing. The saturation condition flag is also ignored if the TQM is in a textile TIRE TYPE inspection mode (TRUCK/T 1 or 2) since the saturated signal does not affect the information being processed. However, if the TQM is in one of the four steel-belted TIRE TYPE inspection modes (TRUCK/S 1 or 2, PASS/S 1 or 2), the set saturation condition flag may have an effect depending on the recent inspection history of the TQM, as illustrated in Figure 5-17.

If the saturation is detected after the TIRE TYPE has been selected and gain calibrated and before the first analysis has been accomplished (by pushing the ANALYZE button and observing an inspection result), the TQM will be forced into a calibration request state signaled by a flashing "-CAL" message. When the operator responds by performing a TEST CAL gain calibration, the TQM will behave as described in par. 5.5.3. However, with the saturation condition flag set, an array of calibration setpoints different from those portrayed in Table 5-3(a) will be accessed. These setpoints will be typically lower in value to alleviate the originating saturation problem. Table 5-3(b) lists these alternate setpoints as they are stored in the EEPROM. Until a tire type is re-selected or the TQM is turned off, these alternate setpoints will be enabled.

Because the TQM can automatically detect saturation and change state accordingly, and because the GPP reference block normally reflects saturated signals, the operator must set the TEMP display mode before placing the transducer on the reference block for TEST calibration of a tire type. This defeats ultrasonic acquisition and, hence, saturation detection and its subsequent effects. The operator thereby assures that the simple act of gain calibration will not switch the TQM to an unwanted setpoint value. Conversely, the operator must also remove the transducer from the reference block before selecting another display mode.

On the other hand, if an analysis has been successfully accomplished since the last gain calibration, or if the TQM is already calibrated to the alternate gain setpoint of the TIRE TYPE selected, the saturation condition flag will be ignored. The philosophy behind this feature is that if a subset of tires of the selected TIRE TYPE exhibits a higher reflectivity than the usual tires of the TIRE TYPE selected, and if a group of such high-reflectivity tires is being inspected, then the first tire to be inspected from this group is likely to be representative of the group. Its high reflectivity will create the saturation which, in turn, will trigger the TQM to go into a state more consistent with the inspection of this group of tires. If, on the other hand, the first tire to be inspected is representative of a group of normally reflecting tires, the TQM will not detect saturation and will maintain the principal gain setpoint of the TIRE TYPE selected. It will also ignore subsequent saturation conditions until a future selection of TIRE TYPE, in effect presuming that such saturations are not representative of the tire group being inspected.

5.3.6. Temperature/Thickness Compensations. After reflection envelope features have been extracted, the values of the maximum amplitudes $p_a^e(i)$ are next adjusted to standard conditions. This is necessary to compensate for the attenuation of ultrasound with distance of travel through rubber and to compensate for attenuation and velocity variations with temperature in rubber. The compensation factor imposed is selected as a function of the value of the last calibrated tread temperature and of the depth of each reflection envelope as measured by the times $t_p^e(i)$ at which each reflection was acquired. Because the velocity of ultrasound varies significantly with temperature, these times must be corrected to a standard temperature value. This is:

$$t_p^e(i) = t_p^e(i) \cdot \left[1 + \frac{\text{SHIFTPERTEMP}}{2.125}(70 - T)\right] \quad i = 1, \ldots, 7$$

The constant values 70 and 2.125 are respectively, the standard temperature (°F) and its associated inverse velocity in rubber (sec/(1/16 inch)). The parameter SHIFTPERTEMP is stored in EEPROM at E7EA and is alterable using techniques described in par. 5.7.2.3. Its present value is hexadecimal 28, representing a velocity variation with temperature of 0.065 us/in/°F.

The times thus corrected and the calibrated temperature serve as indices cross-referencing a look-up table of peak amplitude compensating factors. The TQM is delivered with a set of three preprogrammed temperature/thickness compensation tables in EEPROM, one table for each tire type. Selection of a TIRE TYPE automatically selects the appropriate compensation table. The entries in these tables can be altered by procedures presented in par. 5.7.2.3.

Thus, as part of its pattern recognition processing, the TQM executes simple multiplicative compensations of ultrasonic reflection amplitudes for a common temperature and for respective temperature-compensated depths. The processing logic is outlined in Figure 5-28. The envelopes are now ready to be isolated by the application of appropriate "windows."

5.3.7. Windowing. After all the maximum amplitudes of reflection envelopes have been compensated for temperature and respective depth, the envelopes' features are searched for time discrepancies. This is done to prevent features of multiply-rebounding ultrasonic reflections from contaminating the feature sample. It also helps to exclude features from the transducer ringout and, for shoulder inspections, to separate tread and casing features. This process of time "windowing" is illustrated in Figure 5-29 and creates three TIRE TYPE-dependent windows:

- Passenger steel radial $(T_{max}-5us) \leq t < (T_{max}+10us)$
- Truck steel radial $(T_{max}-10us) \leq t < (T_{max}+12us)$
- Truck textile bias $10us \leq t < (t_p^e(a) + 14us)$

Referring to Figure 5-29 the procedural dependence on tire type is obviously the existence of two entry points and, less obviously, the presence of the parameters NEARSTRUTIME and FARSTRUTIME. The values of these two parameters stored in RAM are selected at time of TIRE TYPE selection from all the tire-type-dependent values stored in EEPROM (Table 5-7).

The parameter FARSTRUTIME is always used as an offset from some critical peak time, whereas the use of the parameter NEARSTRUTIME is either an offset or an absolute limit depending on whether the tire is of steel or textile construction respectively. The critical peak time is also dependent on tire type. For textile tires, it is the time $t_p^e(a)$ of peak amplitude $p_a(a)$ of the first reflection envelope P_a in the window. For steel tires, it is the time T_{max} of the largest amplitude P_{max} envelope extracted as discussed in par. 5.3.4. Therefore, as illustrated in Figure 5-29 for all tire types, those envelopes with peak times less than the type-dependent minimum structural time are eliminated from consideration.

The notation P_a, P_b, ...P_g refers to the seven sets of envelope features possible with each P_i referring to the set of features $t_s^e(i)$, $p_a^e(i)$, $t_p^e(i)$, $t_e^e(i)$ of envelope i. Once those envelopes occurring earlier than the minimum time are eliminated, envelopes with peak times larger than the type-dependent maximum structural time are sought. Note that for steel tires a decision is made as to whether the computed offset time or the second reflection time is to be used as the maximum.

No such decision is made for textile tires due to the necessity of detecting at least two envelopes for precise classification, even if the second envelope is a second reflection of the first. When envelopes beyond the latest structural time are detected, they are eliminated and the envelopes, thus "windowed," have been prepared for classification.

```
Process Amplitude and Time Compensation
                  :
                  V              no
      Inspecting Shoulder? --------.
            yes :                  :
                V                  :
  Compensate porosity reflections  :
        (Flowchart 3.7a)           :
                :                  :
                V                  :
                 <-----------------'
                V
  Compensate structure envelopes
        (Flowchart 3.7a)
                :
                V
              Exit
```

```
        Compensate xxx xxx
                  :
                  V
            j <- 1
                  V
 .----------->
 :                V
 :     ts(j)  <- ts(j)*(2.125+[SHIFTPERTEMP]*(70-T))/2.125
 :     tp(j)  <- tp(j)*(2.125+[SHIFTPERTEMP]*(70-T))/2.125
 :     te(j)  <- te(j)*(2.125+[SHIFTPERTEMP]*(70-T))/2.125
 :                V
 :     id(j)  <- [tp(j)/2.125]-4
 :        iT  <- (T-30)/5
 :                V
 :        Cf  <- F(id(j),iT)
 :        Cg  <- F(id(j),iT+1)
 :                V
 :        Cf  <- Cf + ((Cg - Cf)*(T - 85*iT)/5)
 :                V
 :     pa(j)  <- BCD[Cf*pa(j)]
 :                V
 :          j <- j + 1
 :      no        V
 ---------- j = 8?
        yes :
            V
          Exit
```

Figure 5-28. Amplitude and Time Compensation

```
                  .------- Process Windowing ------.
                  :                                :
                  V                                V
          TEXTILE TIRE ENTRY                 STEEL TIRE ENTRY
                  V                                V
               j <- 1                           j <- 1
              T1 <- [NEARSTRUTIME]             T1 <- Tmax - [NEARSTRUTIME]
                  V                                V
                   <------------.     .------------>
          yes     V             :     :            V      yes
        .----- tp(a) >= T1?     :     :     tp(a) >= T1? -----.
        :      no :             :     :         no :          :
        :         V             :     :            V          :
        :     Pa <- Pb          :     :        Pa <- Pb       :
        :         :             :     :            :          :
        :     Pf <- Pg          :     :        Pf <- Pg       :
        :     Pg <- 0           :     :        Pg <- 0        :
        :         V             :     :            V          :
        :      j <- j + 1       :     :         j <- j + 1    :
        :         V      no     :     :       no   V          :
        :       j = 8 ? --------'      --------- j = 8 ?      :
        :     yes :                           yes  :          :
        :         V                                V          :
        :       Exit                             Exit         :
        :                                                     :
        :                                            .---------'
        V                                            V
    Th <- tp(a) + [FARSTRUTIME]                 Th <- Tmax + [FARSTRUTIME]
        :                                            :
        :                                   no       V
        :                          .---------- Th >= 2*tp(a)?
        :                          :            yes  :
        :                          :                 V
        :                          :            Th <- 2*tp(a)
        :                          V                 :
         -------------------------> <----------------'
                                   V
FARSTRUTIME,        .-------------->
NEARSTRUTIME        :              V        yes
 selected from      :       tp(i) >= Th? ----------.
 EEPROM at time     :          no  :               V
 of tire type       :              :           Pi <- 0 <-------.
 selection.         :              V               V           :
 See Table 3.4      :           i <- i + 1      i <- i + 1     :
                    :           j <- j + 1      j <- j + 1     :
                    :         no   V               V     no    :
Pk represents        ----------- j = 8 ?         j = 8 ? ------'
 set of features              yes  :            yes :
 ts(k),pa(k),tp(k),te(k)           V                V
 of unclassified envelope k.     Exit             Exit

 k=a is set describing earliest envelope,        i,j are loop indices
 k=b is set describing next later envelope,
 etc.
```

Figure 5-29. Windowing Flowchart

Table 5-7. Structure Isolation Windows

LABEL	ADDRESS	DESCRIPTION
PSR_I_NSTRTIME	E812	Offset before Pmax (Passenger Steel-Belted 1)
TTX_I_NSTRTIME	E852	Limit before Pa (Truck Textile-Plied 1)
TSR_I_NSTRTIME	E892	Offset before Pmax (Truck Steel-Belted 1)
PSR_II_NSTRTIME	E8D2	Offset before Pmax (Passenger Steel-Belted 2)
TTX_II_NSTRTIME	E912	Limit before Pa (Truck Textile-Plied 2)
TSR_II_NSTRTIME	E952	Offset before Pmax (Truck Steel-Belted 2)
GRP_NSTRTIME	E992	Offset (Glass-Reinforced Plastic Block)
RN_NSTRTIME	E9D2	Offset (Rubber/Nylon Block)

(a) Minimum Peak Times ("NEAR STRUCTURE TIME")

LABEL	ADDRESS	DESCRIPTION
PSR_I_FSTRTIME	E814	Offset after Pmax (Passenger Steel-Belted 1)
TTX_I_FSTRTIME	E854	Limit after Pa (Truck Textile-Plied 1)
TSR_I_FSTRTIME	E894	Offset after Pmax (Truck Steel-Belted 1)
PSR_II_FSTRTIME	E8D4	Offset after Pmax (Passenger Steel-Belted 2)
TTX_II_FSTRTIME	E914	Limit after Pa (Truck Textile-Plied 2)
TSR_II_FSTRTIME	E954	Offset after Pmax (Truck Steel-Belted 2)
GRP_FSTRTIME	E994	Offset (Glass-Reinforced Plastic Block)
RN_FSTRTIME	E9D4	Offset (Rubber/Nylon Block)

(b) Maximum Peak Times ("FAR STRUCTURE TIME")

5.3.8. Envelope Classification. After feature extraction, compensation of amplitudes for temperature and thickness, and windowing, the reflection envelopes are next classified into tire structure categories according to rules which have been derived from past observations of the structures. The basic structure categories are bondline, body plies, and liner. When steel-belted tires are inspected, the categories of first belt and second belt are added. In all the discussions that follow, textile tire belts are referred to as top body plies. The term "belt" is reserved for steel belts which are treated as a special case in the TQM.

The structure categories obviously vary with tire type, but so do the classification rules. The following is a summary of these rules:

- Steel Radial Tires:

  -$p_a^e(a) \geq 0.6\ p_a^e(b)$ P_a is first steel belt, etc.

  -$p_a^e(a) < 0.6\ p_a^e(b)$ P_a is bondline, etc.

- Textile Bias Tires:

  -Single envelope/single superenvelope:
  -Pre-retread:

$10.0us > t_p^e(a)$	P_a is bondline
$30.0us > t_p^e(a) \geq 10.0us$	P_a is body plies
$t_p^e(a) \geq 30.0us$	P_a is body plies

- Post-retread:

$29.9us > t_p^e(a)$	P_a is bondline
$44.0us > t_p^e(a) \geq 29.9us$	P_a is body plies
$t_p^e(a) \geq 44.0us$	P_a is liner

- Multi-envelope/multi-superenvelope (≤ 2):

$5.6us > t_p^e(b) - t_p^e(a)$	P_a is bondline, P_b is body plies, etc.
$8.2us > t_p^e(b) - t_p^e(a) \geq 5.6us$	execute single envelopes/s.s. tests
$13.0us > t_p^e(b) - t_p^e(a) \geq 8.2us$	P_a is body plies, P_b is liner, etc.
$t_p^e(b) - t_p^e(a) \geq 13.0us$	P_a is bondline, P_b is liner, etc.

- Multi-envelope/multi-superenvelope (≥ 3):

$$t_p^e(c) - t_p^e(a) + M > 2[t_p^e(b) - t_p^e(a) \geq t_p^e(c) - t_p^e(a) - M$$

multiple ringing detected, execute single envelope/s.s. tests

As before, indices a, b, and c refer to the first, second, and third isolated unclassified envelopes and P_i refers to the sets of envelope i features of which $p_a^e(i)$ is the peak amplitude and $t_p^e(i)$ is its associated time. In the case of textile tire inspection, the creation of superenvelopes is an extra stage of feature extraction and will be discussed more fully in par. 5.3.8.2.

5.3.8.1. Classification of steel radial tire envelopes. Experience has shown the ultrasonic reflection envelope classification to be simply based on the relative amplitudes of the two first-detected signal envelopes. The algorithm assumes the first steel belt will always be detected and decides the classification on the results of a measurement for bondline presence. This measurement is conducted using the parameter C1 in a way such that if the first-second reflection amplitude ratio is equal to or greater than C1, the first envelope is classified as a first steel belt reflection and the second envelope is classified as a second steel belt reflection. If the amplitude ratio is less than C1, the first envelope will be classified as a bondline reflection and the second envelope will be classified as a first steel belt reflection. This is equivalent to saying that bondlines in steel-belted tires reflect less ultrasonic energy than belts by a factor of C1. Mathematically, this is expressed as:

$p_a^e(a) \geq C_1 . p_a^e(b)$	classifies Pa as steel belt 1, P_b as steel belt 2, etc.
$p_a^e(a) < C_1 . p_a^e(b)$	Classifies Pa as bondline P_b as steel belt 1, etc.

The value of parameter C1 is selected at the time of TIRE TYPE from values stored in EEPROM. Each is alterable by procedures discussed in par. 5.7.2.3. Figure 5-30 illustrates the logic flow of the steel tire classification process.

5.3.8.2. Classification of textile tire envelopes. Experience has shown the ultrasonic reflection envelope classification to be based on the separation in time between adjacent envelopes. There are three textile tire classification categories (i.e., bondline, body plies, and liner) and three time separation limits are used for each textile tire type. These are stored in EEPROM and are alterable using procedures discussed in par. 5.7. Their labels are LOWGAPLIMIT$_{-n}$, MIDGAPLIMIT$_{-n}$, and HIGHGAPLIMIT$_{-n}$ and their address and values are listed in Table 5-7. The operator should remember that after altering the EEPROM values, he must reselect the desired TIRE TYPE to activate them. (See Figure 5-31.)

```
                                   Process Envelope Classification
                                              :
                                              V
                                         Ce  <- count of envelopes
                                              :
                                              V     yes
                                          Ce=0? ----------------.
                                         no  :                  :
                                              V             no   :
                                  pa(a)  >= C1*pa(b)? ---.       :
                                      yes :                 :    :
                                              V             :    :
                                         P7  <- 0           :    :
P1 is bondline category                  P6  <- 0           :    :
P2 is 1st belt category                  P5  <- Pd          :    :
P3 is 2nd belt category                       :             :    :
P4 is body ply category                  P2  <- Pa          :    :
P5 is liner category                     P1  <- 0           :    :
                                              V             V    :
Pa through Pd are sets of                      <------------- <--'
 unclassified envelope features.              :
                                              V
                                            Exit
```

Figure 5-30. Steel-Belted Tire Classification Algorithm

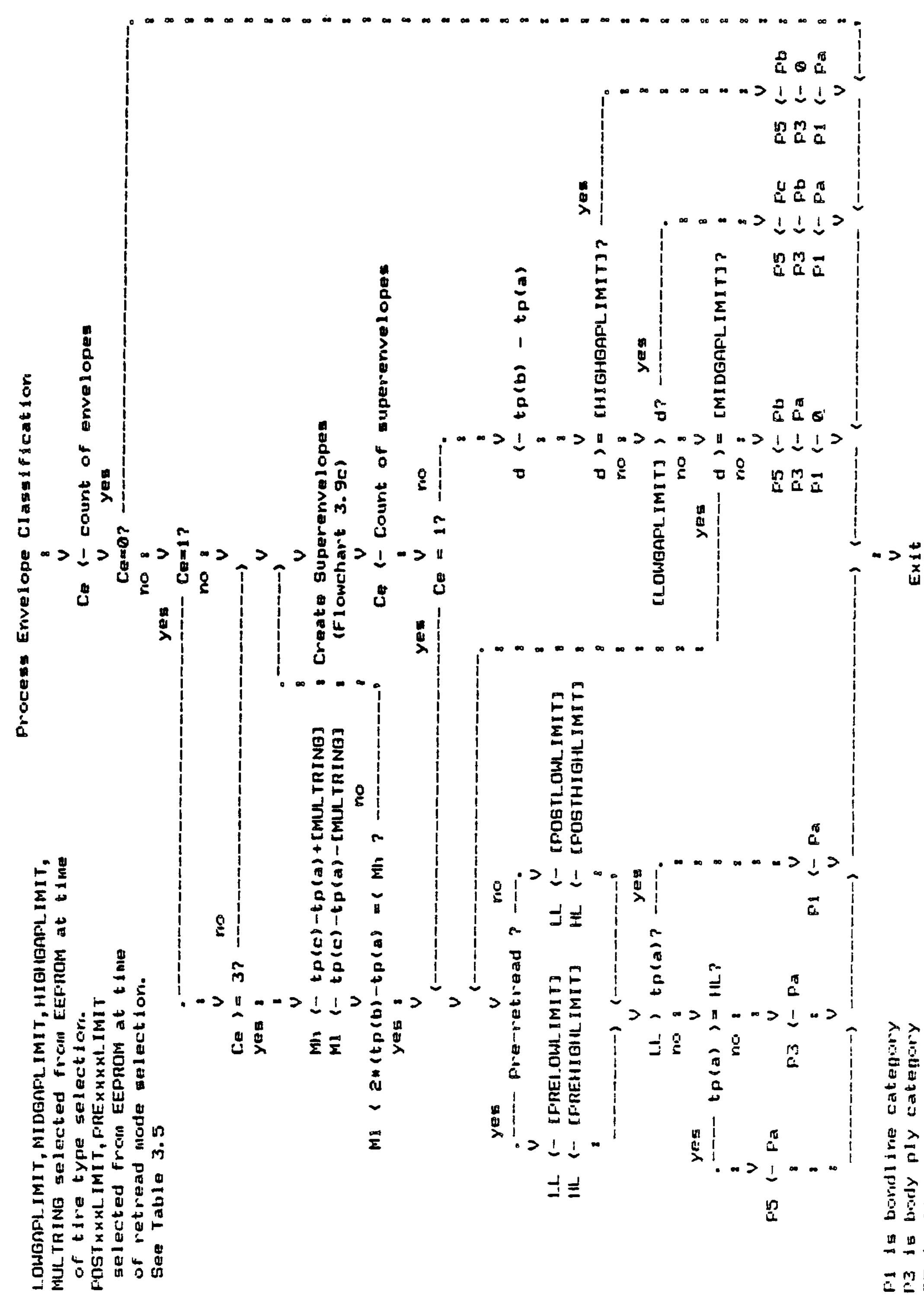


Figure 5-31. Textile-Plied Tire Classification Algorithm

Because textile tires tend to ultrasonically exhibit less dense structure than steel-belted tires, two extra considerations must be made. First there exists the possibility that only one envelope will be detected and no separation time can be computed. Second, it is possible that a single-body ply structure may be represented by more than one envelope with a consequent misclassification of structures. The single-envelope possibility is handled by the TQM processing a special case when it detects only one envelope. This special case decides the classification of the single envelope by how deep under the tread surface it lies. A bondline/plies limit and a plies/liner limit are used and the values set depend on the RETREAD MODE set during inspection. Table 5-7 lists the two pair of values stored in EEPROM and labeled $PRELOWLIMIT_{-n}$ through $POSTHIGHLIMIT_{-n}$. These values are also alterable by procedures discussed in par. 5.7.2.3., but the operator must remember to reset the desired RETREAD MODE after alteration to activate the new value(s).

