



## SIGNAL TRAINING

### Volume 2 Chapter 8

#### Hot Box Detectors

##### Introduction

The hot box detectors are devices which can scan passing trains to determine if a journal is becoming overheated, thereby establishing information by which the offending journal can be identified. Some installations include this information on a recorder at a dispatcher's location where it can be visually observed. Other installations provide this information at a so-called readout location where it is observed by the train crew and remedial action may be taken.

The basic concept of a hot box detector is that wheel journal bearings, as a result of the friction involved, emit infra-red radiation. The hot box detector determines the amount of heat being radiated and if this amount is excessive, then an alarm condition is created.

The scanning or observing of journals of a passing train is accomplished by the use of transducers located on the rail in a direct relationship to the scanners. The scanners, actually the sensors within, observe journal box condition. As the wheel passes the lead transducer, it causes the scanner shutter to open, allowing the sensor to observe heat in its range. The heat observed is focused onto a heat cell located within the sensor, which is, in turn, within the scanner housing. This heat energy is converted into an electrical signal which is amplified and applied to the pulse processors in the data processing unit. The

pulse processors further amplify the signal and raise it to a level sufficient to drive the recorder. The signal from the pulse processors, after further amplification, is applied to the data control unit where gating and further system programming is accomplished.

The term "gating" is used to represent the turning on and off of the heat signal registered as the wheel is within the range of the sensor; by action of the transducers immediately before and beyond the scanner.

At this point, what happens with the defined heat signal is dependent upon the type of hot box detector system with which you are actually working.

After the train passes, the shutter will close to protect the sensor lens assembly from damage.

In the basic bidirectional system, Figure 1, magnetic wheel detectors on both approaches to the scanner location initiate system operation. The track-mounted equipment consists of two mounting assemblies (scanner and blower), four wheel detectors, three arrester boxes, two junction boxes, and connecting cables. The basic bidirectional system also includes a modular equipment cabinet, with plug-in printed circuit boards, which is designed for mounting in a 19-inch rack in a way-side housing. This equipment can vary depending on the type of system.

A basic unidirectional system does not require wheel detectors 2 and 4, Figure 1, and a direction relay printed circuit board. An optional reverse direction lockout feature is available to avoid scanning in the reverse direction. The option usually consists of an advance wheel detector and a direction relay printed circuit board.