The TQM handles the possibility of multiple envelopes from one structure by always generating "superenvelopes." This process is conceptually similar to the envelope-generating process discussed in par. 5.3.4. and is nothing more than the extraction of "superenvelope" features from envelope features when adjacent envelope start and end times are separated by less than a required amount (see Figure 5-32). This amount is labeled $TEXTNULLGAP_{-n}$, and is alterable in EEPROM by procedures presented in par. 5.7. Its address and values are listed in Table 5-8. If only one superenvelope is generated, the TQM proceeds to the single-envelope process discussed above. Otherwise, classification is done by time separation between superenvelopes. If multiple ringing is still detected at this point, the algorithm allows a single-envelope detection using the first envelope. Mathematically, these rules are expressed below:

- Single Envelope/Superenvelope:
- Pre-Retread Mode:

$\text{PRELOWLIMIT} > t_p^e(a)$ — P_a is bondline (P_1)

$\text{PREHIGHLIMIT} > t_p^e(a) \geq \text{PRELOWLIMIT}$ — P_a is body plies (P_3)

$t_p^e(a) \geq \text{PREHIGHLIMIT}$ — P_a is liner (P_5)

- Post-Retread Mode:

$\text{POSTLOWLIMIT} > t_p^e(a)$ — P_a is bondline (P_1)

$\text{POSTHIGHLIMIT} > t_p^e(a) \geq \text{POSTLOWLIMIT}$ — P_a is body plies (P_3)

$t_p^e(a) \geq \text{POSTHIGHLIMIT}$ — P_a is liner (P_5)

- Multiple Superenvelope:

```
                  Creat Superenvelopes
                                :
                                V
                           n  <- 1
                           s  <- 1
                                :
                                V
                                 <------------------------------.
                                V                                :
                    ts(s)  <- ts(n)                              :
                    pa(s)  <- pa(n)                              :
                    tp(s)  <- tp(n)                              :
                    te(s)  <- te(n)                              :
                                :                                :
                                V                                :
 .------------------->                                           :
 :                              V                                :
 :                         n <- n + 1                        s <- s + 1
 :                              :                                ^
 :                              V    yes                         :
 :                           n = 8? --------> Return to          :
 :                          no  :            Calling routine     :
 :                              :                                :
 :                              V                  yes           :
 :        te(s) - ts(n)  >= [TEXTNULLGAP]? ---------------------'
 :                          no  :
 :            no                V
 :    .--------- pa(n)  >= pa(s)?     TEXTNULLGAP selected from EEPROM
 :    :              yes :             at time of tire type selection.
 :    :                  V             See Table 3.5
 :    :        pa(s)  <- pa(n)
 :    :        tp(s)  <- tp(n)        ts( ) is start time
 :    :                  :            pa( ) is largest amplitude
 :    :                  V            tp( ) is time of largest amplitude
 :    -------> te(s)  <- te(n)        te( ) is end time
 :                       :
 -----------------------'             Index n for envelopes
                                      Index s for superenvelopes
```

Figure 5-32. Superenvelope Feature Extraction

Table 5-8. Truck Textile-Plied Tire Classification Parameters

LABEL	ADDRESS	DESCRIPTION
PRELOWLIMIT	EA40	PRE-RETREAD depth to Body Ply
PREHIGHLIMIT	EA42	PRE-RETREAD depth to Liner
POSTLOWLIMIT	EA44	POST-RETREAD depth to Body Ply
POSTHIGHLIMIT	EA46	POST-RETREAD depth to Liner
LOWGP LIMIT	EA48	Minimum Bondline-Ply Peak Separation
MIDGAPLIMIT	EA4A	Minimum Ply-Liner Peak Separation
HIGHGAPLIMT	EA4C	Maximum Ply-Liner Peak Separation
TEXTNULLGAP	EA4E	Gap Limit

(a) TRUCK/T 1 TIRES

LABEL	ADDRESS	DESCRIPTION
PRELOWLIMIT_2	EB00	PRE-RETREAD depth to Body Ply
PREHIGHLIMIT_2	EB02	PRE-RETREAD depth to Liner
POSTLOWLIMIT_2	EB04	POST-RETREAD depth to Body Liner
POSTHIGHLIMIT	EB06	POST-RETREAD depth to Liner
LOWGP LIMIT_2	EB08	Minimum Bondline-Ply Peak Separation
MIDGAPLIMIT_2	EB0A	Minimum Ply-Liner Peak Separation
HIGHGAPLIMT_2	EB0C	Maximum Ply-Liner Peak Separation
TEXTNULLGAP_2	EB0E	Gap Limit

(b) TRUCK/T 2 TIRES

LOWGAPLIMIT $> t_p^e(b) - t_p^e(a)$	P_a is bondline (P_1); P_b is body plies (P_3)
MIDGAPLIMIT $> t_p^e(b) - t_p^e(a) \geq$ LOWGAPLIMIT	execute test above
HIGHGAPLIMIT $> t_p^e(b) - t_p^e(a) \geq$ MIDGAPLIMIT	P_a is body plies (P_3); P_b is liner (P_5)
$t_p^e(b) - t_p^e(a) \geq$ HIGHGAPLIMIT	P_a is bondline (P_1); P_b is liner (P_5)

5.3.9. Storage and Quality Analysis. The discussion to this point has been of TQM action to maintain a tread depth or quality number display updated at a 3-Hz rate. Automatic analysis of the quality of the inspected tire is done by saving three to five different sets of envelope features using the STORE operation and then commencing the analysis using the ANALYZE operation. The analysis first checks all the STOREd envelope feature tables for time and amplitude consistency and, if enough consistent tables exist, they are combined into one composite table upon which a variety of tests are performed to assess tire quality. Otherwise, the TQM requests more STORE operations.

5.3.9.1. Saving envelope features. When in the QUALITY display mode the inspector is satisfied that he is receiving a stable, representative signal, he may save the envelope features of that signal by pressing the STORE button. The TQM will then save the set of envelope features extracted at the time of its receipt of the STORE command (see Figure 5-33). Upon completion of the save, the STORE LED will be turned on for 1 second. Up to five such saves can be made and, for good sampling, it is recommended that at least three be made. If more than five saves are made, only the latest five features sets will be analyzed.

5.3.9.2. Majority analysis. When the inspector depresses the ANALYZE key, the accept/reject test series appropriate to the selected tire type will commence. The first step is a check for sampled data consistency. The TQM compares each sample with the other two to four to confirm the presence of a common pattern of envelope features among them. Any sample exhibiting a categorized envelope whose peak amplitude is sufficiently different from the peak amplitudes of identically categorized envelopes for a majority of other samples is removed from the sample population because of amplitude inconsistency. Likewise, any sample with a classified envelope whose time of peak occurrence does not lie between the start and end times of identically classified envelopes for a majority of other samples is removed from the sample population due to a lack of time similarity. This process, referred to as "majority analysis," is summarized in Figure 5-34. If less than three samples survive this examination, the TQM will display the message:

```
                 Process STORE Command
                           :
                           V                         yes
    Is Display Held With ANALYZE Result? --------> Exit
                        no :
                           V
      STORELEDCLOCK <- 3
           Turn on STORE led
                           :
                           V            no
                Listings Enabled? ----------.
                       yes :                 :
                           V                 :
                 Enable STORE listing        :
                           :                 :
                           V                 :
                            <----------------'
                           :
                           V
   Advance Structure Cyclic Array Pointer
   Advance Porosity Cyclic Array Pointer
    Lock in Latest P1,P2,P3,P4,P5,P6,P7
                           :
                           V            yes
                  TABLECOUNT = 5? -------------------> Exit
                        no :
                           V
            TABLECOUNT <- [TABLECOUNT] + 1
                           :
                           V
                          Exit
```

Figure 5-33. STORE Command Execution

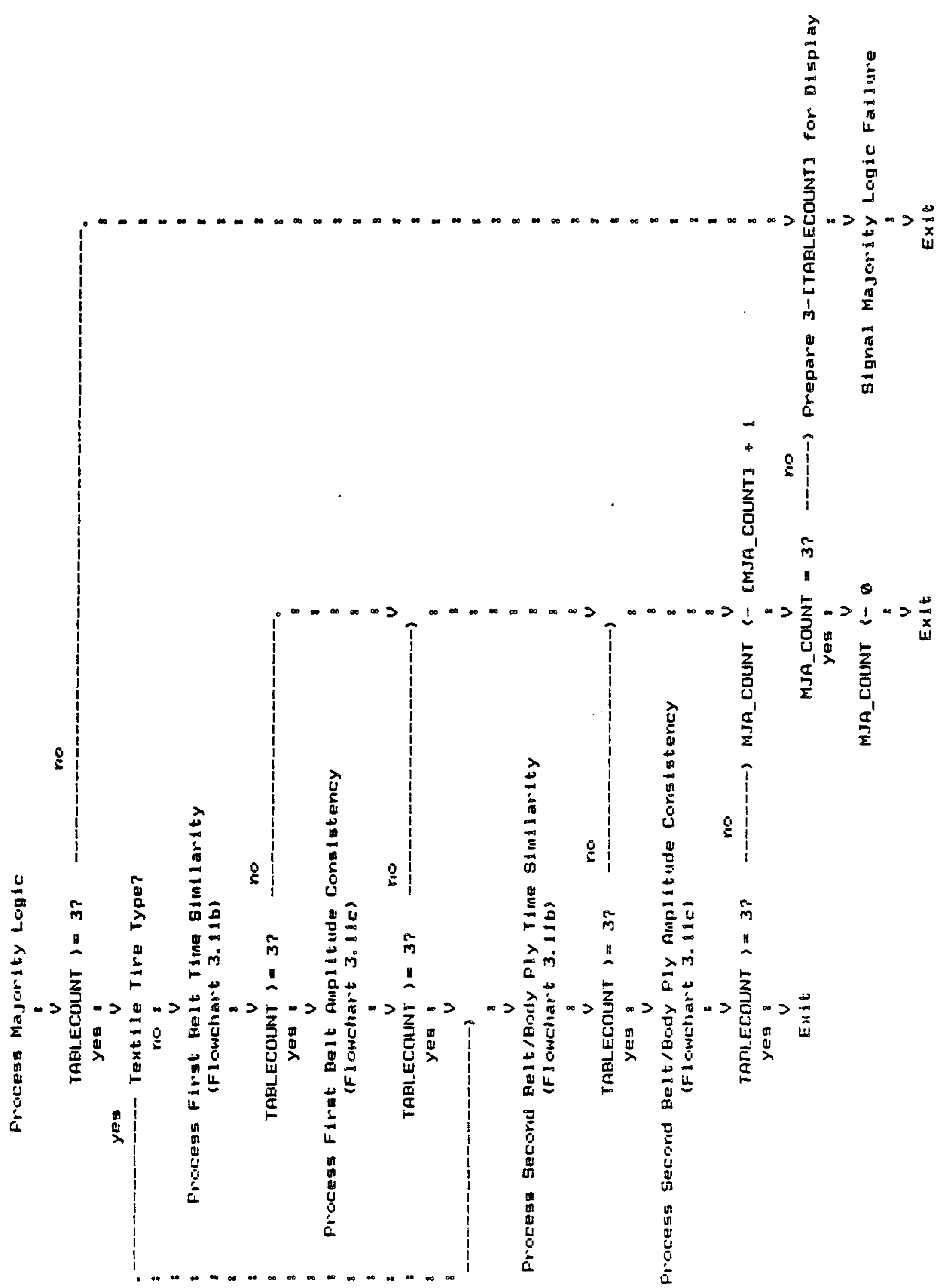


Figure 5-34. Majority Analysis Logic

"n Add"

where n is the number of additional samples required to bring the STOREd complement up to the minimum of three samples. This display will hold with a flashing ANALYZE LED until the operator pushes the ANALYZE button (see Figure 5-35). The operator can then proceed to STORE more samples. If the TQM cannot detect three or more consistent samples after more than two tries, it will proceed with an analysis based on the surviving samples. Of course, if three or more samples survive any "majority analysis," the inspection analysis will proceed as described below.

5.3.9.3. Amplitude averaging. The next analysis step is a computation of the average value of the maximum amplitude for each categorized reflection envelope. If, during this computation, a flag is sensed indicating acquisition of data while the TQM had a stored temperature value less than 30 ^{o}F or greater than 115 ^{o}F, the analysis will abort and the OUT-OF-TEMP LED will light. Otherwise, the TQM proceeds with peak amplitude processing (see Figures 5-36 and 5-37).

5.3.9.4. Amplitude processing. After classification, storage, and averaging, the envelope peak amplitudes are measured in various ways to detect patterns characteristic of known types of tire flaws. The flaw characterization rules have been derived from past observations of tire structures by experts in the ultrasonic inspection of tires. The basic flaw categories are poor bonding, separation or degradation of the body plies, and porosity. When inspecting steel-belted tires, the categories of first and second belt separation must be added. The flaw classification rules vary with tire type. In general, flaw classification in textile tires is based on comparisons of ultrasonic amplitudes with absolute threshold limits and flaw classification in steel-belted tires is based mostly on comparisons of ultrasonic amplitudes with the ultrasonic amplitudes of neighboring structures.

5.4. Inspections

5.4.1. Steel Radial Tires. The two types of inspections performable on steel-belted tires are reflected by the implementation of two sets of flaw classification rules for these tire types.

5.4.1.1. Midline inspections. The series of accept/reject flaw classification tests programmed into the Monitor is illustrated in Figure 5-38. It is an ordered sequence of relational comparisons of measured reflection amplitudes with each other and of absolute comparisons to set standards. The ordering of the test sequence reflects the sensitivity of each test to the detection of the flaw. For example, the detection of second belt separation is more reliably detectable by comparing second and first belt reflection energies than by comparing the second belt energy to an absolute standard (see Table 5-9). Careful examination of Figure 5-38 shows that the actual number of tests is small. There are only 11 (1 relational and 1 absolute test for separation of each belt, 2

```
                 Process ANALYZE Command
                           :
                           V
           Blank Seven-Segment Displays
                           V       yes
                 TABLECOUNT = 0? ---------------------------------------.
                       no :                                              V
                           V             yes                 Release ANALYZE Display "Hold"
     Is Display Held With Partial Sampling? --------------.       Turn Off ANALYZE led
                       no :                               :   Turn Off Accept/Reject and Flaw leds
                           V                              :  Clear STORE Tables and Reset Pointers
          Enable ANALYZE Display "Hold"                   V                   :
                           :                 Release ANALYZE Display "Hold"   :
                           V             no     Turn Off ANALYZE led          :
    Majority Analysis Logic Enabled? ---.                 :                   :
                      yes :              :                V                   V
                           V             :               Exit                Exit
             Process Majority Logic      :
              (Flowchart 3.11a)          :
                           V             :
           yes          Majority         :
   Exit <------ Analysis Failure?        :
                       no :              :
                           V             :
                       <-----------------'
                           V
              Average All Samples
                           V          yes
           Temperature Out of Range? ---------------------.
                       no :                                V
                           V                  Release ANALYZE Display "Hold"
              Turn on ANALYZE led                 Turn Off ANALYZE led
               Point to Averages              Turn Off Accept/Reject and Flaw leds
                           V        no       Clear STORE Tables and Reset Pointers
              Listings Enabled? -----.                     V
                      yes :          :           Turn On "Out-of-Temp" led
                           V          :                     :
            Enable ANALYZE listing   :                     V
                           V          :                    Exit
                       <--------------'
                           V
          Process Accept/Reject Tests
               (Flowchart 3.12)
                           V
         Enable ANALYZE Display "Hold"
              TABLECOUNT <- 0
                           :
                           V
                          Exit
```

Figure 5-35. Analyze Command Execution

```
                     Process [ ] Time Similarity
                                 :
                                 V
                           i  <- [TABLECOUNT]
                                 :
                                 V
                                  <-------------------------------.
                                 :                                :
                                 V                                :
                           J  <- i                                :
                           H  <- 0                                :
                           M  <- 0                                :
                                 :                                :
                                 V                                :
                                  <---------------------------.   :
                                 :                            :   :
      yes                        V                   no       :   :
   .----- ts([ ]J) =( tp([ ]i ( te([ ]J) ? -----.          :   :
   :                                            :          :   :
   V                                            V          :   :
H <- H+1                                     M <- M+1      :   :
   :                                            :          :   :
   --------------------> <--------------------'          :   :
                                 :                            :   :
                                 V                            :   :
                           J  <- J-1                          :   :
                                 :                            :   :
                                 V     no                     :   :
                             J=0?  ---------------------------'   :
                           yes  :                                 :
                                V      no                         :
                             M > H? -----------------.            :
                           yes  :                    :            :
                                V                    :            :
                  Remove Sample i From Arrays        :            :
                  TABLECOUNT <- [TABLECOUNT] - 1     :            :
                                :                    :            :
                                V                    :            :
                                 <-------------------'            :
                                :                                 :
                                V                                 :
                           i <- i-1                               :
                                :                                 :
                                V     no                          :
                             i=0? --------------------------------'
                           yes  :
                                V
                              Exit
```

Figure 5-36. Time Majority Analysis Logic

```
                 Process [ ] Amplitude Consistency
                                   :
                                   V
                           i  <-  [TABLECOUNT]
                                   :
                                   V
                                    <--------------------------------.
                                   :                                 :
                                   V                                 :
                           j  <-  i                                  :
                           H  <-  0                                  :
                           M  <-  0                                  :
                                   :                                 :
                                   V                                 :
                                    <--------------------------.     :
                                   :                           :     :
                                   V                           :     :
              Pl(j)  <-  pa([ ]j)*(1.0-[HOMOL_OFFSET])         :     :
              Ph(j)  <-  pa([ ]j)*(1.0+[HOMOL_OFFSET])         :     :
                                   :                           :     :
        yes                        V                 no        :     :
     .-------  Pl(j) =< pa([ ]i < Ph(j) ? --------.            :     :
     :                                            :            :     :
     V                                            V            :     :
H <- H+1                                     M <- M+1          :     :
     :                                            :            :     :
     ---------------------->  <-------------------'            :     :
                                   :                           :     :
                                   V                           :     :
                           j  <-  j-1                          :     :
                                   :                           :     :
                                   V    no                     :     :
                                 j=0?  ------------------------'     :
                             yes   :                                 :
                                   V      no                         :
                                M > H? ---------------.              :
                             yes   :                  :              :
                                   V                  :              :
                 Remove Sample i From Arrays          :              :
                 TABLECOUNT <- [TABLECOUNT] - 1       :              :
                                   :                  :              :
                                   V                  :              :
                                    <-----------------'              :
                                   :                                 :
                                   V                                 :
                           i  <-  i-1                                :
                                   :                                 :
                                   V    no                           :
                                 i=0? -------------------------------'
                             yes   :
                                   V
                                  Exit
```

Figure 5-37. Amplitude Majority Analysis Logic

```
                                   Process Steel-Belted Tire Accept/Reject Tests
                                                      :
                                                      V
                                                 AA1 <- [A1]
                                                 AA2 <- [A2]
                                                      V         yes
                                                No reflections? ----> r deg  B 01
                                                   no :
                                                      V        yes
                                               One reflection? ------> r sep 1B 02
                                                   no :
                                   yes, no bondline   V    no, detected bondline           no
              .------------------------------------ P1=0? ------------> P1>=[SIG_BONDLINE]? ----.
              :                                                        yes :                    :
              :                                                            V                    :
              :                                                     AA1 <- [A1]*[BL_RED_FACTOR] :
              :                                                     AA2 <- [A2]*[BL_RED_FACTOR] :
              :                                                            V                    :
              V                                                             (-------------------'
            P3>P2? ---------> r sep 2B 69,70,71    yes, small bondline     V              no, significant bondline
           no :        yes                            .--------------- B2*P2>P1? -------------.
              V                                       V                                       V
           P3>=B3*P2? --> r sep 2B 72,73,74        P3>=B3*P2? --> r sep 2B 00,33,34        P3>=B3*P2? --> r sep 2B
           no :        yes                         no :        yes                         no :        yes   00,03,04
              V                                       V                                       V
         B4*P2>P3? ---------> r sep 1B 75,76,77  B4*P2>P3? ---------> r sep 1B 35,36,37  B4*P2>P3? ---------> r sep 1B
           no :        yes                         no :        yes                         no :        yes   05,06,07
              V                                       V                                       V
  yes .- B3*P2>P3>=B5*P2? -. no           yes .- B3*P2>P3>=B5*P2? -. no           yes .- B3*P2>P3>=B5*P2? -. no
      V                  V                    V                  V                    V                  V
   P4>=B8*P3? -.      P4>=B7*P3? -.        P4>=B8*P3? -.      P4>=B7*P3? -.        P4>=B8*P3? -.      P4>=B7*P3? -.
   no :   yes V       no :   yes V         no :   yes V       no :   yes V         no :   yes V       no :   yes V
      :     r sep  B     :     r sep  B       :     r sep  B     :     r sep  B       :     r sep  B     :     r sep  B
      :      00,89,90    :      00,78,79      :      00,00,50    :      00,00,39      :      00,00,20    :      00,00,09
      V                  V                    V                  V                    V                  V
 B6*P3>P4? ----.    B6*P3>P4? ----.      B6*P3>P4? ----.    B6*P3>P4? ----.      B6*P3>P4? ----.    B6*P3>P4? ----.
   no :   yes V       no :   yes V         no :   yes V       no :   yes V         no :   yes V       no :   yes V
      :     r deg  B     :     r deg  B       :     r deg  B     :     r deg  B       :     r deg  B     :     r deg  B
      :      91,92,93    :      80,81,82      :      00,52,53    :      00,41,42      :      00,22,23    :      00,11,12
      V                  V                    V                  V                    V                  V
   P3>=AA1? ---.      P3>=AA1? ---.        P3>=AA1? ---.      P3>=AA1? ---.        P3>=AA1? ---.      P3>=AA1? ---.
   no :   yes V       no :   yes V         no :   yes V       no :   yes V         no :   yes V       no :   yes V
      :     r sep 2B     :     r sep 2B       :     r sep 2B     :     r sep 2B       :     r sep 2B     :     r sep 2B
      :      00,94,95    :      00,83,84      :      00,00,55    :      00,00,44      :      00,00,25    :      00,00,14
      V                  V                    V                  V                    :                  :
   AA2>P3? ----.      AA2>P3? ----.        AA2>P3? ----.      AA2>P3? ----.           :                  :
   no :   yes V       no :   yes V         no :   yes V       no :   yes V            :                  :
      :     r sep 1B     :     r sep 1B       :     r sep 1B     :     r sep 1B       :                  :
      :      00,96,97    :      00,85,86      :      00,00,57    :      00,00,46      :                  :
      V                  V                    V                  V                    V                  V
   Shoulder  yes      Shoulder  yes        Shoulder  yes      Shoulder  yes        Shoulder  yes      Shoulder  yes
 Inspection? ---.   Inspection? ---.     Inspection? ---.   Inspection? ---.     Inspection? ---.   Inspection? ---.
   no :        V         :        V           :        V      no :        V        no :        V      no :        V
      :     Process      :     Process        :     Process      :     Process        :     Process      :     Process
      :  Shoulder Tests  :  Shoulder Tests    :  Shoulder Tests  :  Shoulder Tests    :  Shoulder Tests  :  Shoulder Tests
      : (Flowchart 3.13) : (Flowchart 3.13)   : (Flowchart 3.13) : (Flowchart 3.13)   : (Flowchart 3.13) : (Flowchart 3.13)
      V no     V         V no     V           V no     V         V no     V           V no     V         V no     V
       (---- r por Cp?    (---- r por Cp?      (---- r por Cp?    (---- r por Cp?      (---- r por Cp?    (---- r por Cp?
      :    yes :         :    yes :           :    yes :         :    yes :           :    yes :         :    yes :
      :        V         :        V           :        V         :        V           :        V         :        V
      :        r por Cp  :        r por Cp    :        r por Cp  :        r por Cp    :        r por Cp  :        r por Cp
      V                  V                    V                  V                    V                  V
  dt <- tp(5)-tp(3)  dt <- tp(5)-tp(3)        a ... P3 00,00,59  a ... P3        Post-Retread? -.    Post-Retread? -.
      V        yes       V        yes                                  00,00,48    no :    yes V      no :     yes V
DT_F>dt>=DT_N? ---.   DT_F>dt>=DT_N? ---.                                             :     r bln P1    :       r bln P1
   no :          :    no :          :                                                 :      00,00,29   :        00,00,18
      V  yes     V       V   yes    V                                                 V                  V
       (------ P5)=B9*P3? (------ P5)=B9*P3?                                          a P3 00,00,29      a P3 00,00,18
      :       no :       :       no :
      :          V       :          V
      :        r deg 2B  :        r deg 2B
      :              99  :              88
      V                  V
      a ... P3 00,98,99  a ... P3 00,87,88
                                               Pj = pa(j) for j=1,2,3,4,5
```

Figure 5-38. Steel-Belted Tire

Table 5-9. Liner Accept/Reject Test Parameters

LABEL	ADDRESS	DESCRIPTION
PSR_I_LBN	E816	Passenger Steel-Belted 1
TSR_I_LBN	E896	Truck Steel-Belted 1
PSR_II_LBN	E8D6	Passenger Steel-Belted 2
TSR_II_LBN	E956	Truck Steel-Belted 2

(a) Minimum 2nd Belt--Liner Time Difference

LABEL	ADDRESS	DESCRIPTION
PSR_I_LBF	E818	Passenger Steel-Belted 1
TSR_I_LBF	E898	Truck Steel-Belted 1
PSR_II_LBF	E8D8	Passenger Steel-Belted 2
TSR_II_LBF	E958	Truck Steel-Belted 2

(b) Maximum 2nd Belt--Liner Time Difference relational tests for separation of the body plies, 1 relational test for body ply degradation, and 3 switching tests). When combined, there are 40 potential tests that can be applied to a tire being inspected. These tests can end in one of 69 possible results. Eight of these indicate an acceptance of the tire.

Figure 5-38 shows the flow of the accept/reject test series. Detectable and significant bondline tests split the processing flow into three branches. Close examination shows the equivalence of each branch with respect to test priority and parameters used. Test priority is such that flaws of the belts and then of the body plies are assessed by relative comparisons and then belt flaws are measured by absolute thresholds. The right-hand branch in Figure 5-38 is slightly different in that an extra test of the inspection mode is made and an absolute test for first-belt separation is deleted. This branch for "excessive bondline" presumes that the large energy return from the bondline will render meaningless any absolute measure for first-belt separation and it, of course, senses the Monitor inspection mode before judging whether the bondline is a flawed retread product or an expendable part of a retread candidate.

Each branch is bifurcated on the basis of relative second belt reflection energy. This has no obvious rationale, but has been programmed to mimic the basis upon which tire inspectors have been known to make correct decisions.

5.4.1.2. Shoulder inspections. This type of inspection is used to detect casing belt-edge separations in the shoulders of retread candidate tires or porous tread in the shoulders of retread tires resulting from undercure during the retread process. As a result, the Monitor will inspect for porosity in this mode only if the POST-RETREAD mode is also enabled. When inspecting steel-belted tires in any SHOULDER TEST LOCATION mode, the midline accept/reject test series is always run first to inspect for belt-edge separations in the shoulders. If the Monitor is in the POST-RETREAD mode and no casing flaws are found in the shoulder, the test for rejectable porosity begins when three porosity reflections are detected within the appropriate time window. If it is then found that the amplitude of any of these reflections is greater than a set porosity threshold, a rejection due to porosity presence is indicated.

5.4.2. Textile Tires. The two types of inspection performable on textile-plied tires is reflected by the implementation of two sets of flaw classification rules for this tire type.

5.4.2.1. Midline inspections. The series of accept/reject textile tire flaw classification tests programmed into the Monitor is illustrated in Figure 5-39. It is a sequence of absolute comparisons of measured reflection amplitudes to set standards. Careful examination of Figure 5-39 shows that there are only two tests (one absolute test each for separation and for degradation of the body plies). Altogether, there are eight poten-

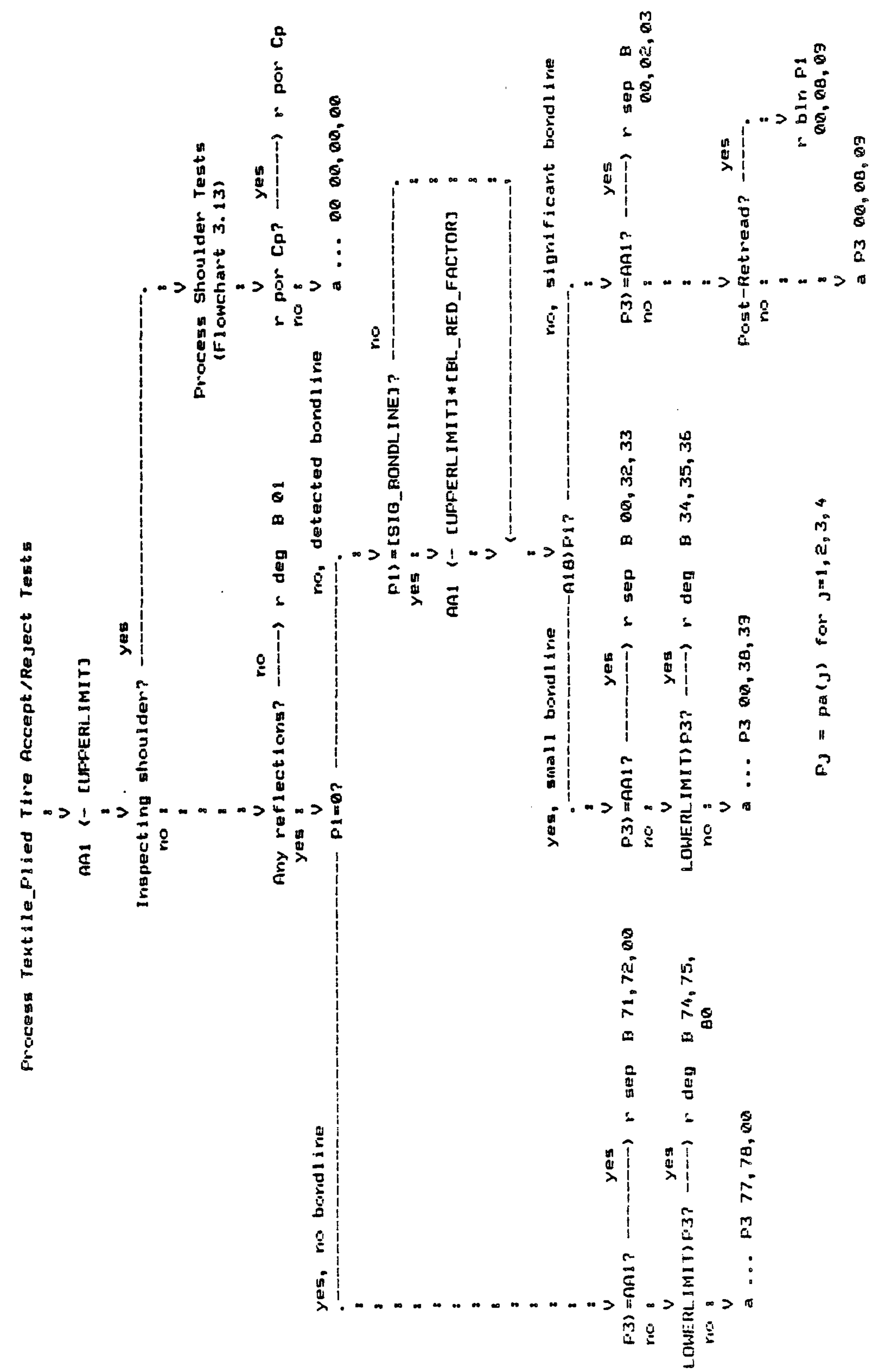


Figure 5-39. Textile-Plied Tire Accept/Reject Algorithm

tial tests that can be applied to a tire being inspected. These tests can end in one of 21 possible results. Six of these indicate an acceptance of the tire.

Figure 5-39 shows the flow of the accept/reject test series. Detectable and significant bondline tests split the processing flow into three branches. Close examination shows that the testing sequence in each branch is equivalent and that body ply flaws are detected by comparing reflection amplitude with absolute thresholds. The right-hand branch in Figure 5-39 is slightly different in that there is no test for body ply degradation and an extra test of inspection mode is made. The presence of a significant bondline reduces body ply amplitude and makes any degradation test meaningless. This branch is followed when a significant bondline reflection is detected and is used to sense the TQM inspection mode before judging whether the bondline is a flawed retread product or an expendable part of a retread candidate casing.

5.4.2.2. Shoulder inspections. This type of inspection is used to detect porous tread in the shoulders of retreaded tires resulting from undercure during the retreading process. As a result, the TQM will inspect for porosity in this mode only if the POST-RETREAD mode is also selected. If the PRE-RETREAD mode is selected, the TQM will not do accept/reject processing and will issue blank displays and "accept" decision only. If the TQM is in the POST-RETREAD mode, the test for rejectable porosity begins when three porosity reflections are detected within the appropriate time window. If it is then found that the amplitude of any of these reflections is greater than a set porosity threshold, a rejection due to porosity presence is indicated along with a display of the number of reflections. Otherwise an acceptance is indicated. Figure 5-40 outlines the logic of porosity testing.

5.5. Calibration

5.5.1. General. The TQM is programmed to perform three types of automatic self-calibration. They are:

(1) Temperature Calibration

(2) Gain Calibration, and

(3) DAC Adjustment.

Temperature and gain calibrations are frequently executed as part of the daily operation of the TQM. DAC adjustment is performed every 6 months as part of scheduled maintenance. The Operator, Maintenance, and Calibration Manuals describe the use of these calibrations in more detail. This chapter discusses the supporting software.

5.5.2. Temperature Calibration. The calibration of the TQM to the temperature of a tire casing is done by reading the output of the accessory thermocouple as it is embedded in the tire tread. As illustrated in

```
              Process Shoulder Tests
                      :
                      V                  no
          Post-retread inspection? -----> Exit to
                      :                    calling routine
                  yes :
                      V
      Cp <- Porosity reflection count
                      :
                      V     yes
                   Cp < 4? --------------> Exit to
                   no :                    calling routine
                      V
      Cp <- Porosity [pa >= A11] count
                      :
                      V     yes
                   Cp = 0? --------------> Exit to
                   no :                    calling routine
                      V
                      r por Cp
```

Figure 5-40. Common Tire Porosity Accept/Reject Algorithm

Figures 5-41 and 5-42 this procedure executes the normal TEMP display process described in par. 5.3. in order to read the thermocouple and update the display. It then processes a comparison of the two most recently acquired temperatures and terminates with a finished calibration if their difference is less than 2°. The finished calibration termination is simply a storage, for later reference, of the last temperature read and a computation from its value of the indices required for data compensation. If, after a period of 20 seconds of attempting temperature calibration, the TQM cannot acquire two consecutive temperatures whose difference is less than 2°, it terminates in an uncalibrated condition.

5.5.3. Gain Calibration. The calibration of the TQM receiver section gain is an adjustment of the voltage controlling the gain of the first amplifier (AGC_1) in the receiver until the maximum peak amplitude of the ultrasonic reflection sampled off a GRP-to-air interface falls within a range of one unit around a TIRE TYPE-dependent setpoint (see Table 5-10). As illustrated in Figures 5-43 and 5-44, this procedure executes the normal reflection feature extraction process described in par. 5.3., isolates the peak of maximum amplitude lying between time limits specified by EEPROM variables E7B0 (CAL_LOW_WINDOW) and E7B2 (CAL_HIGH_WINDOW), and compares this amplitude value with a setpoint value selected by TIRE TYPE and by saturation disposition history (par. 5.3.5). If the maximum peak amplitude is less than the setpoint value, the AGC_1 gain is increased and if the maximum amplitude is greater than the setpoint value, the AGC_1 gain is decreased. The TQM then continues this acquisition, compare, and adjust cycle until a match yields a termination with good calibration or until it reaches the limits of AGC_1 gain adjustment, at which point the TQM issues a "-CAL" message and terminates in an uncalibrated state.

5.5.4. Automatic DAC Adjustment. The adjustment of the DAC is a variation of the gain calibration procedure described above. As explained in Section 4.3.3.3. of the Calibration Manual, the automatic DAC adjustment is started by pressing the TEST CAL switch. However, if the RAM memory address FFC1 (AUTO_DAC_FLAG) has been loaded with the number one (by procedures described in par. 5.7.2.3.), instead of starting the gain calibration, the TQM will start adjusting the DAC. This process is summarized in Figures 5-45 and 5-46.

The aim of the automatic DAC adjustment procedure is to modify the slope control voltage of amplifier AGC_2 so as to minimize the variance between TQM reflection amplitudes and "idealized" amplitudes at three points in time. To do this the TQM first adjusts the gain of the first receiver amplifier (AGC_1) until the first reflection off the ¼-inch rubber test block is unsaturated. It then uses this amplitude to compute the specific values of the "idealized" compensation curve for the third and fifth multiple reflection. This part of the DAC adjustment is designated as stage 1 in Figure 5-46. Stage 2 is simply the computation of the initial variance (v) between the detected reflection amplitudes pa(i) and the "idealized" values ta(i) according to:

```
   Start Temperature Calibration
                 :
                 V
          Set FLAGS(b2)    ["in-service" true]
        Clear FLAGS(b6)    ["timed-out" false]
      Clear FSELECT+1(b6) [no calibration error condition]
                 :
                 V
     CALTRYCNT <- 3*20
 CALAVERAGECNT <- 4
     CALENDCNT <- 4
 CALTOTALPEAKS <- 0
                 :
                 V
        TEMTIM <- 0
                 :
                 V
       Turn On TEMP CAL led
                 :
                 V
    Process Temperature Display
         (Flowchart 3.3)
                 :
                 V
    CALIB_TEMP <- [LAST_TEMP_READ]
                 :
                 V
                Exit
```

Figure 5-41. Start of Temperature Calibration

```
                 Process Temperature Calibration
                                :
                                V
                    Process Temperature Display
                          (Flowchart 3.3)
                                :
                                V
                      T(t-1)  <- [CALIB_TEMP]
           T <- CALIB_TEMP  <- [LAST_TEMP_READ]
                                :
                yes             V              no
             .----- |T(t) - T(t-1)|  < 1? ---------.
             :                                     :
             V                                     V
    CALENDCNT <- [CALENDCNT] - 1        CALENDCNT <- 4
             :                                     :
    no       V                                     V
Exit <--- CALENDCNT = 0?                CALTRYCNT <- [CALTRYCNT] - 1
         yes :                                     :
             V                                     V        no
  Process Compensation of Limits            CALTRYCNT = 0? ----> Exit
             :                                 yes :
             V                                     :
Clear "Out-Of-Temp" bits in STORE Tables           :
Compute Lookup Table (TEMPDIVBY5) index            :
Compute Interpolation (TEMPREMAIN) index           :
             :                                     :
             V      yes                            :
      Indices in Range? -------------.             :
             :                       :             :
             V                       :             :
Set "Out-Of-Temp" bits in STORE Tables :           :
             :                       :             :
             V                       :             :
              <----------------------'             :
             :                                     :
             V                                     V
      TEMTIM <- 3*60*15              Set FLAGS(b6)     ["timed-out" true]
     Turn Off TEMP CAL led         Clear FLAGS(b4,b2)  ["hold","in-service"
             :                                     :                 false]
             V                                     :
  Set FLAGS(b4)     ["hold" true]                  :
Clear FLAGS(b6,b2) ["timed-out","in-service" false] :
             :                                     :
             V                                     V
            Exit                                  Exit
```

Figure 5-42. Temperature Calibration

Table 5-10. Gain Calibration Setpoint Values*

TIRE TYPE	ADDRESS	DESCRIPTION
AMPTABLE PSR_I	E790	Passenger Steel-Belted 1
TTX_I	E792	Truck Textile-Plied 1
TSR_I	E794	Truck Steel-Belted 1
GRP_	E796	Glass-Reinforced Plastic Block
RN	E798	Rubber/Nylon Block
PSR_II	E79A	Passenger Steel-Belted 2
TTX_II	E79C	Truck Textile-Plied 2
TSR_II	E79E	Truck Steel-Belted 2

(a) Primary Gain Calibration Setpoints

TIRE TYPE	ADDRESS	DESCRIPTION
ALTTABLE PSR_I	E7A0	Passenger Steel-Belted 1
TTX_I	E7A2	Truck Textile-Plied 1
TSR_1	E7A4	Truck Steel-Belted 1
GRP_	E7A6	Glass-Reinforced Plastic Block
RN	E7A8	Rubber/Nylon Block
PSR_II	E7AA	Passenger Steel-Belted 2
TTX_II	E7AC	Truck Textile-Plied 2
TSR_II	E7AE	Truck Steel-Belted 2

(b) Secondary Gain Calibration Setpoints

*TQM Reading of Setpoints = Setpoint/4.23
Example for GRP (refer to Listing in Appendix):
$15 = 63/4.23$ where $63_{10} = 3F_{16}$

```
             Start Gain Calibration
                        :
                        V
                Set FLAGS(b3)    ["in-service" true]
              Clear FLAGS(b7)    ["timed-out" false]
            Clear FSELECT+1(b6) [no calibration error condition]
                        :
                        V
          CALTRYCNT  <- 4
      CALAVERAGECNT  <- 4
          CALENDCNT  <- 4
      CALTOTALPEAKS  <- 0
                        :
                        V
             CALTIM  <- 0
                        :
                        V
           Turn On TEST CAL led
                        :
                        V                       yes
    Automatic DAC Adjustment Enabled? ------------.
                     no :                          :
                        V                          V
             agc(3) <- [GRP_OUTGAIN]        Start DAC Adjustment
           Save present NOISEWIDTH           (Flowchart 4.3)
       NOISEWIDTH <- [GRP_PRE_NWID]
                        :
                        V
           Clear ANALYSTATUS(b7,b0)  ["analysis-since-calibration","hold" false]
            Turn Off ANALYZE led
       Turn Off Accept/Reject and Flaw leds
    Reset STORE Tables and Initialize Pointers
                        :
                        V
                      Exit
```

Figure 5-43. Start of Gain Calibration

```
                Process Gain Calibration
                           V
         Process Reflection Feature Extraction
                    (Flowchart 3.4)
                           V                  yes
          Automatic DAC Adjustment Enabled? ----------------------.
                        no :                                       :
                           V                                       V
         Process Maximum Amplitude Search Between      Process DAC Adjustment
           CAL_LOW_WINDOW and CAL_HIGH_WINDOW             (Flowchart 4.6)
                    (Flowchart x.x)
                           V                  no
          Does Peak Amplitude pa(Max) Exist? ---------------------------.
                       yes :                                            :
                           V                                            :
            CALTOTALPEAKS <- [CALTOTALPEAKS]+pa(Max)                    :
            CALAVERAGECNT <- [CALAVERAGECNT] - 1                        :
              no           V                                            :
    Exit <------- CALAVERAGECNT = 0?                                    :
                       yes :                                            :
                           V                                            :
                Average <- [CALTOTALPEAKS]/4                            :
                           V                                            :
         Process Preparation of Amplitude Display                       :
                   (Flowchart x.x)                                      :
                           V                                            :
                CALAVERAGECNT <- 4                                      :
                CALTOTALPEAKS <- 0                                      :
                           V          yes                               :
             Average > [SETPOINT]+1? -----------------------.           :
                        no :                                :           :
                           V          yes                   :           :
             Average < [SETPOINT]-1? ---------.             :           :
                        no :                  V             :           :
                           V              Increase        Reduce        :
             CALENDCNT <- [CALENDCNT] - 1   Gain           Gain         :
               no          V                  :             :           :
    Exit <----------- CALENDCNT = 0?          -----> <-----'            :
                      yes :                          :                  :
                           V      yes                V                  :
                     GRP Type? --------------.      Gain       yes      V
                        no :                 :    Control at -------->
                           V                 :     Limits?              :
              Restore original NOISEWIDTH    :     no :                 V
                agc(3) <- [ROM_OUTGAIN]      :        :      CALTRYCNT <- [CALTRYCNT] - 1
                           V                 :        :                 V        no
                           <-----------------'        :          CALTRYCNT = 0? -----> Exit
                           V                          V             yes :
                agc(1) <- Gain              agc(1) <- New Gain          :
                           V                          :                 :
                CALTIM <- 3*60*15                     :                 :
              Turn Off TEST CAL Led                   :                 V
                           V                          :         Set FSELECT+1(b6)
                   Set FLAGS(b5)                      :           Set FLAGS(b7)
                 Clear FLAGS(b7,b3)                   :         Clear FLAGS(b5,b3)
                           V                          V                 V
                         Exit                        Exit              Exit
```

Figure 5-44. Gain Calibration

```
            Start DAC Adjustment
                       :
                       V
            Save RAM_TMP_SLOPE
            Save RAM_TMP_INGAIN
            Save RAM_TMP_OUTGAIN
            Save RAM_TMP_FN_GAIN
                       :
                       V
            agc(2,c)  <- 0600H
                       :
                       V
                  INC  <- 0
                 TERM  <- [RAM_TMP_SLOPE]
                       :
                       V
           CALTRYCNT  <- 4
      CALAVERAGECNT  <- 4
          CALENDCNT  <- 4
          P5_TRYCNT  <- 4
      CALTOTALPEAKS  <- 0
                       :
                       V
              PEAK_n  <- 0   (n=1,3,5)
                       :
                       V
               Enable Stage 1
                       :
                       V
                     Exit
```