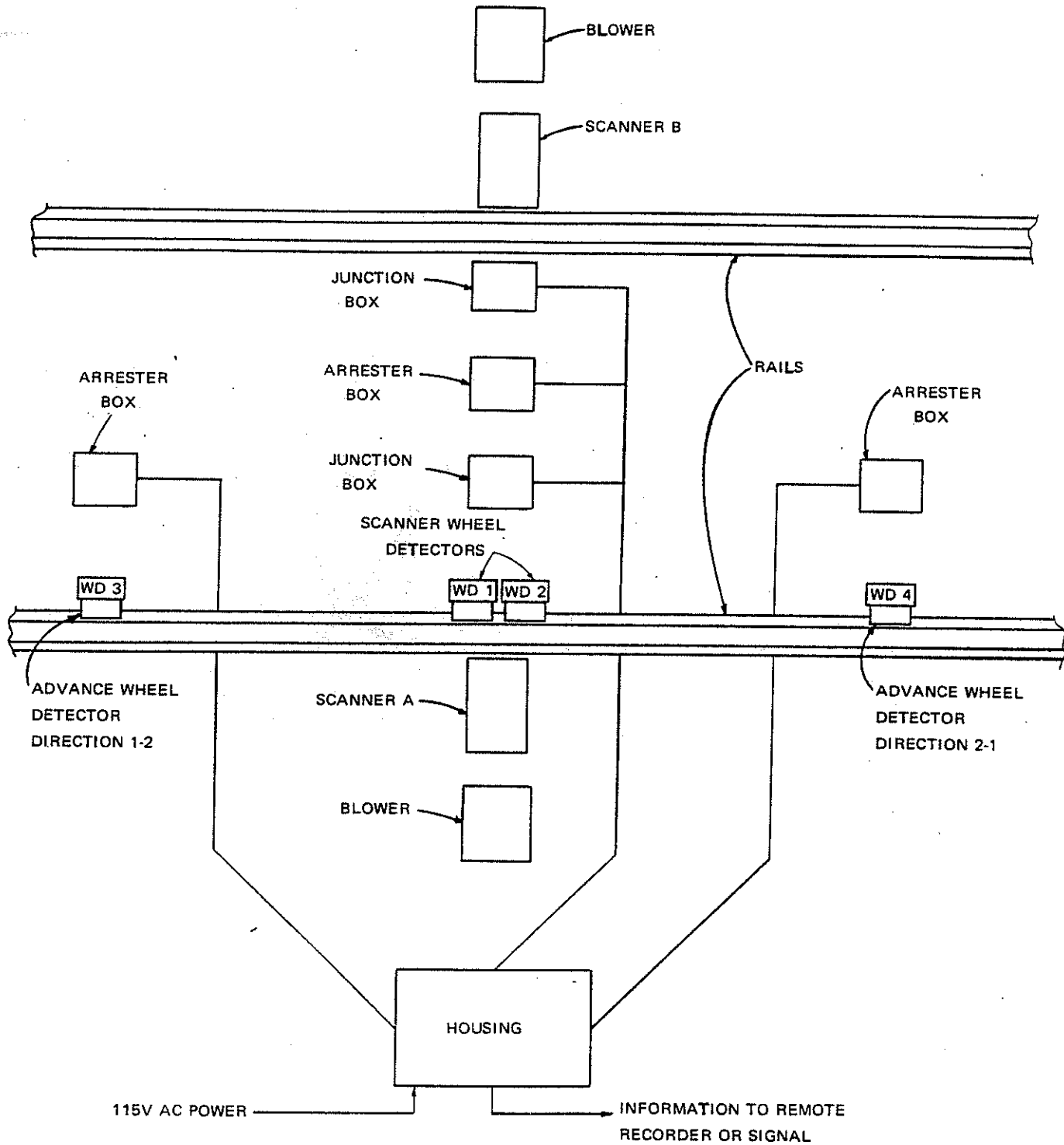


Figure 1. Basic arrangement of a bidirectional system.