Figure 5-45. Start of DAC Adjustment

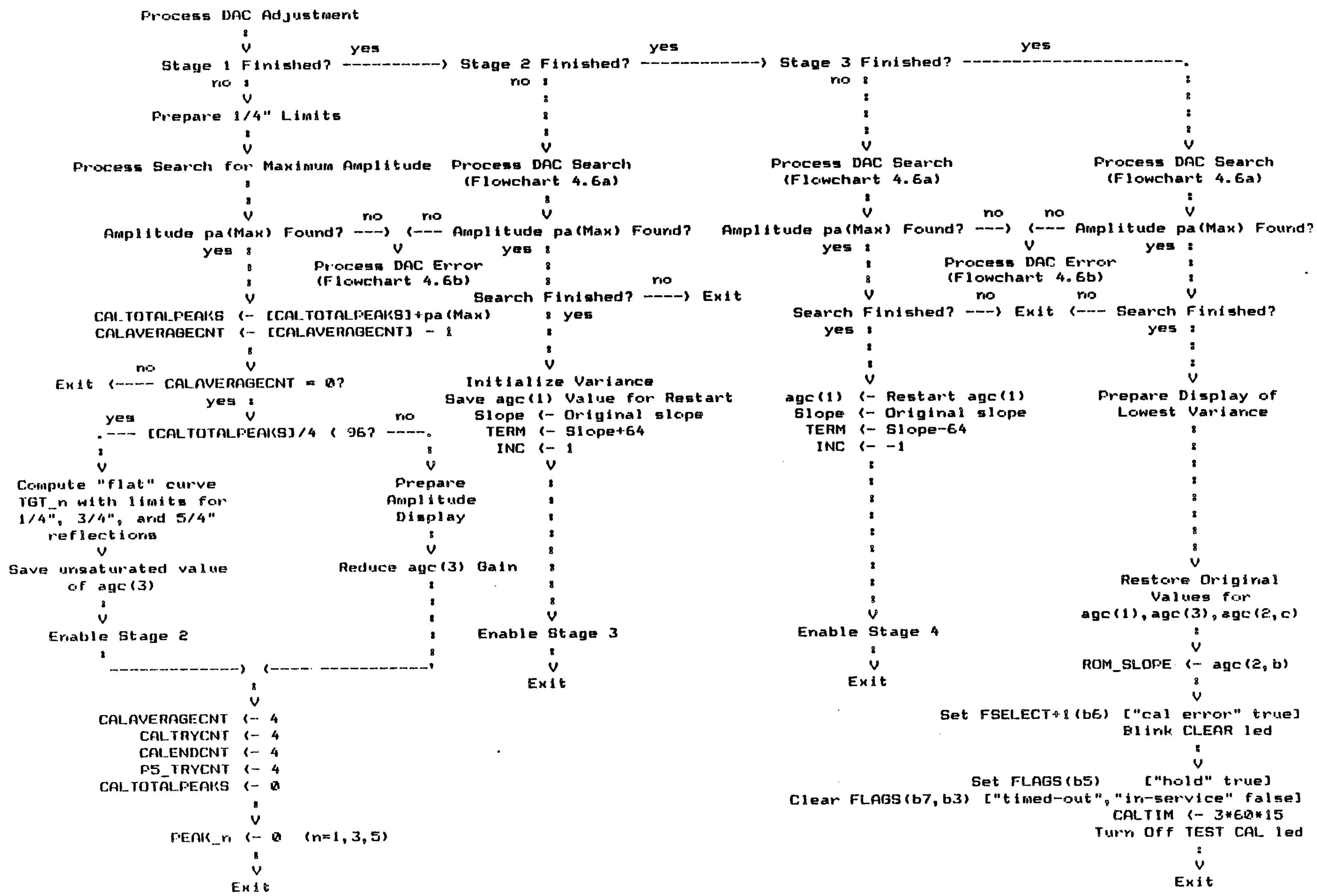


Figure 5-46. Automatic DAC Adjustment

$$v = \sum_{i = 1, 3, 5} | pa(i) - ta(i) |$$

Stages 3 and 4 in Figure 5-46 constitute searches either side of the initial AGC_2 slope value for such a value which minimizes the variance (v) as computed above (see also Figures 5-47 and 5-48). Since the locus of variance with respect to slope cannot be expected to be monotonic, the search algorithm adjusts the TQM slope in a simple, sequential manner. As presently constituted, the TQM limits this search to 64 values of slope either side of the starting point, yielding a processing time of less than 10 minutes. Each time a variance is computed with value less than the previous variance, this new variance becomes the next previous and the value of the voltage controlling the slope of AGC_2 is saved. At the end of the search, this saved value then becomes both the active controlling voltage of AGC_2 slope (by being sent to the hardware port) and the permanent backup value (by being written into EEPROM memory E786). As discussed in Section 4.3.3.3. of the Calibration Manual, the TQM then displays the value of the lowest variance computed (as a measure of the quality of the adjustment) and waits for the operator to press the CLEAR switch.

5.6. Displays

5.6.1. Alphanumeric Display. Various types of information are provided on the alphanumeric display. These are described in the Operating Manual. Indicated in this report is the fact that coded information supplemental to analyzed accept/reject decisions is provided. It is in a form:

Number Code Tire Information

Number Code is specific to type of tire inspected, steel or textile. See Tables 5-11 and 5-12 for a list of code meanings.

For each code number, as appropriate, the tables provide the TQM constant which caused this code to appear, whether the critical reject decision was made on a relative or absolute basis, which part of the tire was involved, the reject decision basis, the number of peak envelopes detected, the bondline level detected, and whether (for steel-belted tires) the 2nd belt/1st belt amplitude ratio is low or high.

Tire-Information is presented as:

1b - if 1st belt signal is reason for rejection

2b - if 2nd belt signal is reason for rejection

b - if body plies are reason for rejection

averaged quality number - if the tire is accepted

```
                 Process DAC Search
                          :
                          V
                       n <- 5
                          V
.------------------------->
:                         V
:  Process Search for Maximum Amplitude Between
:    n/4" Limits [DAC_LOW_n] and [DAC_HIGH_n]
:                         V               no
:         Amplitude pa(Max) Found? ------> Process DAC Error
:                     yes :                 (Flowchart 4.6b)
:                         V
:              PEAK_n <- [PEAK_n]+pa(Max)
:                     n <- n-2
:                  no     V
-------------------- n = -1?
                     yes :
                          V
       CALAVERAGECNT <- [CALAVERAGECNT] - 1
                          V                no
              CALAVERAGECNT = 0 ? ------------> Exit
                     yes :
                          V
              PEAK_n <- [PEAK_n]/4    (n = 1,3,5)
                          V                no
        [DAC_HIGH_1] > PEAK_1? ---------------------------------------.
                     yes :                                              :
                          V                no                           :
              PEAK_1 >= [DAC_LOW_1]? -------------------.              :
                     yes :                               V              V
                          V                     Increase agc(1)   Decrease agc(1)
                 Var <- Sum | PEAK_n - TGT_n |        Gain              Gain
                          :  n=1,3,5                   :                 :
                          V            no              ------> <------'
            Variance >= [Var]? ------------.                  :
                     yes :                 :                  :
                          V                :                  :
            Variance <- [Var]              :                  :
                          V                :                  :
                          <----------------'                  :
                          V                                    V
       CALAVERAGECNT <- 4                    CALAVERAGECNT <- 4
           CALTRYCNT <- 4                        CALTRYCNT <- 4
           CALENDCNT <- 4                        CALENDCNT <- 4
           P5_TRYCNT <- 4                        P5_TRYCNT <- 4
       CALTOTALPEAKS <- 0                    CALTOTALPEAKS <- 0
              PEAK_n <- 0  (n=1,3,5)                PEAK_n <- 0  (n=1,3,5)
                          V                                 :
               Slope <- [Slope] + [INC]                     V
                          V                               Exit
         Prepare Slope Control Display
                          V         yes
               Slope = [TERM]? -----> End Search
                       no :
                          V
                         Exit
```

Figure 5-47. DAC Search Procedure

```
                Process DAC Error
                        :
                        V
         CALTRYCNT <- [CALTRYCNT] - 1
                        :
                        V          no
              CALTRYCNT = 0? -----> Exit
                   yes  :
                        V
             Set FSELECT+1(b6)
               Set FLAGS(b7)
             Clear FLAGS(b5,b3)
                        :
                        V
   Restore Original RAM_TMP_SLOPE
   Restore Original RAM_TMP_INGAIN
   Restore Original RAM_TMP_OUTGAIN
   Restore Original RAM_TMP_FN_GAIN
                        :
                        V
                      Exit
```

Figure 5-48. Automatic DAC Adjustment Error Handler

Table 5-11. Textile-Plied Tire Accept/Reject Codes

CODE	INTERPRETATION
01	ply degradation rejectable with 0 peaks
02	ply separation rejectable with 1 peak and significant bondline
03	ply separation rejectable with 2 peaks and significant bondline
08	acceptable with 1 peak and significant bondline
08	if retread, bondline rejectable with 1 peak and significant bondline
09	acceptable with 2 peaks and significant bondline
09	if retread, bondline rejectable with 2 peaks and significant bondline
32	ply separation rejectable with 1 peak and significant bondline
33	ply separation rejectable with 2 peaks and small bondline
34	ply degradation rejectable with 0 peak and small bondline
35	ply degradation rejectable with 1 peak and small bondline
36	ply degradation rejectable with 2 peaks and small bondline
38	acceptable with 1 peak and small bondline
39	acceptable with 2 peaks and small bondline
71	ply separation rejectable with 1 peak
72	ply separation rejectable with 2 peaks
74	ply degradation rejectable with 1 peak
75	ply degradation rejectable with 2 peaks
77	acceptable with 1 peak
78	acceptable with 2 peaks
80	ply degradation rejectable with 1 peaks (Liner)

Table 5-12. Steel-Belted Tire Accept/Reject Codes

CODE	INTERPRETATION
01	abs SB2 degradation rejectable with 0 peaks
02	abs SB1 separation rejectable with 1 peak
03	B3 rel SB2 separation rejectable with 2 peaks, significant bondline
04	B3 rel SB2 separation rejectable with 3 peaks, significant bondline
05	B4 rel SB1 separation rejectable with 1 peak, significant bondline
06	B4 rel SB1 separation rejectable with 2 peaks, significant bondline
07	B4 rel SB1 separation rejectable with 3 peaks, significant bondline
09	B7 rel ply separation rejectable with 3 peaks, significant bondline, and low SB2:SB1
11	B6 rel ply degradation rejectable with 2 peaks, significant bondline, and low SB2:SB1
12	B6 rel ply degradation rejectable with 3 peaks, significant bondline, and low SB2:SB1
14	A1 abs SB2 separation rejectable with 3 peaks, significant bondline, and low SB2:SB1
18	acceptable with 3 peaks, significant bondline, and low SB2:SB1
18	if retread, bondline rejectable with 3 peaks, significant bondline, and low SB2:SB1
20	B8 rel ply separation rejectable with 3 peaks, significant bondline, and high SB2:SB1
22	B6 rel ply degradation rejectable with 2 peaks, significant bondline, and high SB2:SB1
23	B6 rel ply degradation rejectable with 3 peaks, significant bondline, and high SB2:SB1
25	A1 abs SB2 separation rejectable with 3 peaks, significant bondline, and high SB2:SB1
29	acceptable with 3 peaks, significant bondline, and high SB2:SB1
29	if retread, bondline rejectable with 3 peaks, significant bondline, and high SB2:SB1
33	B3 rel SB2 separation rejectable with 2 peaks, small bondline
34	B3 rel SB2 separation rejectable with 3 peaks, small bondline
35	B4 rel SB1 separation rejectable with 1 peak, small bondline
36	B4 rel SB1 separation rejectable with 2 peaks, small bondline
37	B4 rel SB1 separation rejectable with 3 peaks, small bondline
39	B7 rel ply separation rejectable with 3 peaks, small bondline, and low SB2:SB1
41	B6 rel ply degradation rejectable with 2 peaks, small bondline, and low SB2:SB1
42	B6 rel ply degradation rejectable with 3 peaks, small bondline, and low SB2:SB1
44	A1 abs SB2 separation rejectable with 3 peaks, small bondline, and low SB2:SB1
46	A2 abs SB1 separation rejectable with 3 peaks, small bondline, and low SB2:SB1
48	acceptable with 3 peaks, small bondline, and low SB2:SB1
50	B8 rel ply separation rejectable with 3 peaks, small bondline, and high SB2:SB1
52	B6 rel ply degradation rejectable with 2 peaks, small bondline, and high SB2:SB1
53	B6 rel ply degradation rejectable with 3 peaks, small bondline, and high SB2:SB1
55	A1 abs SB2 separation rejectable with 3 peaks, small bondline, and high SB2: SB1
57	A2 abs SB1 separation rejectable with 3 peaks, small bondline, and high SB2:SB1
59	acceptable with 3 peaks, small bondline, and high SB2:SB1
69	rel SB2 separation rejectable with 2 peaks, no detected bondline
70	rel SB2 separation rejectable with 3 peaks, no detected bondline
71	rel SB2 separation rejectable with 4 peaks, no detected bondline
72	B3 rel SB2 separation rejectable with 2 peaks, no detected bondline
73	B3 rel SB2 separation rejectable with 3 peaks, no detected bondline
74	B3 rel SB2 separation rejectable with 4 peaks, no detected bondline
75	B4 rel SB1 separation rejectable with 2 peaks, no detected bondline
76	B4 rel SB1 separation rejectable with 3 peaks, no detected bondline
77	B4 rel SB1 separation rejectable with 4 peaks, no detected bondline
78	B7 rel ply separation rejectable with 3 peaks, no detected bondline, and low SB2:SB1

Table 5-12. (Continued) Steel-Belted Tire Accept/Reject Codes

79	B7 rel ply	separation	rejectable with 4 peaks, no detected bondline, and low	SB2:SB1
80	B6 rel ply	degradation	rejectable with 2 peaks, no detected bondline, and low	SB2:SB1
81	B6 rel ply	degradation	rejectable with 3 peaks, no detected bondline, and low	SB2:SB1
82	B6 rel ply	degradation	rejectable with 4 peaks, no detected bondline, and low	SB2:SB1
83	A1 abs SB2	separation	rejectable with 3 peaks, no detected bondline, and low	SB2:SB1
84	A1 abs SB2	separation	rejectable with 4 peaks, no detected bondline, and low	B2:SB1
85	A2 abs SB1	separation	rejectable with 3 peaks, no detected bondline, and low	SB2:SB1
86	A2 abs SB1	separation	rejectable with 4 peaks, no detected bondline, and low	SB2:SB1
87			acceptable with 3 peaks, no detected bondline, and low	SB2:SB1
88			acceptable with 4 peaks, no detected bondline, and low	SB2:SB1
89	B8 rel ply	separation	rejectable with 3 peaks, no detected bondline, and high	SB2:SB1
90	B8 rel ply	separation	rejectable with 4 peaks, no detected bondline, and high	SB2:SB1
91	B6 rel ply	separation	rejectable with 2 peaks, no detected bondline, and high	SB2:SB1
92	B6 rel ply	separation	rejectable with 3 peaks, no detected bondline, and high	SB2:SB1
93	B6 rel ply	degradation	rejectable with 4 peaks, no detected bondline, and high	SB2:SB1
94	A1 abs SB2	separation	rejectable with 3 peaks, no detected bondline, and high	SB2:SB1
95	A1 abs SB2	separation	rejectable with 4 peaks, no detected bondline, and high	SB2:SB1
96	A2 abs SB1	separation	rejectable with 3 peaks, no detected bondline, and high	SB2:SB1
97	A2 abs SB1	separation	rejectable with 4 peaks, no detected bondline, and high	SB1:SB2
98			acceptable with 3 peaks, no detected bondline, and high	SB1:SB2
99			acceptable with 4 peaks, no detected bondline, and high	SB1:SB2

Only the last two items will appear if the TQM is in the textile TIRF TYPE mode.

5.6.2. Oscilloscope Display. An analog RF display is available which monitors, via oscilloscope, the tire reflection signal as received by the transducer and amplified by the fixed and variable gain amplifiers in the receiver stage. This signal is supplied by a BNC output on the TQM front panel. The signal output amplitude is limited to ±1.0 volts peak-to-peak and no external trigger or synchronization mark is supplied. Recommended oscilloscope settings are:

- Vertical: 0.2 dc volts/div
- Horizontal: 10.0 microseconds/div, internally triggered.

The analog RF signal is refreshed at a 100-Hz rate. On a properly set and triggered oscilloscope, the transducer "main bang" response will appear approximately 17 microseconds after trigger and the region of interest (i.e., ultrasonic reflections from the tire casing) will lie between 17 and 81 microseconds (Figure 5-49). The analog RF signal is equivalent to the RF signal output of a standard ultrasonic tester.

5.6.3. Printing Listings. Tabular listings of reflection features and envelope features are available through a dedicated output on the TQM front panel. This output is compatible with the EIA serial RS232C format. The output rate is set at 9,600 baud, RTS logic positive, eight bits compose a transmitted character, there is one stop bit and no parity, and the data format has been optimized for use with a Datel APP-48 printer. The operator should consult his printer manual for equivalent alignment.

Tabular listings are enabled by access to a flag in memory and, if enabled, are activated as part of normal STORE and ANALYZE functions. To enable listings, a code number must be entered into memory FF00 using the UPDATE mode direct memory reprogramming sequence described in par. 5.7.2.3. The allowable code numbers and their meaning are:

0 listings disabled

1 short form listing enabled

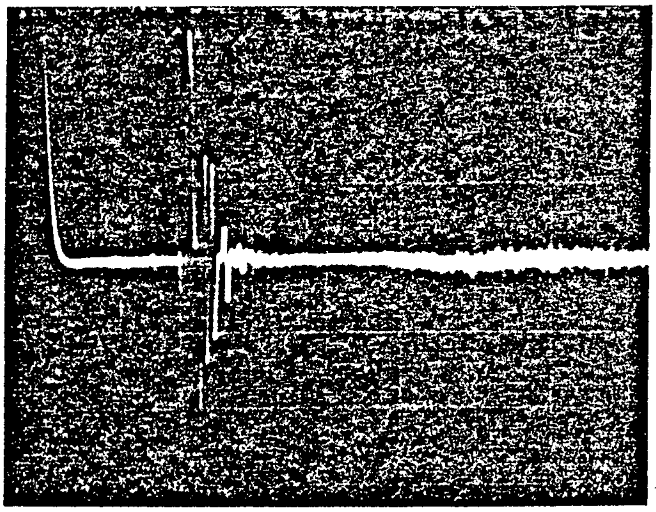
2 long form listing enabled

At turn-on time, the TQM defaults to a "listing disabled" stage. If listings are desired, the following steps must be performed:

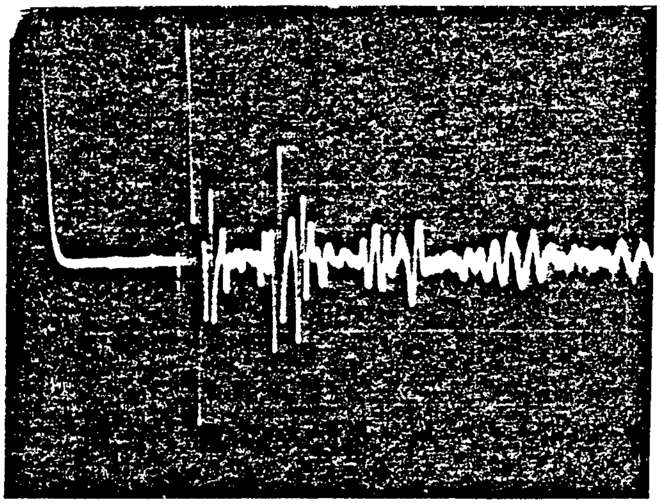
(1) Enter UPDATE mode using keyswitch

(2) Address memory FF00 (see par. 5.7.2.3.)

(3) Enter desired code into memory (see par. 5.7.2.3.)



(a) Transducer Response



(b) Tire Inspection

Figure 5-49. Analog RF Display

(4) Leave UPDATE mode

Figure 5-50 illustrates the listing formats available. The short-term listing (Code 1) prints the calibrated temperature, tread depth, and envelope features of the ultrasonic signal captured when the STORE key is depressed. The envelope amplitudes have been compensated for temperature and depth and are in binary-coded decimal (BCD) format. Each time has been compensated for velocity variation with temperature and is represented in two ways. The first is the accumulation of a 20-MHz clock, as used by the CPU, and the second is in terms of equivalent microseconds, useful for oscilloscope comparisons or depth computations by the operator.

The long-form listing (Code 2) prints, in addition to the short-form listing described above, the reflection features from which the envelope features were derived. The reflection amplitudes are as rectified and smoothed in memory and the times are again represented in 20-MHz clock accumulation and in equivalent microseconds. Briefly, the tables list:

- Amplitudes of reflections ($0 \leq pa \leq 127$) or envelopes ($0.00 \leq pa \leq 9.99$)
- Reflection/envelope start times (t_s)
- Reflection/envelope peak times (t_p)
- Reflection/envelope end times (t_e)

The operator must be careful when comparing times between the reflection and the envelope parts of the long-form listing. Each reflection feature time is compensated for temperature-dependent acoustic velocity variations when it is processed into an envelope feature time. The temperature used is listed in the printout for adjustments.

Depth within the casing is derived from the propagation time by the relation:

$$d = \frac{t}{2.125}$$

d is depth in units of one-sixteenth inch

t is propagation time in microseconds

When the ANALYZE key is depressed while either printing mode is enabled, a short-form listing will be generated which tabulates the averages of features captured in the tables generated by previous STORE operations. The number of such tables will also be listed.

5.7. Reprogramming Procedure

LONG FORM

Raw Amplitude	50 n. Counts T_{start}	50 n. Counts T_{peak}	50 n. Counts T_{end}	µSeconds T_{start}	µSeconds T_{peak}	µSeconds T_{end}
16	154	159	163	7.70	7.95	8.15
22	167	170	173	8.35	8.50	8.65
43	175	179	185	8.75	8.95	9.25
61	185	191	197	9.25	9.55	9.85
47	199	204	211	9.95	10.20	10.55
16	219	223	226	10.95	11.15	11.30
35	229	234	240	11.45	11.70	12.00
28	243	247	253	12.15	12.35	12.65
17	257	260	265	12.85	13.00	13.25
18	269	274	279	13.45	13.70	13.95
12	284	286	291	14.20	14.30	14.55
10	296	299	303	14.80	14.95	15.15
9	312	317	320	15.60	15.85	16.00
15	337	344	349	16.85	17.20	17.45
17	353	358	362	17.65	17.90	18.10
17	366	371	377	18.30	18.55	18.85
17	392	399	404	19.60	19.95	20.20
23	408	414	421	20.40	20.70	21.05
11	498	507	510	24.90	25.35	25.50
12	517	522	527	25.85	26.10	26.35
11	533	538	544	26.65	26.90	27.20
11	573	579	582	28.65	28.95	29.10
9	614	622	627	30.70	31.10	31.35
12	696	702	710	34.80	35.10	35.50
6	776	781	782	38.80	39.05	39.10

SHORT FORM

TEMPERATURE: 72 DEG THICKNESS: 3/16"

STORED DATA:

Compensated Amplitude	T_s	T_p	T_{end}	T_s	T_p	T_{end}
00.00	0	0	0	0.00	0.00	0.00
00.99	154	191	197	7.70	9.55	9.85
00.46	219	234	252	10.95	11.70	12.60
00.20	267	272	302	13.35	13.60	15.10
00.12	336	369	375	16.80	18.45	18.75
00.00	0	0	0	0.00	0.00	0.00
00.00	0	0	0	0.00	0.00	0.00

Figure 5-50. Printer Output

CAUTION

PROGRAMMING MUST ONLY BE PERFORMED BY AN EXPERIENCED PROGRAMMER

IMPROPER DATA ENTRY CAN MAKE EQUIPMENT INOPERABLE.

5.7.1. Alternate Keyboard.

5.7.1.1. Primary interpretations. Reprogramming the TQM is initiated by setting the front panel key switch to the TABLE UPDATE position. This disables the normal operations of the Monitor and enables the reprogramming mode. When in this mode, most of the front panel switches are disabled. Those that remain enabled fall into two groups. One group retains its operational interpretation. This includes the six TIRE TYPE and the two RETREAD MODE switches. The other group is enabled only in the reprogamming mode. These are the CLEAR, NEXT, and ENTER switches. All other switches have no Monitor operations interpretation in the reprogramming mode. See Figure 5-51 for panel markings to be used in the update mode.

The NEXT switch is used for two functions. When depressed initially, it starts an active reprogramming sequence. This is indicated by the flashing of the NEXT LED. Any subsequent depressions of the NEXT switch while its LED is flashing act to step through the reprogramming sequence. The specifics of the stepping operation depend on which reprogramming sequence is active.

The active reprogramming sequence is determined by which switch is depressed immediately after the initial depressing of the NEXT key. This switch stroke will enable what is called the primary interpretation of the switch. The supplied keyboard shows the primary interpretation of each switch as the first text below the switch. For example, referring to Figure 5-51, the switch which selects the TRUCK/T 1 TIRE TYPE in the operational mode will have a primary interpretation of THICK in the reprogramming mode. This provides access to the stored index of tread thickness which will enable the programmer to ultimately access the stored temperature/thickness compensation factors. This switch also has a secondary interpretation as the number "6." This will be discussed later in par. 5.7.2.3. on memory modification.

If any keystroke results in an error condition (signaled by the appearance of an "E" on the display, a flashing of the CLEAR LED, and a failure in Monitor responsiveness), the CLEAR switch must be depressed to release the failure condition hold state and to abort the current reprogramming sequence. The operator may also use the CLEAR switch at any time he chooses to abort a reprogramming sequence for any reason.

The ENTER switch is used to terminate a reprogramming sequence normally. If no data has been entered, the ENTER function leaves memory unaltered and extinguishes the NEXT LED. If data has been entered, it is stored into memory.

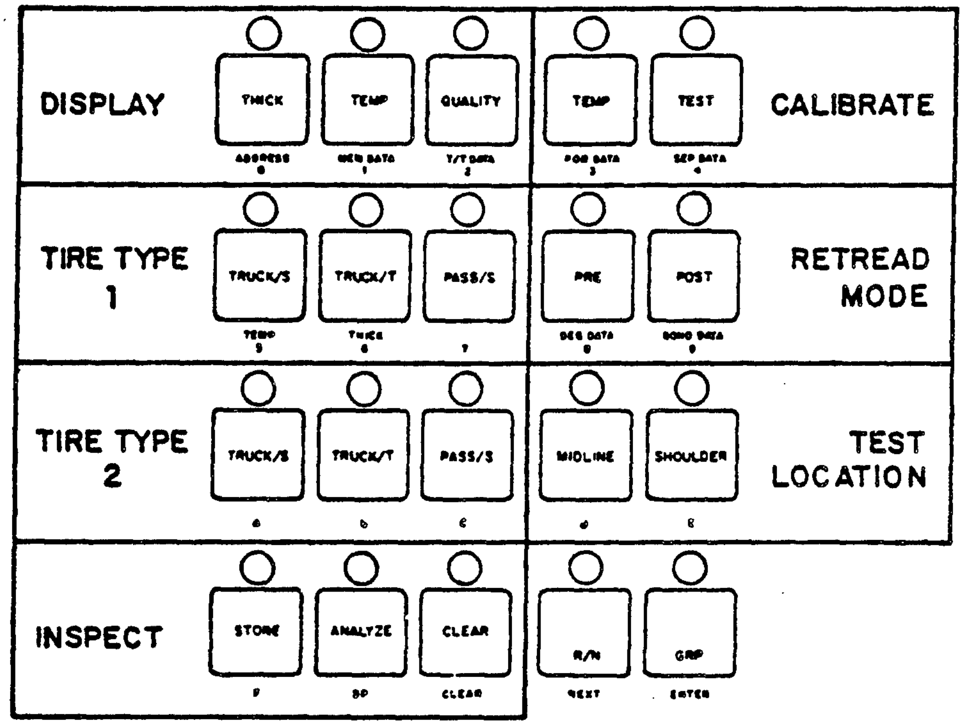


Figure 5-51. TQM Selector Switches

5.7.1.2. Secondary interpretations. Once a parameter of primary interpretation has been entered, all the front panel switches become interpretable according to the second function indicated on the front panel overlay. Typically this is an interpretation of numeric input with value 0 to 9, alphabetic input of letters A through F, and/or a decimal point. The correctness and meaning of subsequent input will be dictated by the primary interpretation of the sequence-initiating switch.

CAUTION

AT NO TIME SHOULD POWER BE REMOVED FROM THE TQM DURING UPDATE OPERATIONS. ADDITIONALLY, THE TQM MUST NOT BE TURNED OFF BY REMOVING ITS LINE PLUG FROM A POWER SOURCE AT ANY TIME. TRANSIENTS GENERATED BY SUCH POWER LOSSES CAN PARTIALLY OR COMPLETELY ERASE EEPROM CONTENTS.

5.7.2. Keying Instructions.

5.7.2.1. Temperature/thickness compensation tables. The Monitor is delivered with capability of revising the lookup tables used to compensate reflected ultrasonic amplitudes for both tread thickness and tread temperature. Each compensating factor is dually indexed by a temperature index between 30° and 115° and by a thickness index between four- and twenty-sixteenths of an inch. The first access to any temperature/thickness compensation factor must be preceded by at least one setting of each index. An error condition will result if an attempt is made to access a compensating factor without prior indexing.

- Temperature Indexing. Setting the compensation table temperature index is performed by pressing the NEXT and TEMP switches in sequence when in the reprogramming mode. This initiates the temperature index reprogramming sequence as indicated by the flashing of the NEXT LED and by the display of the current temperature index. If the current index is the value desired by the programmer, he should leave the value unaltered by pressing the ENTER switch next in sequence. This will terminate the temperature index reprogramming sequence. However, if the programmer wishes to alter the temperature index, he may do so by one of two methods. One method is to successively press the NEXT switch until the desired index value is displayed. The other method is to explicity enter the desired value by sequentially pressing switches according to their secondary interpretations. The number entered must be a multiple of 5 (60, 65, 70, etc.). Either method requires depression of the ENTER switch to store the new index value and terminate the temperature index reprogramming sequence. An error condition will result if an attempt is made to set the temperature index outside the range of 30° to 115° or if an index is entered that is not divisible by five.

- Thickness Indexing. Setting the compensation table thickness index is performed by pressing the NEXT and THICK switches in sequence when in the reprogramming mode. This initiates the thickness index reprogramming sequence as indicated by the flashing of the NEXT LED and by the display of the current thickness index. If the current index is the value desired by the programmer, he should leave the value unchanged by pressing the ENTER switch next in sequence. This will terminate the thickness index reprogramming sequence. However, if the programmer wishes to change the thickness index, he may do so by one of two methods. One method is to successively press the NEXT switch until the desired index value is displayed. The other method is to explicitly enter the desired value by sequentially pressing switches according to their secondary interpretation. Either method requires depression of the ENTER switch to store the new index value and terminate the thickness index reprogramming sequence. If a thickness index value outside the range of 4 to 20 is entered, an error condition will result.

- Tire Type Selections. After temperature and thickness indices have been set, the operator should assure himself that he has selected the appropriate TIRE TYPE before accessing the compensation factor. This is because the TCM holds three tables of compensation factors for the three pair of tire types. Which table is accessed is determined by the TIRE TYPE enabled at the time of access. If the type selected is that desired by the operator, he may then proceed to the access described in the next paragraph. Otherwise, he may select the desired TIRE TYPE without leaving the UPDATE mode by simply pressing the appropriate TIRE TYPE switch using its operational interpretation. For this, no use is made of the NEXT or ENTER switches.

- Compensation Factor Examination/Alteration. If both temperature and thickness indices have been set, access to the compensation factor can be made by pressing the NEXT and T/T DATA switches in sequence when in the reprogramming mode. This initiates the compensation factor reprogramming sequence as indicated by the flashing of the NEXT LED and by the display of the indexed compensation factor. If the current factor is the value desired by the programmer, he may leave the value unchanged by pressing either the NEXT switch or the ENTER switch. Pressing the NEXT switch will step the Monitor to the next compensation factor in the table. Whether this step was toward a factor related to higher temperature or to greater thickness depends upon which of the two indices was last accessed prior to the compensation factor access. The programmer will be reminded of which index was last accessed by the flashing of its LED during the compensation factor reprogramming sequence. Pressing the ENTER switch will terminate the compensation factor reprogramming sequence. If the programmer wishes to alter the value of the indexed factor, he must explicitly enter the desired value by sequentially pressing switches according to their secondary interpretation. He must then press the ENTER switch to store the new compensation factor and to terminate the compensating factor reprogramming sequence. Any attempt to enter a factor in excess of 9.99 will cause an error condition.

5.7.2.2. Accept/reject parameters. The monitor is delivered with the capability of revising the thresholds and coefficients used in classification and analysis of the ultrasonic reflection pattern during tire quality testing. There are four parameter categories grouped according to the related tire fault. These categories are:

- Porosity detection parameters
- Separation detection parameters
- Degradation detection parameters
- Bondline detection parameters

Where a parameter is uniquely specified by the operational mode switch settings of TIRE TYPE and RETREAD MODE, reprogramming mode access to that parameter will yield its current stored value to display and modification. In all cases, access to the parameter value will be mediated by an intermediate access through the name of the parameter. That is, the programmer will not access the parameter value until he enters the parameter name using the secondary interpretation of the switches followed by an ENTER switch depression.

The principal function of the intermediate name access is to provide a built-in list reminding the programmer of the various parameters available. Thus, after he selects the parameter category, the programmer may access the parameter value by one of two methods. He may sequence through parameter names by successively pressing the NEXT switch until he finds the desired name and enters it, or he may enter the parameter name immediately without prior searching. In either case, it is the active entry of the name followed by pressing the ENTER switch that provides access to the value. If a nonexistent or unrelated parameter name is entered, an error condition will result.

Parameters can be of a threshold type and a coefficient type. Thresholds are integer numbers scaled to the 0 to 30 quality scale displayed during inspection. Coefficients are real positive numbers restricted to values less than 10.00. Any entry of an unexpected or inappropriate number, name, or character will generate an error condition.

If the parameter value is to be left unaltered after viewing, the programmer simply presses the ENTER switch to return to a state where he can start another reprogramming sequence. However, if the programmer wishes to alter the value of the parameter, he must enter the new value by pressing the switches according to their secondary interpretation. If the new value is not an interger, the DP (decimal point) switch must be used. The new value will be echoed on the TCM display, but will not be stored until the programmer presses the ENTER switch.

Two examples are presented to clarify the techniques of accept/reject parameter reprogramming:

- Example 1: Altering the Porosity Detection Amplitude threshold applied to Post-Retread Inspection: This parameter can take on one of two values depending on whether the RETREAD MODE is PRE or POST. Therefore, before initiating the porosity accept/reject parameter reprogramming sequence, the programmer must assure that he will access the correct parameter by first selecting the appropriate RETREAD MODE. This can be done without leaving the reprogramming mode by simply pressing the desired RETREAD MODE switch according to its operational interpretation. The LED confirms successful mode selection. The programmer can now begin the reprogramming sequence by pressing the NEXT and POR DATA switches in order. The displays will show a flashing NEXT LED and the name of the accessible porosity parameter, A11. As indicated in the upper left of Figure 5-52 there is only this one parameter name in the list and it accesses RETREAD MODE-specific storage. To access the parameter value, the programmer next enters the name by pressing the switch sequence:

  A 1 1 ENTER

  using secondary interpretation of the relevant switches. At this point, the integer value (usually a 10) will appear. If the programmer does not want to change this value, he can exit this reprogramming sequence by pressing the ENTER switch and the value will be retained. However, if the programmer wishes to change this parameter to a new value, he must enter the new value by pressing switches according to their secondary interpretation. For example, if the new value is to be 5, the programmer must press the switch sequence:

  5 ENTER

  The value is stored when the ENTER switch is pressed.

- Example 2: Altering the Bondline Detection Parameter C1 Applied to Passenger 1 Inspection: The bondline

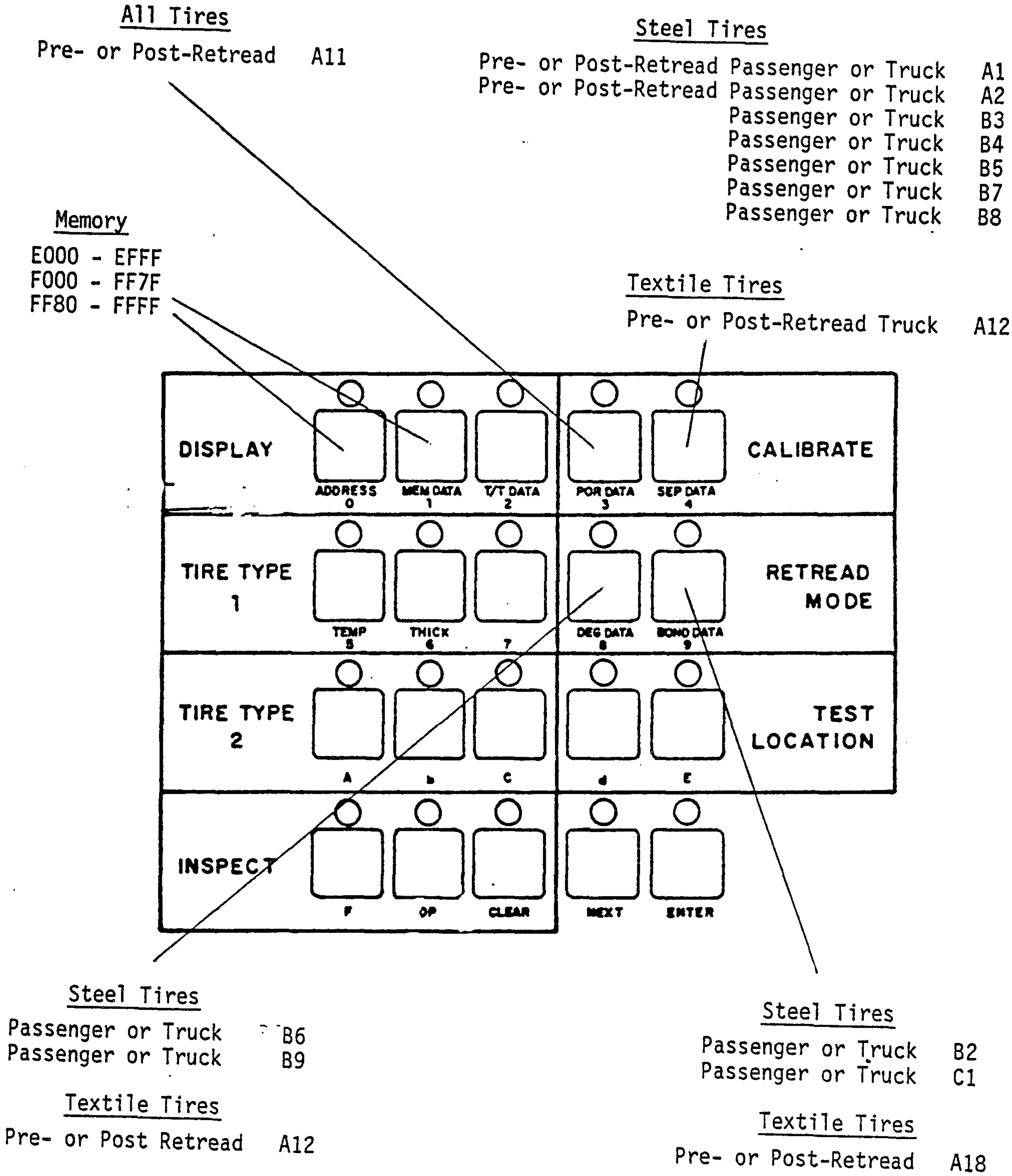


Figure 5-52. Parameters

accept/reject parameters can take on 1 of 12 possible values depending on the TIRE TYPE selected and, if a textile TIRE TYPE is selected, the RETREAD MODE. Therefore, before initiating the bondline parameter reprogramming sequence, the programmer must assure that he will access the correct parameter by first selecting the appropriate TIRE TYPE and, if necessary, the RETREAD MODE. As explained in example 1, this can be done without leaving the reprogramming mode by pressing the relevant switches according to their operational interpretation. The LEDs will confirm successful selection. Incorrect selections will create an error lock condition with a displayed "E," capable of reset by pressing the CLEAR switch. Once the above assurances are made, the programmer can begin the bondline parameter reprogramming sequence by pressing the NEXT and BOND DATA switches in order. The displays will show a flashing NEXT LED and a name of a bondline parameter. As indicated in the lower right of Figure 5-52, there are two such parameters (B2 and C1) for each steel-belted TIRE TYPE and one such parameter (A18) for each textile plied TIRE TYPE. However, each textile tire bondline parameter can take on one of two values depending on the RETREAD MODE selected (as in example 1.) The reprogramming of textile tire bondline parameters is similar to that described in example 1.

In this example, the TIRE TYPE selected is PASS/S 1. Therefore, the first bondline reprogramming sequence display will be the parameter name B2. At this point, the programmer can sequence through the name list by consecutively pressing the NEXT switch and eventually he will reach the name he wants (in his case, C1). To access the parameter value, the programmer must enter the parameter name. In this example, this done by pressing the switch sequence:

C 1 ENTER

At this point, a non-integer value (usually 0.60) will appear. To change the parameter to a new value, the programmer must now enter the new value by pressing switches according to their secondary interpretation. For example, if the new value is to be 0.70, the programmer can press any one of the following switch sequences:

DP 7 ENTER

DP 7 ENTER

0 DP 7 0 ENTER

0 DP 7 0 ENTER

The value will stored when the ENTER switch is pressed.

5.7.2.3. Direct memory reprogramming. The Monitor is delivered with the capability of directly examining and revising the microcomputer RAM. All communications for this type of reprogramming are done using numbers expressed in the base-sixteen, or hexadecimal, number system. Memory that can be altered lie in these address ranges:

E000 - EFFF	EEPROM
F000 - FF7F	General RAM
FF80 - FFFF	Monitor Stack Region

Any attempt to alter memory that lies outside these ranges will result in an error condition. However, any memory within the microcomputer's addressing space of 0000 - FFFF can be examined.

CAUTION

DIRECT MEMORY REPROGRAMMING SHOULD ONLY BE PERFORMED BY PERSONS WITH MICROCOMPUTER SYSTEM EXPERIENCE IN AND KNOWLEDGE OF THE ALLOCATION OF MEMORY WITHIN THIS MONITOR. IMPROPER ALTERATION OF MEMORY CAN CAUSE UNPREDICTABLE MALFUNCTIONS. THE PROGRAMMER ESPECIALLY SHOULD BE AWARE THAT ALTERATION OF MEMORY IN THE STACK REGION WILL CAUSE A MONITOR "CRASH."

Normal alterations for TQM maintenance or adjustment will only be done within the EEPROM address range. The TQM automatically handles addressing for alterations of the temperature/thickness compensation tables and of the accept/reject parameters as described in pars. 5.7.2.1. and 5.7.2.2. Other alterations are accomplished by directly accessing EEPROM as described in this section.

Most of the directly accessed parameters are not used as they reside in EEPROM. Instead, each is loaded into RAM by an appropriate selection process triggered from the front panel keys and it is from that RAM that the CPU reads its value. Because of this, the programmer should remember to reselect the mode(s) of the desired inspection after altering EEPROM in this way so as to activate the altered parameter values.

Access to any memory is typically executed by first programming the memory address and then accessing the addressed memory or consecutive string of memories.

- Addressing. Setting the memory address index is performed by pressing the NEXT and ADDRESS switches in sequence when in the reprogramming mode. This initiates the memory address reprogramming sequence as indicated by the flashing of the NEXT LED and by the display of the current address in hexadecimal code. If the displayed address is the value desired by the programmer, he should leave it unchanged by pressing the ENTER switch next in sequence. However, if the programmer wishes to alter the address, he may do so by one of two methods. One method is to successively press the NEXT switch until the desired address is displayed. The other method is to explicitly enter the desired address by sequentially pressing switches according to their secondary interpretation. Either method requires depression of the ENTER switch to set the new address and terminate the memory address reprogramming sequence.

- Memory Examination/Alteration. If the programmer knows or has set the address, access to the memory can be made by pressing the NEXT and MEM DATA switches in sequence when in the reprogramming mode. This initiates the direct memory reprogramming sequence as indicated by the flashing of the NEXT LED and by the display of the addressed memory content in hexadecimal code. If the displayed content is the content desired by the programmer, he may leave it unchanged. by pressing the NEXT or the ENTER switch. Pressing the next switch will step the Monitor to the next address in memory and display its contents. Pressing the ENTER switch at any time will terminate the direct memory reprogramming sequence. If the programmer wishes to alter the content of the addressed memory, he must explicitly enter the desired content by sequentially pressing switches according to their secondary interpretation. He must then press the ENTER switch to store the new memory contents and to terminate the direct memory reprogramming sequence.

5.7.2.4. Summary of reprogramming key commands. The following is a summary of the reprogramming sequence initiating commands discussed above. The accompanying flowchart in Figure 5-53 illustrates the process flow within a typical reprogramming sequence. The programmer's actions are enclosed in rectangles; the Monitor's responses or processes are enclosed in circles. Ten switches have a primary interpretation when the Monitor is in the reprogramming mode and each one, when pressed subsequent to an initial NEXT switch depression, will cause a display of the current stored value of the associated parameter. For example, a NEXT TEMP switch sequence would cause a display of the current value of the stored temperature index to a temperature/thickness compensation factor.

From this state, the programmer can 1) terminate the reprogramming sequence by pressing the ENTER switch, 2) step to another value of the associated parameter by pressing the NEXT switch to cause the Monitor to increment an index i by an associated amount j, or 3) insert a new

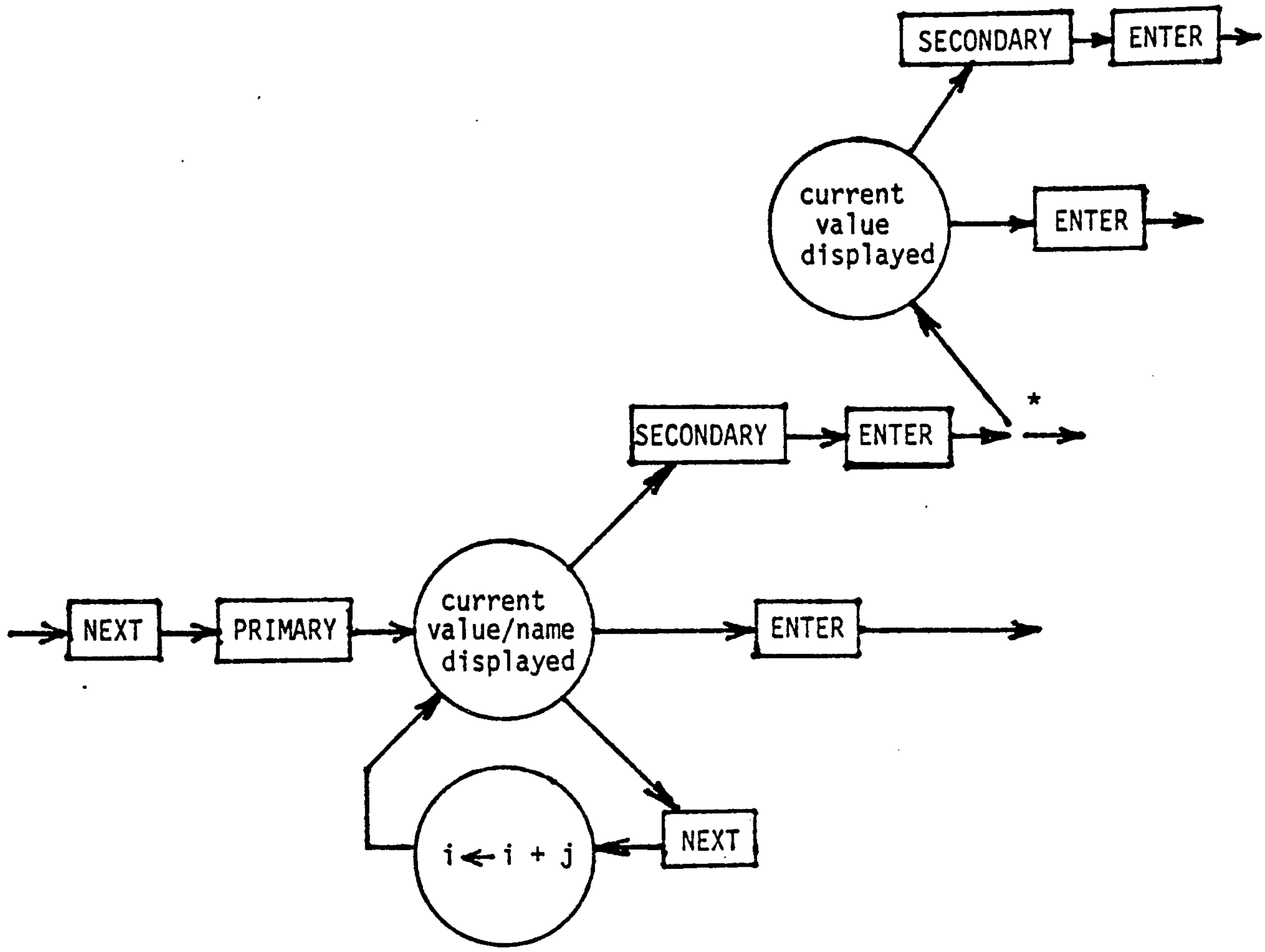


Figure 5-53. Reprogramming Sequences

value by pressing switches according to their secondary interpretation in a sequence terminated by an ENTER switch depression.

Note that in certain cases, entry of values according to their secondary interpretation of the keys will not terminate the reprogramming sequence, but will branch to a second display of a current stored value. This point is identified on the flowchart by a "*." This occurs when accept/reject parameters are being reprogrammed and access to the specific parameter value requires invocation of the parameter name. The first entry of a value in this case in interpreted as the entry of the parameter name. The branch to second display then shows the current value of the parameter itself. This branch will occur only once. The stepping use of the NEXT switch will not work in this branch.

As an illustration of this type of interaction, suppose the programmer has entered the switch sequence NEXT SEP DATA. If the selected TIPE TYPE is any TRUCK/S or PASS/S, the display will show the second belt separation threshold name A1. It cannot clearly show the thresholds (Bn's) associated with various comparative structural tests. The programmer must now enter a letter-number combination to specify the parameter he wants to access, e.g., A1. The branch will then show the value stored for the threshold A1. These procedures apply to all the following switch commands.

(1) Direct Memory Reprogramming

NEXT ADDRESS	Accesses memory address for memory read/write
NEXT MEM DATA	Access memory for memory read/write

(2) Temperature/Thickness Compensation Factor Reprogramming

NEXT T/T DATA	Accesses compensation factor
NEXT TEMP	Accesses temperature factor index to factor
NEXT THICK	Accesses thickness index to factor

(3) Accept/Reject Parameter Reprogramming

NEXT POR DATA	Accesses porosity threshold name
NEXT SEP DATA	Accesses separation parameter name
NEXT DEG DATA	Accesses degradation parameter name
NEXT BOND DATA	Accesses bondline parameter name

(4) Reprogramming Mode Control

NEXT	Steps through list
CLEAR	Aborts reprogramming sequence, resets errors
ENTER	Terminates reprogramming sequence.

APPENDIX A

EEPROM LISTING

```
LOCATION OBJECT CODE LINE     SOURCE LINE

                        *  TEMPERATURE/THICKNESS COMPENSATION TABLES:

                        *                                     TEMPERATURE
                        *                 .------------------------------------->
                        *               T I
                        *               H I
                        *               I I
                        *               C I
                        *               K I
                        *               N I
                        *               E I
                        *               S I
                        *               S I
                        *                 V



                         ORG BASE


                        *  PASSENGER STEEL-BELTED

                        *  4/16"

                        *  30 deg                        70 deg                        115 deg

E000                    PSRTBL
E000 05410458            DW 541H,458H,380H,302H,254H,204H,189H,174H,161H,146H,135H,125H,118H,110H,108H,106H,105H,104H
E024 04710398            DW 471H,398H,327H,260H,216H,173H,159H,146H,134H,121H,112H,104H,097H,090H,087H,086H,084H,083H
E048 04090347            DW 409H,347H,281H,223H,184H,147H,133H,123H,111H,101H,093H,086H,079H,074H,071H,070H,067H,067H
E06C 03560302            DW 356H,302H,242H,192H,156H,125H,112H,103H,092H,083H,077H,071H,065H,061H,057H,056H,054H,053H
E090 03100262            DW 310H,262H,208H,165H,133H,106H,094H,087H,076H,069H,064H,059H,053H,050H,046H,046H,043H,043H
E0B4 02700228            DW 270H,228H,179H,142H,113H,091H,079H,073H,063H,058H,053H,049H,044H,041H,038H,037H,034H,034H
E0D8 02350199            DW 235H,199H,154H,122H,096H,077H,066H,061H,053H,046H,044H,041H,036H,033H,031H,030H,028H,027H
E0FC 02040173            DW 204H,173H,132H,105H,081H,065H,056H,051H,044H,040H,037H,034H,029H,027H,025H,024H,022H,022H
E120 01780150            DW 178H,150H,114H,090H,069H,056H,047H,043H,036H,033H,030H,028H,024H,022H,020H,020H,018H,017H
E144 01540131            DW 154H,131H,098H,078H,059H,047H,039H,036H,030H,027H,025H,023H,020H,018H,016H,016H,014H,014H
E168 01340114            DW 134H,114H,084H,067H,050H,040H,033H,030H,025H,023H,021H,019H,016H,015H,013H,013H,011H,011H
E18C 00000000            DW 000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H
E1B0 00000000            DW 000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H
E1D4 00000000            DW 000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H
E1F8 00000000            DW 000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H
E21C 00000000            DW 000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H
E240 00000000            DW 000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H,000H

                        * 20/16"
```

```
LOCATION OBJECT CODE LINE     SOURCE LINE

                       60 *  TEMPERATURE/THICKNESS COMPENSATION TABLES:
                       61
                       62 *                         TEMPERATURE
                       63 *                .----------------------------------->
                       64 *              T I
                       65 *              H I
                       66 *              I I
                       67 *              C I
                       68 *              K I
                       69 *              N I
                       70 *              E I
                       71 *              S I
                       72 *              S I
                       73 *                V
                       74
                       75
                       76
                       77 *   TRUCK     TEXTILE-BELTED
                       78
                       79 *  4/16"
                       80
                       81 *  30 deg                          70 deg                           115 deg
                       82
E264                   83 TTXTEL
E264 02600225          84  DW 260H,225H,200H,174H,157H,146H,136H,125H,114H,108H,102H,096H,090H,095H,100H,105H,110H,115H
E288 02500220          85  DW 250H,220H,190H,164H,147H,134H,122H,112H,102H,096H,091H,085H,079H,084H,089H,094H,098H,102H
E2AC 02400215          86  DW 240H,215H,185H,153H,137H,122H,108H,099H,090H,084H,079H,074H,069H,073H,077H,082H,087H,091H
E2D0 02540220          87  DW 254H,220H,180H,143H,127H,110H,094H,086H,078H,073H,068H,064H,060H,066H,070H,073H,076H,079H
E2F4 02620225          88  DW 262H,225H,185H,147H,131H,115H,100H,089H,078H,071H,065H,058H,052H,057H,060H,062H,065H,068H
E318 02700230          89  DW 270H,230H,190H,150H,135H,120H,105H,091H,078H,069H,062H,055H,048H,048H,051H,053H,055H,057H
E33C 02750235          90  DW 275H,235H,195H,155H,141H,126H,112H,098H,082H,073H,064H,054H,045H,045H,046H,047H,048H,048H
E360 02800240          91  DW 280H,240H,200H,160H,146H,132H,118H,101H,085H,074H,066H,056H,046H,046H,047H,048H,049H,049H
E384 02850245          92  DW 285H,245H,205H,165H,152H,137H,124H,106H,088H,077H,067H,057H,047H,047H,048H,049H,050H,051H
E3A8 02900250          93  DW 290H,250H,210H,170H,157H,143H,130H,110H,090H,080H,069H,059H,048H,048H,049H,050H,051H,053H
E3CC 02950255          94  DW 295H,255H,215H,175H,162H,148H,135H,115H,093H,082H,071H,062H,049H,049H,052H,053H,055H,055H
E3F0 03000260          95  DW 300H,260H,220H,180H,167H,153H,140H,120H,095H,083H,072H,061H,050H,052H,054H,056H,058H,059H
E414 03050265          96  DW 305H,265H,225H,185H,172H,158H,145H,125H,098H,086H,075H,063H,051H,053H,055H,058H,060H,063H
E438 03100270          97  DW 310H,270H,230H,190H,177H,163H,150H,130H,100H,088H,077H,065H,052H,055H,058H,061H,064H,067H
E45C 03150275          98  DW 315H,275H,235H,195H,182H,168H,155H,135H,103H,091H,079H,066H,053H,057H,061H,065H,069H,072H
E480 03200280          99  DW 320H,280H,240H,200H,187H,173H,160H,140H,105H,093H,080H,067H,054H,058H,063H,067H,071H,076H
E4A4 03250285         100  DW 325H,285H,245H,205H,192H,178H,165H,145H,108H,095H,082H,069H,055H,060H,065H,070H,075H,080H
                      101
                      102 * 20/16"
```

```
LOCATION OBJECT CODE LINE     SOURCE LINE

                          *  TEMPERATURE/THICKNESS COMPENSATION TABLES:

                          *                            TEMPERATURE
                          *                   .--------------------------------------->
                          *                 T I
                          *                 H I
                          *                 I I
                          *                 C I
                          *                 K I
                          *                 N I
                          *                 E I
                          *                 S I
                          *                 S I
                          *                   V




                          *   TRUCK      STEEL-BELTED

                          *  4/16"

                          *  30 deg                           70 deg                            115 deg

E4C8                      TSRTBL
E4C8 02620222              DW 252H,222H,201H,168H,152H,146H,142H,135H,133H,125H,117H,108H,108H,104H,104H,099H,098H,093H
E4EC 02480211              DW 248H,211H,189H,158H,142H,136H,131H,125H,121H,114H,106H,098H,097H,093H,092H,088H,087H,082H
E510 02360201              DW 236H,201H,178H,148H,132H,126H,121H,115H,110H,104H,097H,089H,088H,084H,082H,078H,076H,072H
E534 02240191              DW 224H,191H,167H,139H,123H,117H,111H,105H,100H,095H,088H,081H,079H,076H,073H,070H,067H,064H
E558 02130181              DW 213H,181H,157H,131H,114H,109H,102H,097H,091H,086H,080H,074H,071H,068H,065H,062H,059H,056H
E57C 02020172              DW 202H,172H,148H,123H,106H,101H,094H,089H,083H,078H,073H,067H,064H,061H,058H,055H,052H,049H
E5A0 01920163              DW 192H,163H,139H,116H,099H,094H,086H,082H,075H,071H,066H,061H,058H,055H,051H,049H,046H,043H
E5C4 01830155              DW 183H,155H,130H,109H,092H,088H,079H,076H,069H,065H,060H,056H,052H,050H,046H,044H,040H,038H
E5E8 01730147              DW 173H,147H,123H,102H,085H,082H,073H,069H,062H,059H,055H,051H,047H,045H,041H,039H,035H,034H
E60C 01650140              DW 165H,140H,115H,096H,079H,076H,067H,064H,057H,054H,050H,046H,042H,040H,036H,035H,031H,030H
E630 01570133              DW 157H,133H,108H,090H,074H,071H,062H,059H,052H,049H,045H,042H,038H,036H,032H,031H,027H,026H
E654 01490126              DW 149H,126H,102H,085H,069H,066H,057H,054H,047H,044H,041H,038H,034H,033H,029H,027H,024H,023H
E678 01410120              DW 141H,120H,096H,080H,064H,061H,052H,050H,043H,040H,038H,035H,031H,029H,026H,024H,021H,020H
E69C 01340114              DW 134H,114H,090H,075H,059H,057H,048H,046H,039H,037H,034H,032H,028H,026H,023H,022H,019H,018H
E6C0 01280108              DW 128H,108H,085H,071H,055H,053H,044H,042H,035H,033H,031H,029H,025H,024H,020H,019H,016H,015H
E6E4 01210103              DW 121H,103H,079H,066H,051H,049H,041H,039H,032H,030H,028H,026H,022H,021H,018H,017H,014H,014H
E708 01150098              DW 115H,098H,075H,062H,048H,046H,038H,036H,029H,028H,026H,024H,020H,019H,016H,015H,013H,012H

                          * 20/16"

                          *RUBBER CALIBRATION BLOCK       (THICKNESS ONLY)

                          *UNITY MULTIPLICATION FACTOR FOR THE RUBBER BLOCKS...ENABLE FINAL FACTORS
                          * WHEN DECISION IS MADE

E72C                      RUBBERTABLE
E72C 01000100              DW 100H,100H,100H,100H,100H,100H,100H,100H,100H,100H,100H,100H,100H,100H,100H,100H,100H

                          *DW 184H,158H,136H,117H,100H,086H,074H,063H,054H,047H,040H,034H,030H,025H,022H,019H
                          *DW 016H
```

```
LOCATION OBJECT CODE LINE     SOURCE LINE

                      160  ORG BASE+0780H
                      161
                      162 *HARDWARE GAIN VALUES:
                      163
E780 0AD2             164 ROM_INGAIN  DW 0AD2H  GAIN OF RECEIVER STAGE 1
E782 0900             165 ROM_FN_GAIN DW 0900H  MAXIMUM AGC GAIN AT 5/4" (LOW CONTROL VOLTAGE)
E784 0740             166 ROM_PK_GAIN DW 0740H  MINIMUM AGC GAIN AT 1/4" (HIGH CONTROL VOLTAGE)
E786 02C6             167 ROM_SLOPE   DW 02C6H  DAC SLOPE
E788 0984             168 ROM_OUTGAIN DW 0964H  GAIN OF RECEIVER STAGE 2
                      169
E78A 09E8             170 GRP_OUTGAIN DW 09E8H  GAIN OF RECEIVER STAGE 2 WHEN GRP TYPE ACTIVE
                      171
E78C                  172  DS 4
                      173
                      174 *CALIBRATION CONSTANTS:
                      175
E790                  176 AMPTABLE
E790 0032             177  DW 50 PSR_I  12=50/4.23
E792 003F             178  DW 63 TTX_I  15=63/4.23
E794 005C             179  DW 92 TSR_I  22=92/4.23
E796 003F             180  DW 63 GRP    15=63/4.23
E798 002A             181  DW 42 RN     10=42/4.23
E79A 0032             182  DW 50 PSR_II 12=50/4.23
E79C 003F             183  DW 63 TTX_II 15=63/4.23
E79E 005C             184  DW 92 TSR_II 22=92/4.23
                      185
E7A0                  186 ALTTABLE
E7A0 0032             187  DW 50 PSR_I  12=50/4.23
E7A2 003F             188  DW 63 TTX_I  15=63/4.23
E7A4 0032             189  DW 50 TSR_I  12=50/4.23
E7A6 003F             190  DW 63 GRP    15=63/4.23
E7A8 002A             191  DW 42 RN     10=42/4.23
E7AA 0032             192  DW 50 PSR_II 12=50/4.23
E7AC 003F             193  DW 63 TTX_II 15=63/4.23
E7AE 0032             194  DW 50 TSR_II 12=50/4.23
                      195
E7B0 01DE             196 CAL_LOW_WINDOW  DW SR*2390/SC  23.9 us
E7B2 031E             197 CAL_HIGH_WINDOW DW SR*3990/SC  39.9 us
                      198
E7B4                  199                 DS 4
                      200
E7B8 009C             201 DAC_LOW_1       DW SR*(0930-0150)/SC  7.8 us
E7BA 00D8             202 DAC_HIGH_1      DW SR*(0930+0150)/SC 10.8 us
E7BC 0156             203 DAC_LOW_2       DW SR*(1860-0150)/SC 17.1 us
E7BE 0192             204 DAC_HIGH_2      DW SR*(1860+0150)/SC 20.1 us
E7C0 0210             205 DAC_LOW_3       DW SR*(2790-0150)/SC 26.4 us  ESTIMATED FROM
E7C2 024C             206 DAC_HIGH_3      DW SR*(2790+0150)/SC 29.4 us    SCOPE
E7C4 02CA             207 DAC_LOW_4       DW SR*(3720-0150)/SC 35.7 us
E7C6 0306             208 DAC_HIGH_4      DW SR*(3720+0150)/SC 38.7 us
E7C8 0384             209 DAC_LOW_5       DW SR*(4650-0150)/SC 45.0 us
E7CA 03C0             210 DAC_HIGH_5      DW SR*(4650+0150)/SC 48.0 us
                      211
E7CC                  212                 DS 6
```

```
LOCATION OBJECT CODE LINE     SOURCE LINE

E7D2 0078            AGC_TRIG_OFFSET DW SR*0600/SC TIME AGC TAKES EFFECT AFTER TDR TRIGGER
E7D4 0140            MAINBANG_OFFSET DW SR*1600/SC TIME MAIN BANG OCCURS AFTER TDR TRIGGER

E7D6                                 DS 4

E7DA FFC4            MULTRING_LOW    DW -SR*0300/SC  - 3.00 us
E7DC 003C            MULTRING_HIGH   DW  SR*0300/SC  + 3.00 us

E7DE                                 DS 4

E7E2 0025            HOMOL_OFFSET    DW 0025H BCD REPRESENTATION OF PERCENTAGE AMPLITUDE VARIATION
E7E4 0042            SIG_BONDLINE    DW 0042H BCD REPRESENTATION OF AMPLITUDE OF "SIGNIFICANT" BONDLINE =10
E7E6 0064            BL_RED_FACTOR   DW 0064H BCD REPRESENTATION OF SEPARATION REJECTION LIMIT COEFFICIENT

E7E8                                 DS 2

E7EA 0028            SHIFTPERTEMP    DW   650/16     0.265us PER DEGREE PER INCH
E7EC 0098            TEMP_SLOPE      DW 136-(-16)
E7EE 0000            TEMP_OFFSET     DW        0
```

```
LOCATION OBJECT CODE LINE     SOURCE LINE

                         ORG BASE+0800H

                         * PEAK EXTRACTION AND WINDOWING PARAMETERS:

E800 06                  PSR_I_PRE_NAMP  DB 6                    MAXIMUM NOISE AMPLITUDE FROM GROUND
E801 06                  PSR_I_PRE_NWID  DB 6             50*06 NS MAX NOISE PEAKWIDTH
E802 06                  PSR_I_PST_NAMP  DB 6                    MAXIMUM NOISE AMPLITUDE FROM GROUND
E803 06                  PSR_I_PST_NWID  DB 6             50*06 NS MAX NOISE PEAKWIDTH
E804 0098                PSR_I_RINGOUT   DW SR*0760/SC  7.60 us MAIN BANG RINGOUT MASK
E806 000E                PSR_I_ENVGAP    DW SR*0070/SC  0.70 us INTER-ENVELOPE GAP
E808 001E                PSR_I_WIDTHMIN  DW SR*0150/SC  1.50 us NARROW ENVELOPE LIMIT
E80A 003C                PSR_I_ENVWIDTH  DW SR*0300/SC  3.00 us MAXIMUM ENVELOPE WIDTH
E80C 012C                PSR_I_FCLNTIME  DW SR*1500/SC 15.00 us MAX GARBAGE TIME LIMIT          ("FAR CLEANLINESS TIME")
E80E 0078                PSR_I_NPORTIME  DW SR*0600/SC  6.00 us MIN POROSITY TIME LIMIT         ("NEAR POROSITY TIME")
E810 012C                PSR_I_FPORTIME  DW SR*1500/SC 15.00 us MAX POROSITY TIME LIMIT         (" FAR POROSITY TIME")
E812 0064                PSR_I_NSTRTIME  DW SR*0500/SC  5.00 us MIN PEAK TIME OFFSET BEFORE PMAX ("NEAR STRUCTURE TIME")
E814 00C8                PSR_I_FSTRTIME  DW SR*1000/SC 10.00 us MAX PEAK TIME OFFSET AFTER PMAX  (" FAR STRUCTURE TIME")
E816 0028                PSR_I_LBN       DW SR*0200/SC  2.00 us MIN 2ND BELT - LINER TIME DIFFERENCE
E818 0050                PSR_I_LBF       DW SR*0400/SC  4.00 us MAX 2ND BELT - LINER TIME DIFFERENCE

E81A                      DS 38

E840 05                  TTX_I_PRE_NAMP  DB 5                    MAXIMUM NOISE AMPLITUDE FROM GROUND
E841 04                  TTX_I_PRE_NWID  DB 4             50*04 NS MAX NOISE PEAKWIDTH
E842 05                  TTX_I_PST_NAMP  DB 5                    MAXIMUM NOISE AMPLITUDE FROM GROUND
E843 04                  TTX_I_PST_NWID  DB 4             50*04 NS MAX NOISE PEAKWIDTH
E844 00A0                TTX_I_RINGOUT   DW SR*0800/SC  8.00 us MAIN BANG RINGOUT MASK
E846 0028                TTX_I_ENVGAP    DW SR*0200/SC  2.00 us INTER-ENVELOPE GAP
E848 001E                TTX_I_WIDTHMIN  DW SR*0150/SC  1.50 us NARROW ENVELOPE LIMIT
E84A 0078                TTX_I_ENVWIDTH  DW SR*0600/SC  6.00 us MAXIMUM ENVELOPE WIDTH
E84C 01F4                TTX_I_FCLNTIME  DW SR*2500/SC 25.00 us MAX GARBAGE TIME LIMIT        ("FAR CLEANLINESS TIME")
E84E 00C8                TTX_I_NPORTIME  DW SR*1000/SC 10.00 us MIN POROSITY TIME LIMIT       ("NEAR POROSITY TIME")
E850 0244                TTX_I_FPORTIME  DW SR*2900/SC 29.00 us MAX POROSITY TIME LIMIT       (" FAR POROSITY TIME")
E852 00C8                TTX_I_NSTRTIME  DW SR*1000/SC 10.00 us MIN PEAK TIME LIMIT BEFORE PA ("NEAR STRUCTURE TIME")
E854 00DC                TTX_I_FSTRTIME  DW SR*1100/SC 11.00 us MAX PEAK TIME OFFSET AFTER PA (" FAR STRUCTURE TIME")
E856 0000                TTX_I_LBN       DW SR*0000/SC
E858 0000                TTX_I_LBF       DW SR*0000/SC

E85A                      DS 38

E880 08                  TSR_I_PRE_NAMP  DB 8                    MAXIMUM NOISE AMPLITUDE FROM GROUND
E881 06                  TSR_I_PRE_NWID  DB 6             50*06 NS MAX NOISE PEAKWIDTH
E882 08                  TSR_I_PST_NAMP  DB 8                    MAXIMUM NOISE AMPLITUDE FROM GROUND
E883 06                  TSR_I_PST_NWID  DB 6             50*06 NS MAX NOISE PEAKWIDTH
E884 00A0                TSR_I_RINGOUT   DW SR*0F00/SC  8.00 us MAIN BANG RINGOUT MASK
E886 0014                TSR_I_ENVGAP    DW SR*0100/SC  1.00 us INTER-ENVELOPE GAP
E888 0028                TSR_I_WIDTHMIN  DW SR*0200/SC  2.00 us NARROW ENVELOPE LIMIT
E88A 0050                TSR_I_ENVWIDTH  DW SR*0400/SC  4.00 us MAXIMUM ENVELOPE WIDTH
E88C 01F4                TSR_I_FCLNTIME  DW SR*2500/SC 25.00 us MAX GARBAGE TIME LIMIT          ("FAR CLEANLINESS TIME")
E88E 0104                TSR_I_NPORTIME  DW SR*1300/SC 13.00 us MIN POROSITY TIME LIMIT         ("NEAR POROSITY TIME")
E890 021C                TSR_I_FPORTIME  DW SR*2700/SC 27.00 us MAX POROSITY TIME LIMIT         (" FAR POROSITY TIME")
E892 00C8                TSR_I_NSTRTIME  DW SR*1000/SC 10.00 us MIN PEAK TIME OFFSET BEFORE PMAX ("NEAR STRUCTURE TIME")
E894 00F0                TSR_I_FSTRTIME  DW SR*1200/SC 12.00 us MAX PEAK TIME OFFSET AFTER PMAX  (" FAR STRUCTURE TIME")
E896 003C                TSR_I_LBN       DW SR*0300/SC  3.00 us MIN 2ND BELT - LINER TIME DIFFERENCE
E898 0078                TSR_I_LBF       DW SR*0600/SC  6.00 us MAX 2ND BELT - LINER TIME DIFFERENCE

E89A                      DS 38
```

```
LOCATION OBJECT CODE LINE     SOURCE LINE

    E8C0 06           292 PSR_II_PRE_NAMP DB 6                    MAXIMUM NOISE AMPLITUDE FROM GROUND
    E8C1 06           293 PSR_II_PRE_NWID DB 6           50*26 NS MAX NOISE PEAKWIDTH
    E8C2 06           294 PSR_II_PST_NAMP DB 6                    MAXIMUM NOISE AMPLITUDE FROM GROUND
    E8C3 06           295 PSR_II_PST_NWID DB 6           50*06 NS MAX NOISE PEAKWIDTH
    E8C4 0098         296 PSR_II_RINGOUT  DW SR*0760/SC  7.60 us MAIN BANG RINGOUT MASK
    E8C6 000E         297 PSR_II_ENVGAP   DW SR*0070/SC  0.70 us INTER-ENVELOPE GAP
    E8C8 001E         298 PSR_II_WIDTHMIN DW SR*0150/SC  1.50 us NARROW ENVELOPE LIMIT
    E8CA 003C         299 PSR_II_ENVWIDTH DW SR*2300/SC  3.00 us MAXIMUM ENVELOPE WIDTH
    E8CC 012C         300 PSR_II_FCLNTIME DW SR*1500/SC 15.00 us MAX GARBAGE TIME LIMIT           ("FAR CLEANLINESS TIME")
    E8CE 0078         301 PSR_II_NPORTIME DW SR*0600/SC  6.00 us MIN POROSITY TIME LIMIT          ("NEAR POROSITY TIME")
    E8D0 012C         302 PSR_II_FPORTIME DW SR*1500/SC 15.00 us MAX POROSITY TIME LIMIT          (" FAR POROSITY TIME")
    E8D2 0064         303 PSR_II_NSTRTIME DW SR*0500/SC  5.00 us MIN PEAK TIME OFFSET BEFORE PMAX ("NEAR STRUCTURE TIME")
    E8D4 00C8         304 PSR_II_FSTRTIME DW SR*1000/SC 10.00 us MAX PEAK TIME OFFSET AFTER PMAX  (" FAR STRUCTURE TIME")
    E8D6 0028         305 PSR_II_LBN      DW SR*0200/SC  2.00 us MIN 2ND BELT - LINER TIME DIFFERENCE
    E8D8 0050         306 PSR_II_LBF      DW SR*0400/SC  4.00 us MAX 2ND BELT - LINER TIME DIFFERENCE
                      307
    E8DA              308  DS 38
                      309
    E900 05           310 TTX_II_PRE_NAMP DB 5                    MAXIMUM NOISE AMPLITUDE FROM GROUND
    E901 04           311 TTX_II_PRE_NWID DB 4           50*04 NS MAX NOISE PEAKWIDTH
    E902 05           312 TTX_II_PST_NAMP DB 5                    MAXIMUM NOISE AMPLITUDE FROM GROUND
    E903 04           313 TTX_II_PST_NWID DB 4           50*04 NS MAX NOISE PEAKWIDTH
    E904 00A0         314 TTX_II_RINGOUT  DW SR*0800/SC  8.00 us MAIN BANG RINGOUT MASK
    E906 0028         315 TTX_II_ENVGAP   DW SR*0200/SC  2.00 us INTER-ENVELOPE GAP
    E908 001E         316 TTX_II_WIDTHMIN DW SR*0150/SC  1.50 us NARROW ENVELOPE LIMIT
    E90A 0078         317 TTX_II_ENVWIDTH DW SR*0600/SC  6.00 us MAXIMUM ENVELOPE WIDTH
    E90C 01F4         318 TTX_II_FCLNTIME DW SR*2500/SC 25.00 us MAX GARBAGE TIME LIMIT        ("FAR CLEANLINESS TIME")
    E90E 00C8         319 TTX_II_NPORTIME DW SR*1000/SC 10.00 us MIN POROSITY TIME LIMIT       ("NEAR POROSITY TIME")
    E910 0244         320 TTX_II_FPORTIME DW SR*2900/SC 29.00 us MAX POROSITY TIME LIMIT       (" FAR POROSITY TIME")
    E912 00C8         321 TTX_II_NSTRTIME DW SR*1000/SC 10.00 us MIN PEAK TIME LIMIT BEFORE PA ("NEAR STRUCTURE TIME")
    E914 00DC         322 TTX_II_FSTRTIME DW SR*1100/SC 11.00 us MAX PEAK TIME OFFSET AFTER PA (" FAR STRUCTURE TIME")
    E916 0000         323 TTX_II_LBN      DW SR*0000/SC
    E918 0000         324 TTX_II_LBF      DW SR*0000/SC
                      325
    E91A              326  DS 38
                      327
    E940 08           328 TSR_II_PRE_NAMP DB 8                    MAXIMUM NOISE AMPLITUDE FROM GROUND
    E941 06           329 TSR_II_PRE_NWID DB 6           50*06 NS MAX NOISE PEAKWIDTH
    E942 08           330 TSR_II_PST_NAMP DB 8                    MAXIMUM NOISE AMPLITUDE FROM GROUND
    E943 06           331 TSR_II_PST_NWID DB 6           50*06 NS MAX NOISE PEAKWIDTH
    E944 00A0         332 TSR_II_RINGOUT  DW SR*0800/SC  8.00 us MAIN BANG RINGOUT MASK
    E946 0014         333 TSR_II_ENVGAP   DW SR*0100/SC  1.00 us INTER-ENVELOPE GAP
    E948 0028         334 TSR_II_WIDTHMIN DW SR*0200/SC  2.00 us NARROW ENVELOPE LIMIT
    E94A 0050         335 TSR_II_ENVWIDTH DW SR*0400/SC  4.00 us MAXIMUM ENVELOPE WIDTH
    E94C 01F4         336 TSR_II_FCLNTIME DW SR*2500/SC 25.00 us MAX GARBAGE TIME LIMIT           ("FAR CLEANLINESS TIME")
    E94E 0104         337 TSR_II_NPORTIME DW SR*1300/SC 13.00 us MIN POROSITY TIME LIMIT          ("NEAR POROSITY TIME")
    E950 021C         338 TSR_II_FPORTIME DW SR*2700/SC 27.00 us MAX POROSITY TIME LIMIT          (" FAR POROSITY TIME")
    E952 00C8         339 TSR_II_NSTRTIME DW SR*1000/SC 10.00 us MIN PEAK TIME OFFSET BEFORE PMAX ("NEAR STRUCTURE TIME")
    E954 00F0         340 TSR_II_FSTRTIME DW SR*1200/SC 12.00 us MAX PEAK TIME OFFSET AFTER PMAX  (" FAR STRUCTURE TIME")
    E956 003C         341 TSR_II_LBN      DW SR*0300/SC  3.00 us MIN 2ND BELT - LINER TIME DIFFERENCE
    E958 0078         342 TSR_II_LBF      DW SR*0600/SC  6.00 us MAX 2ND BELT - LINER TIME DIFFERENCE
                      343
    E95A              344  DS 38
```

```
LOCATION OBJECT CODE LINE     SOURCE LINE

   E980 10            346 GRP_PRE_NAMP DB 16                  MAXIMUM NOISE AMPLITUDE FROM GROUND
   E981 07            347 GRP_PRE_NWID DB 7          50*07 NS MAX NOISE PEAKWIDTH
   E982 10            348 GRP_PST_NAMP DB 16                  MAXIMUM NOISE AMPLITUDE FROM GROUND
   E983 07            349 GRP_PST_NWID DB 7          50*07 NS MAX NOISE PEAKWIDTH
   E984 00B0          350 GRP_RINGOUT  DW SR*0880/SC  8.80 US MAIN BANG RINGOUT MASK
   E986 0028          351 GRP_ENVGAP   DW SR*0200/SC  2.00 US INTER-ENVELOPE GAP
   E988 0028          352 GRP_WIDTHMIN DW SR*0200/SC  2.00 US NARROW ENVELOPE LIMIT
   E98A 0032          353 GRP_ENVWIDTH DW SR*0250/SC  2.50 US MAXIMUM ENVELOPE WIDTH
   E98C 0002          354 GRP_FCLNTIME DW SR*0010/SC  0.10 US MAX GARBAGE TIME LIMIT
   E98E 0001          355 GRP_NPORTIME DW SR*0005/SC  0.05 US MIN POROSITY TIME LIMIT
   E990 0002          356 GRP_FPORTIME DW SR*0010/SC  0.10 US MAX POROSITY TIME LIMIT
   E992 0001          357 GRP_NSTRTIME DW SR*0005/SC  0.05 US MIN PEAK TIME OFFSET
   E994 07CF          358 GRP_FSTRTIME DW SR*9995/SC 99.95 US MAX PEAK TIME OFFSET
   E996 0000          359 GRP_I_LBN    DW SR*0000/SC
   E998 0000          360 GRP_I_LBF    DW SR*0000/SC
                      361
   E99A               362  DS 38
                      363
   E9C0 08            364 RN_PRE_NAMP  DB 8                   MAXIMUM NOISE AMPLITUDE FROM GROUND
   E9C1 09            365 RN_PRE_NWID  DB 9          50*09 NS MAX NOISE PEAKWIDTH
   E9C2 08            366 RN_PST_NAMP  DB 8                   MAXIMUM NOISE AMPLITUDE FROM GROUND
   E9C3 09            367 RN_PST_NWID  DB 9          50*09 NS MAX NOISE PEAKWIDTH
   E9C4 0098          368 RN_RINGOUT   DW SR*0760/SC  7.60 US MAIN BANG RINGOUT MASK
   E9C6 0028          369 RN_ENVGAP    DW SR*0200/SC  2.00 US INTER-ENVELOPE GAP
   E9C8 0028          370 RN_WIDTHMIN  DW SR*0200/SC  2.00 US NARROW ENVELOPE LIMIT
   E9CA 0032          371 RN_ENVWIDTH  DW SR*0250/SC  2.50 US MAXIMUM ENVELOPE WIDTH
   E9CC 0002          372 RN_FCLNTIME  DW SR*0010/SC  0.10 US MAX GARBAGE TIME LIMIT
   E9CE 0001          373 RN_NPORTIME  DW SR*0005/SC  0.05 US MIN POROSITY TIME LIMIT
   E9D0 0002          374 RN_FPORTIME  DW SR*0010/SC  0.10 US MAX POROSITY TIME LIMIT
   E9D2 0001          375 RN_NSTRTIME  DW SR*0005/SC  0.05 US MIN PEAK TIME OFFSET
   E9D4 07CF          376 RN_FSTRTIME  DW SR*9995/SC 99.95 US MAX PEAK TIME OFFSET
   E9D6 0000          377 RN_I_LBN     DW SR*0000/SC
   E9D8 0000          378 RN_I_LBF     DW SR*0000/SC
                      379
   E9DA               380  DS 38
```

```
LOCATION OBJECT CODE LINE     SOURCE LINE

                         *PASSENGER STEEL-BELTED TIRE I PEAK IDENTIFICATION PARAMETERS:

EA00 0060                C1_PSR_I     DW 0060H I.D. PARSE COEFFICIENT OF PEAK B

                         *PASSENGER STEEL-BELTED TIRE I ACCEPT/REJECT PARAMETERS:

EA02 0024                B2_PSR_I     DW 0024H A/R TEST SB1 COEFFICIENT OF BONDLINE ROUGHNESS
EA04 0090                B3_PSR_I     DW 0090H A/R TEST SB1 COEFFICIENT OF SB2 SEPARATION
EA06 0020                B4_PSR_I     DW 0020H A/R TEST SB1 COEFFICIENT OF IMPLIED SB1 SEPARATION
EA08 0040                B5_PSR_I     DW 0040H A/R TEST SB1 COEFFICIENT OF SB2 AMPLITUDE
EA0A 0001                B6_PSR_I     DW 0001H A/R TEST SB2 COEFFICIENT OF PLY DEGRADATION
EA0C 0080                B7_PSR_I     DW 0080H A/R TEST SB2 COEFFICIENT OF PLY SEPARATION
EA0E 0090                B8_PSR_I     DW 0090H A/R TEST SB2 COEFFICIENT OF PLY SEPARATION
EA10 0030                B9_PSR_I     DW 0030H A/R TEST SB2 COEFFICIENT OF IMPLIED SB2 DEGRADATION
EA12 0089                A1_PSR_I_PRE DW 0089H A/R TEST SB2 SEPARATION THRESHOLD         = 21
EA14 0004                A2_PSR_I_PRE DW 0004H A/R TEST IMPLIED SB1 SEPARATION THRESHOLD =  1
EA16 0089                A1_PSR_I_PST DW 0069H A/R TEST SB2 SEPARATION THRESHOLD         = 21
EA18 0004                A2_PSR_I_PST DW 0004H A/R TEST IMPLIED SB1 SEPARATION THRESHOLD =  1

EA1A                      DS 38

                         *TRUCK TEXTILE-PLIED TIRE I PEAK IDENTIFICATION PARAMETERS:

EA40                     C1_TTX_I_PRE
EA40 00C8                PRELOWLIMIT_1   DW SR*1000/SC 10.00 US DEPTH TO PLY    18.5/64"
EA42                     C2_TTX_I_PRE
EA42 0258                PREHIGHLIMIT_1  DW SR*3000/SC 30.00 US DEPTH TO LINER  56.5/64"
EA44                     C1_TTX_I_PST
EA44 0256                POSTLOWLIMIT_1  DW SR*2990/SC 29.90 US DEPTH TO PLY    55.9/64"
EA46                     C2_TTX_I_PST
EA46 0370                POSTHIGHLIMIT_1 DW SR*4400/SC 44.00 US DEPTH TO LINER  83.0/64"

EA48                     C3_TTX_I
EA48 0070                LOWGAPLIMIT_1   DW SR*0560/SC  5.60 US MIN BONDLINE-PLY PEAK SEPARATION
EA4A                     C4_TTX_I
EA4A 00A4                MIDGAPLIMIT_1   DW SR*0820/SC  8.20 US MIN PLY-LINER PEAK SEPARATION
EA4C                     C5_TTX_I
EA4C 0104                HIGHGAPLIMIT_1  DW SR*1300/SC 13.00 US MAX PLY-LINER PEAK SEPARATION
EA4E                     C6_TTX_I
EA4E 0028                TEXTNULLGAP_1   DW SR*0200/SC  2.00 US GAP LIMIT

                         *TRUCK TEXTILE-PLIED TIRE I ACCEPT/REJECT PARAMETERS:

EA50 0013                A12_TTX_I_PRE DW 0013H A/R TEST DEGRADATION THRESHOLD FOR 0-5 YRS =  3
EA52 0093                A13_TTX_I_PRE DW 0093H A/R TEST SEPARATION THRESHOLD FOR 0-5 YRS  = 22
EA54 0025                A18_TTX_I_PRE DW 0025H A/R TEST BONDLINE THRESHOLD FOR ALL AGES   =  6
EA56 0013                A12_TTX_I_PST DW 0013H A/R TEST DEGRADATION THRESHOLD FOR 0-5 YRS =  3
EA58 0093                A13_TTX_I_PST DW 0093H A/R TEST SEPARATION THRESHOLD FOR 0-5 YRS  = 22
EA5A 0025                A18_TTX_I_PST DW 0025H A/R TEST BONDLINE THRESHOLD FOR ALL AGES   =  6

EA5C                      DS 36
```

```
LOCATION OBJECT CODE LINE     SOURCE LINE

                     437 *TRUCK STEEL-BELTED TIRE I PEAK IDENTIFICATION PARAMETERS:
                     438
   EA80 0060         439 C1_TSR_I     DW 0060H I.D. PARSE COEFFICIENT OF PEAK B
                     440
                     441
                     442 *TRUCK STEEL-BELTED TIRE I ACCEPT/REJECT PARAMETERS:
                     443
   EA82 0024         444 B2_TSR_I     DW 0024H A/R TEST SB1 COEFFICIENT OF BONDLINE ROUGHNESS
   EA84 0090         445 B3_TSR_I     DW 0090H A/R TEST SB1 COEFFICIENT OF SB2 SEPARATION
   EA86 0020         446 B4_TSR_I     DW 0020H A/R TEST SB1 COEFFICIENT OF IMPLIED SB1 SEPARATION
   EA88 0040         447 B5_TSR_I     DW 0040H A/R TEST SB1 COEFFICIENT OF SB2 AMPLITUDE
   EA8A 0001         448 B6_TSR_I     DW 0001H A/R TEST SB2 COEFFICIENT OF PLY DEGRADATION
   EA8C 0080         449 B7_TSR_I     DW 0080H A/R TEST SB2 COEFFICIENT OF PLY SEPARATION
   EA8E 0090         450 B8_TSR_I     DW 0090H A/R TEST SB2 COEFFICIENT OF PLY SEPARATION
   EA90 0030         451 B9_TSR_I     DW 0030H A/R TEST SB2 COEFFICIENT OF IMPLIED SB2 DEGRADATION
   EA92 0089         452 A1_TSR_I_PRE DW 0089H A/R TEST SB2 SEPARATION THRESHOLD         = 21
   EA94 0004         453 A2_TSR_I_PRE DW 0004H A/R TEST IMPLIED SB1 SEPARATION THRESHOLD =  1
   EA96 0089         454 A1_TSR_I_PST DW 0089H A/R TEST SB2 SEPARATION THRESHOLD         = 21
   EA98 0004         455 A2_TSR_I_PST DW 0004H A/R TEST IMPLIED SB1 SEPARATION THRESHOLD =  1
                     456
   EA9A              457  DS 38
```

```
LOCATION OBJECT CODE LINE     SOURCE LINE

                 *PASSENGER STEEL-BELTED TIRE II PEAK IDENTIFICATION PARAMETERS:

EAC0 0060        C1_PSR_II       DW 0060H I.D. PARSE COEFFICIENT OF PEAK B


                 *PASSENGER STEEL-BELTED TIRE II ACCEPT/REJECT PARAMETERS:

EAC2 0024        B2_PSR_II       DW 0024H A/R TEST SB1 COEFFICIENT OF BONDLINE ROUGENESS
EAC4 0090        B3_PSR_II       DW 0090H A/R TEST SB1 COEFFICIENT OF SB2 SEPARATION
EAC6 0020        B4_PSR_II       DW 0020H A/R TEST SB1 COEFFICIENT OF IMPLIED SB1 SEPARATION
EAC8 0040        B5_PSR_II       DW 0040H A/R TEST SB1 COEFFICIENT OF SB2 AMPLITUDE
EACA 0001        B6_PSR_II       DW 2001H A/R TEST SB2 COEFFICIENT OF PLY DEGRADATION
EACC 0080        B7_PSR_II       DW 0080H A/R TEST SB2 COEFFICIENT OF PLY SEPARATION
EACE 0090        B8_PSR_II       DW 2090H A/R TEST SB2 COEFFICIENT OF PLY SEPARATION
EAD0 0030        B9_PSR_II       DW 0030H A/R TEST SB2 COEFFICIENT OF IMPLIED SB2 DEGRADATION
EAD2 0089        A1_PSR_II_PRE DW 0089H A/R TEST SB2 SEPARATION THRESHOLD          = 21
EAD4 0004        A2_PSR_II_PRE DW 0004H A/R TEST IMPLIED SB1 SEPARATION THRESHOLD =  1
EAD6 0089        A1_PSR_II_PST DW 0089H A/R TEST SB2 SEPARATION THRESHOLD          = 21
EAD8 0004        A2_PSR_II_PST DW 2004H A/R TEST IMPLIED SB1 SEPARATION THRESHOLD =  1

EADA              DS 38


                 *TRUCK TEXTILE-PLIED TIRE II PEAK IDENTIFICATION PARAMETERS:

EB00             C1_TTX_II_PRE
EB00 00C8        PRELOWLIMIT_2    DW SR*1000/SC 10.00 US DEPTH TO PLY    18.5/64"
EB02             C2_TTX_II_PRE
EB02 0258        PREHIGHLIMIT_2   DW SR*3000/SC 30.00 US DEPTH TO LINER  56.5/64"
EB04             C1_TTX_II_PST
EB04 0256        POSTLOWLIMIT_2   DW SR*2990/SC 29.90 US DEPTH TO PLY    55.9/64"
EB06             C2_TTX_II_PST
EB06 0370        POSTHIGHLIMIT_2 DW SR*4400/SC 44.00 US DEPTH TO LINER  83.0/64"

EB08             C3_TTX_II
EB08 0070        LOWGAPLIMIT_2    DW SR*0560/SC  5.60 US MIN BONDLINE-PLY PEAK SEPARATION
EB0A             C4_TTX_II
EB0A 00A4        MIDGAPLIMIT_2    DW SR*0820/SC  8.20 US MIN PLY-LINER PEAK SEPARATION
EB0C             C5_TTX_II
EB0C 0104        HIGHGAPLIMIT_2   DW SR*1300/SC 13.00 US MAX PLY-LINER PEAK SEPARATION
EB0E             C6_TTX_II
EB0E 0028        TEXTNULLGAP_2    DW SR*0200/SC  2.00 US GAP LIMIT


                 *TRUCK TEXTILE-PLIED TIRE II ACCEPT/REJECT PARAMETERS:

EB10 0013        A12_TTX_II_PRE DW 0013H A/R TEST DEGRADATION THRESHOLD FOR 2-5 YRS =  3
EB12 0093        A13_TTX_II_PRE DW 0093H A/R TEST SEPARATION THRESHOLD FOR 0-5 YRS  = 22
EB14 0025        A18_TTX_II_PRE DW 0025H A/R TEST BONDLINE THRESHOLD FOR ALL AGES   =  6
EB16 0013        A12_TTX_II_PST DW 0013H A/R TEST DEGRADATION THRESHOLD FOR 0-5 YRS =  3
EB18 0093        A13_TTX_II_PST DW 0093H A/R TEST SEPARATION THRESHOLD FOR 0-5 YRS  = 22
EB1A 0025        A18_TTX_II_PST DW 0025H A/R TEST BONDLINE THRESHOLD FOR ALL AGES   =  6

EB1C              DS 36
```

```
FILE: EAROM1:TQMDOC      HEWLETT-PACKARD: 8085 Assembler                              Wed, 16 Oct 1985, 13:31     PAGE  13

LOCATION OBJECT CODE LINE     SOURCE LINE

                       514 *TRUCK STEEL-BELTED TIRE II PEAK IDENTIFICATION PARAMETERS:
                       515
   EB40 0060           516 C1_TSR_II      DW 0060H I.D. PARSE COEFFICIENT OF PEAK B
                       517
                       518
                       519 *TRUCK STEEL-BELTED TIRE II ACCEPT/REJECT PARAMETERS:
                       520
   EB42 0024           521 B2_TSR_II      DW 0024H A/R TEST SB1 COEFFICIENT OF BONDLINE ROUGHNESS
   EB44 0090           522 B3_TSR_II      DW 0090H A/R TEST SB1 COEFFICIENT OF SB2 SEPARATION
   EB46 0020           523 B4_TSR_II      DW 0020H A/R TEST SB1 COEFFICIENT OF IMPLIED SB1 SEPARATION
   EB48 0040           524 B5_TSR_II      DW 0040H A/R TEST SB1 COEFFICIENT OF SB2 AMPLITUDE
   EB4A 0001           525 B6_TSR_II      DW 0001H A/R TEST SB2 COEFFICIENT OF PLY DEGRADATION
   EB4C 0060           526 B7_TSR_II      DW 0060H A/R TEST SB2 COEFFICIENT OF PLY SEPARATION
   EB4E 0090           527 B8_TSR_II      DW 0090H A/R TEST SB2 COEFFICIENT OF PLY SEPARATION
   EB50 0030           528 B9_TSR_II      DW 0030H A/R TEST SB2 COEFFICIENT OF IMPLIED SB2 DEGRADATION
   EB52 0089           529 A1_TSR_II_PRE DW 0089H A/R TEST SB2 SEPARATION THRESHOLD          = 21
   EB54 0004           530 A2_TSR_II_PRE DW 0004H A/R TEST IMPLIED SB1 SEPARATION THRESHOLD =  1
   EB56 0089           531 A1_TSR_II_PST DW 0089H A/R TEST SB2 SEPARATION THRESHOLD          = 21
   EB58 0004           532 A2_TSR_II_PST DW 0004H A/R TEST IMPLIED SB1 SEPARATION THRESHOLD =  1
                       533
   EB5A                534  DS 38
                       535
                       536
                       537 *ALL TYPES SHOULDER INSPECTION PARAMETERS:
                       538
   EB80 0042           539 A11_PRE       DW 0042H A/R TEST POROSITY THRESHOLD FOR ALL TIRES     = 10
   EB82 0042           540 A11_PST       DW 0042H A/R TEST POROSITY THRESHOLD FOR ALL TIRES     = 10

Errors=    0
```

APPENDIX B

SOFTWARE DOCUMENTATION

ULTRASONIC TIRE QUALITY MONITOR

SOFTWARE DOCUMENTATION

The following information is provided on the Tire Quality Monitor per data requirement A002 of the subject contract in accordance with cited data item description number DI-E-1125.

2.1 Modifications of Prototype TQM software used in Preproduction TQM

1. Addition of a separate set of absolute accept/reject thresholds for use in post-retread inspection. For Steel Radial tires, such thresholds are used to measure the presence of first or second belt separation. As a consequence of the addition, the original retread mode-independent absolute accept/reject thresholds for Steel Radial tires, labeled X1 and X2 in the flowcharts and listings, are now doubled and labeled as A1_mSR_n_PRE, A1_mSR_n_PST, A2_mSR_n_PRE, and A2_mSR_n_PST (where dummy tag m can take on the value of T or P as described in modification 2 and dummy tag n can take on the value of I or II as described in modification 4). For Truck Textile tires, such thresholds are used to measure the presence of body ply separation or degradation. As a consequence of the addition, the original retread mode-independent absolute accept/reject thresholds for Truck Textile tires, labeled X12 and X13 in the flowcharts and listings, are now doubled and labeled as A12_TTX_n_PRE, A12_TTX_n_PST, A13_TTX_n_PRE, and A13_TTX_n_PST (where dummy tag n can take on the value of I or II as described in modification 4). Each of

these thresholds is alterable by methods described in section 6.2b of the Theory of Operation manual. Addition of this accept/reject threshold set for post-retread inspection anticipates possible differences in transmitted ultrasonic energy from the pre-retread inspection environment.

2. Separation of the set of all accept/reject thresholds used in Steel Radial tire inspection into Passenger-specific and Truck-specific sets of accept/reject thresholds. These thresholds are used to measure the presence of separation in the first or second steel belt or body ply and the presence of degradation of the body ply. As a consequence of the separation of threshold sets, the original common Steel Radial tire relative accept/reject thresholds, labeled B2, B3, B4, B5, B6, B7, and B8 in the flowcharts and listings, are now doubled and labeled as B2_PSR_n, B2_TSR_n, B3_PSR_n, B3_TSR_n, B4_PSR_n, B4_TSR_n, B5_PSR_n, B5_TSR_n, B6_PSR_n, B6_TSR_n, B7_PSR_n, B7_TSR_n, B8_PSR_n, and B8_TSR_n (where dummy tag n can take on the value of I or II as described in modification 4). Likewise, the original common Steel Radial tire absolute accept/reject thresholds, labeled X1 and X2 in the flowcharts and listings, are now doubled and labeled as A1_PSR_n_Pm, A1_TSR_n_Pm, A2_PSR_n_Pm, and A2_TSR_n_Pm (where dummy tag n can take on the value of I or II as described in modification 4 and dummy tag m can take on the value of RE or ST as described in modification 1). Each of these thresholds is alterable by methods described in Section 6.2b of the Theory of Operation manual. Separation of this accept/reject threshold set

into Truck and Passenger specific sets anticipates possible differences in the parameters dependent on the type of Steel Radial tire inspected.

3. Addition of a separate set of noise amplitude and width thresholds for use in post-retread inspection. For all inspection modes, such thresholds differentiate background electronic and sampling noise from valid ultrasonic reflection signals during the process of extracting reflection features from the digitized data. As a consequence of the addition, the original retread mode-independent noise thresholds, labeled mNOISEAMP and mNOISEWID in flowcharts and listings (where the dummy tag m can take on the values of PAS, TTX, TSR, RUB, and FIB), are now doubled and labeled as m_n_PRE_NAMP, m_n_PST_NAMP, m_n_PRE_NWID, and m_n_PST_NWID (where the dummy tag m now takes on values of PSR_I, PSR_II, TTX_I, TTX_II, TSR_I, TSR_II, RN, and GRP). Each of these thresholds is alterable by methods described in Section 6.2c in the Theory of Operation manual. Such addition anticipates possible differences in transmitted ultrasonic energy and frequency content from the pre-retread inspection environment during the inspection of retreaded tires. The following is a summary of the noise discrimination threshold additions:

Original		New			
PASNOISEAMP	A792	PSR_I_PRE_NAMP	E800	PSR_II_PRE_NAMP	E8C0
		PSR_I_PST_NAMP	E802	PSR_II_PST_NAMP	E8C2
TSRNOISEAMP	A7A6	TSR_I_PRE_NAMP	E880	TSR_II_PRE_NAMP	E940
		TSR_I_PST_NAMP	E882	TSR_II_PST_NAMP	E942

TTXNOISEAMP	A7BA	TTX_I_PRE_NAMP	E840	TTX_II_PRE_NAMP	E900
		TTX_I_PST_NAMP	E842	TTX_II_PST_NAMP	E902
RUBNOISEAMP	A7CE	RN_PRE_NAMP	E9C0		
		RN_PST_NAMP	E9C2		
FIBNOISEAMP	A7E2	GRP_PRE_NAMP	E980		
		GRP_PST_NAMP	E982		
PASNOISEWID	A793	PSR_I_PRE_NWID	E801	PSR_II_PRE_NWID	E8C1
		PSR_I_PST_NWID	E803	PSR_II_PST_NWID	E8C3
TSRNOISEWID	A7A7	TSR_I_PRE_NWID	E881	TSR_II_PRE_NWID	E941
		TSR_I_PST_NWID	E883	TSR_II_PST_NWID	E943
TTXNOISEWID	A7BB	TTX_I_PRE_NWID	E841	TTX_II_PRE_NWID	E901
		TTX_I_PST_NWID	E843	TTX_II_PST_NWID	E903
RUBNOISEWID	A7CF	RN_PRE_NWID	E9C1		
		RN_PST_NWID	E9C3		
FIBNOISEWID	A7E3	GRP_PRE_NWID	E981		
		GRP_PST_NWID	E983		

4. Provision of a primary and an alternate gain calibration setpoint for each of the tire types. This was implemented by the creation of a duplicate type for each of the already e., creation of tire types Passenger Steel Radial 2, Truck Textile 2, and Truck Steel Radial 2). This was done in anticipation of extending the capability of TQM to handle additional tire categories.

Summary of elaboration of accept/reject thresholds accomplished by addition of post-retread distinction, discrimination between

Passenger and Truck Steel Radial tires, and duplication of tire types:

Original	New			
X12				
X13	A12_TTX_I_PRE		A12_TTX_II_PRE	
X14	A12_TTX_I_PST		A12_TTX_II_PST	
X15	A13_TTX_I_PRE		A13_TTX_II_PRE	
X16	A13_TTX_I_PST		A13_TTX_II_PST	
X17				
	A18_TTX_I_PRE		A18_TTX_II_PRE	
X18				
	A18_TTX_I_PST		A18_TTX_II_PST	
B2	B2_PSR_I	B2_TSR_I	B2_PSR_II	B2_TSR_II
B3	B3_PSR_I	B3_TSR_I	B3_PSR_II	B3_TSR_II
B4	B4_PSR_I	B4_TSR_I	B4_PSR_II	B4_TSR_II
B5	B5_PSR_I	B5_TSR_I	B5_PSR_II	B5_TSR_II
B6	B6_PSR_I	B6_TSR_I	B6_PSR_II	B6_TSR_II
B7	B7_PSR_I	B7_TSR_I	B7_PSR_II	B7_TSR_II
B8	B8_PSR_I	B8_TSR_I	B8_PSR_II	B8_TSR_II
	A1_PSR_I_PRE	A1_TSR_I_PRE	A1_PSR_II_PRE	A1_TSR_II_PRE
X1				
	A1_PSR_I_PST	A1_TSR_I_PST	A1_PSR_II_PST	A1_TSR_II_PST
	A2_PSR_I_PRE	A2_TSR_I_PRE	A2_PSR_II_PRE	A2_TSR_II_PRE
X2				
	A2_PSR_I_PST	A2_TSR_I_PST	A2_PSR_II_PST	A2_TSR_II_PST
	A11_PRE			
X11				
	A11_PST			

5. Elimination of tire age range as a selectable parameter in Textile tire inspection. As a result, the accept/reject thresholds labeled as X14, X15, X16, and X17 in flowcharts and listings no

longer exist. Field tests using the TQM have found tire age to be an insignificant factor in ultrasonic tire inspection.

6. Enhancement of the Textile tire envelope classification logic to include an intermediate threshold for the time difference between two envelope peaks which will branch the classification algorithm away from two-envelope logic to one-envelope logic. This intermediate threshold is designated MIDGAPLIMIT in the flowcharts and listings and its value lies between the bondline-body ply maximum time difference (LOWGAPLIMIT) and the bondline-liner minimum time difference (HIGHGAPLIMIT). This enhancement was requested by the TACOM representative to improve classification in certain Textile tires where simple two-envelope logic was insufficient.

7. Enhancement of the Textile tire envelope classification logic to include detection of multiple ringout in the case of three or more detected envelopes and subsequent branching of the classification algorithm to one-envelope logic. The allowable variation in envelope peak times used to measure the presence of multiple ringaround is stored in EEPROM at addresses E7DA and E7DC. These are respectively labeled MULTRING_LOW and MULTRING_HIGH in the flowcharts and listings. This enhancement was made to further reduce erroneous classification resulting from envelope count ambiguity.

8. Reduction of absolute separation accept/reject thresholds by a preset percentage when bondline amplitude in excess of of a preset threshold is detected. This, of course, refers to the absolute second steel belt threshold in the case of Steel Radial tire

inspection and to the absolute body ply separation threshold in the case of Textile tire inspection. This reduction of absolute threshold was created to compensate for an observed apparent reduction of ultrasonic signal amplitudes returning later in time than significant bondline reflections. The reduction percentage is stored at address E7E6 in the EEPROM and is labeled BL_RED_FACTOR in the flowcharts and listings. The bondline significance threshold is stored at address E7E4 in the EEPROM and is labeled SIG_BONDLINE in the flowcharts and listings.

9. Incorporation of a "majority logic" algorithm into the accept/reject analysis algorithm to detect and remove stored ultrasonic a-scan acquisitions whose pattern does not match the pattern exhibited by a majority of similarly stored a-scan acquisitions. This was done to avoid the averaging together of inappropriate a-scan envelopes, thereby increasing the reliability of the accept/reject processing. The patterns are matched in time and in amplitude for the envelope classified as body ply when inspecting Textile tires and for the envelopes classified as first and second belts when inspecting Steel Radial tires. Pattern matching in time requires that the peak time of the tested envelope of a stored acquisition fall between the start and end times of the similarly classified envelope in each of the other stored acquisitions. Pattern matching in amplitude requires that the peak amplitude of the tested envelope of a stored acquisition fall between plus and minus a preset percentage of the peak amplitude of the similarly classified envelope in each of the

other stored acquisitions. This preset percentage is stored at address E7E2 in EEPROM, is labeled HOMOL_OFFSET in the flowcharts and listings, and is presently valued at 25%. If the failure to find a majority pattern leaves an insufficient number of stored acquisitions to proceed with an analysis, the TQM informs the inspector how many acquisitions are needed to make up the deficit and if a majority pattern cannot be detected after three attempts to find one, the TQM will proceed with an analysis in a manner similar to the original algorithm.

10. Modify saturation-induced alternate gain calibration procedure so that it is enabled only until the first accept/reject analysis after gain calibration is completed. Thereafter, any saturation detected during inspection is ignored, even through successive gain recalibrations for the same tire type. Only after the tire type is explicity reselected will the saturation-induced gain reduction potential be reenabled. Of course, this continues to pertain only to Steel Radial tires. The philosophy behind this modification is that if a group of tires to be inspected during a given gain calibration interval are of a type that exhibit saturation, this will become obvious upon inspection of the first tire after calibration. Therefore, recalibration to reduce the gain for inspection of the entire group is an appropriate response. If, however, a group of tires to be inspected during a gain calibration interval are of a type that do not exhibit saturation, the inspection of the first tire in the group is not likely to show a saturated signal. Therefore, any later tire exhibiting

saturation during inspection will be treated as not representative of the group and no request to reduce gain will be made.

11. Provision has been made for a scheme whereby the TQM can automatically adjust the distance-amplitude correction (DAC) slope of its automatic gain control (AGC) circuit through a special mode of gain calibration. This is accomplished by requiring the monitor to find that DAC slope which minimizes the difference between multiple ultrasonic reflection amplitudes from an air-backed quarter-inch rubber block sensed at 72 degrees F and multiple embedded setpoints. Details of the procedure are explained in the Calibration manual.

12. Modification of the TQM power-up tire type default mode from that of Truck Steel to that of GRP Maintenance. This was done to force the inspector to be explicitly aware of what tire type is selected before commencing inspection.

13. Addition of a relative accept/reject test which inspects for implied degradation of the second steel belt by comparing its amplitude with that of the liner. This addition was requested by the TACOM representative to provide an accept/reject test felt to be missing from the original test sequence.

DISTRIBUTION LIST

	Copies
Commander Defense Technical Information Center Bldg. 5, Cameron Station ATTN: DDAC Alexandria, VA 22314	12
Manager Defense Logistics Studies Information Exchange ATTN: AMXMC-D Fort Lee, VA 23801-6044	2
Commander U.S. Army Tank-Automotive Command ATTN: AMSTA-CF (Mr. Orlicki) Warren, MI 48397-5000	1
Commander U.S. Army Tank-Automotive Command ATTN: AMSTA-DDL (Technical Library) Warren, MI 48397-5000	2
Commander U.S. Army Tank-Automotive Command ATTN: AMSTA-QAT (Mr. Foster Braun) Warren, MI 48397-5000	2
Commander U.S. Army Tank-Automotive Command ATTN: AMSTA-MTA (Mr. Terry Nelson) Warren, MI 48397-5000	1
Commander U.S. Army Tank-Automotive Command ATTN: AMSTA-TMS Warren, MI 48397-5000	1