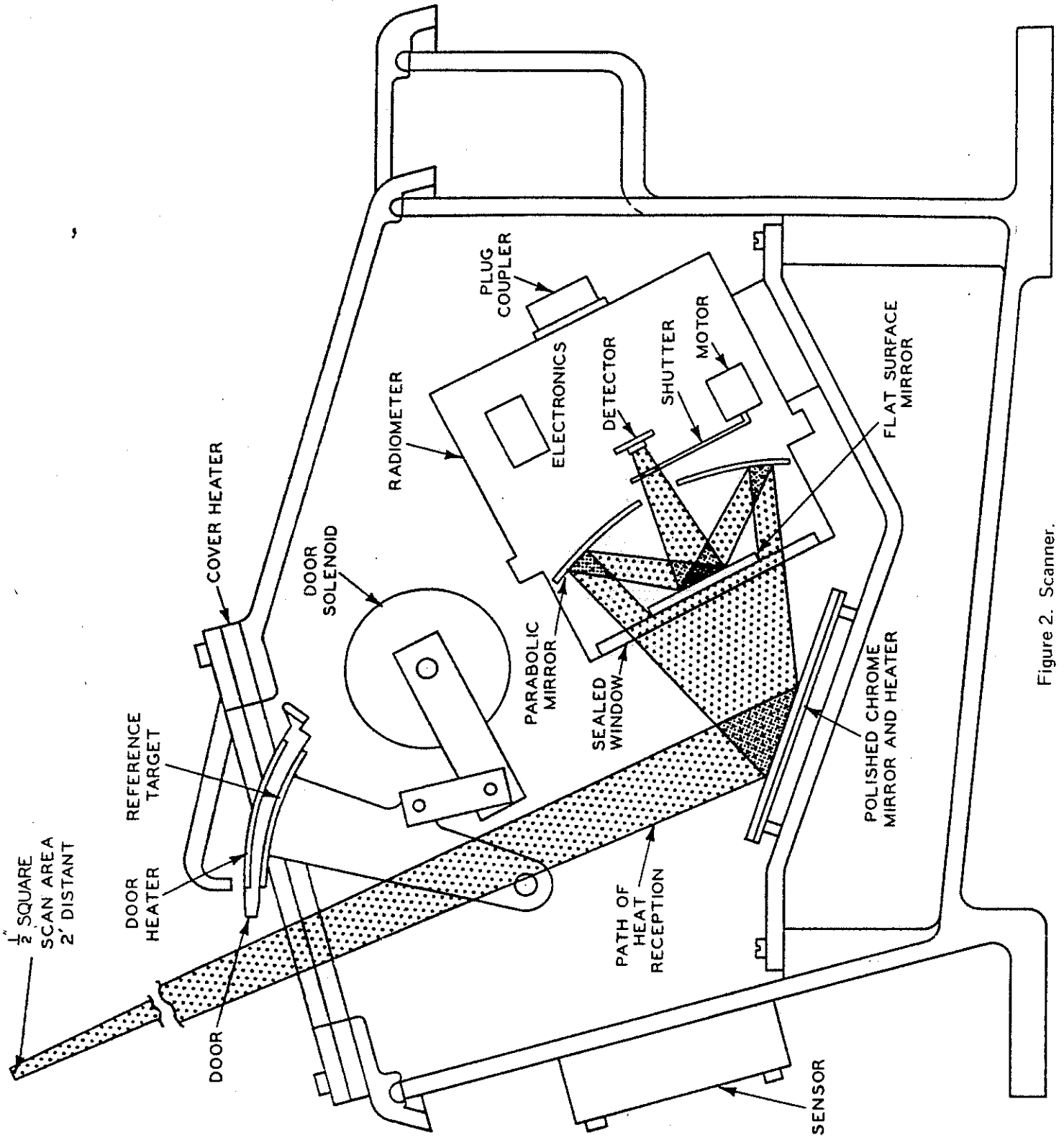


Figure 2. Scanner.

The Santa Fe has several types of hot box detectors in service. They are Servo 7707 and 8808 models and the GRS Optically Gated Wheel Thermo-Scanner Unit. They both, basically operate the same of course. They have their differences but are all installed to do the same thing; prevent accidents. To facilitate the following explanations and description we will be talking about the GRS unit but keep in mind the Servo models have similar equipment and are used in the same function.

### GENERAL DESCRIPTION

#### Scanner

The scanner, Figure 2, consists of a radiometer and associated optics, ambient sensor, door operating mechanism, and environmental heaters which are housed in a sturdy cast aluminum case. The case, and associated blower housing, are mounted on a steel plate which is supported on shock mounts attached to the tie bracket. Cabling within the scanner is completely plug coupled for ease of maintenance.

The scanner is activated by a wheel detector which accurately detects the position of the wheel flange. The scanner scans the wheel for heat radiation at a location on the hub very near the end of the journal. (The journal (the end of the axle) itself is inaccessible for direct measurement because of the wheel bearing and its housing or box). This location has an advantage over measuring journal box temperatures, in that the readings for a given journal temperature are all the same.

#### 1. Radiometer:

The hermetically-sealed radiometer contains: an optical system (which includes a mirror in the bottom of the scanner case) to focus radiated infrared energy from

the wheel journal onto an infrared detector, associated electronics, and a shutter to protect the detector from undesired stray infrared radiation.

2. Sensor:

The sensor, bolted to the outside of the scanner case, is epoxy encapsulated to ensure long life. The sensor controls the temperature of a reference target heater which is mounted on the inside of the scanner door.

3. Door:

The external scanner door is electrically operated and self locking. It protects the radiometer from vandals, dirt, snow, etc. The door opens upon the arrival of a train and closes 14 seconds after the last journal is scanned.

The door's self-lubricating bearings do not require lubrication.

4. Heaters:

Mirror, cover, and door electric heaters ensure all-weather operation. A small heater, mounted under the mirror, melts snow and evaporated moisture. A cover heater and a door heater prevent snow and ice buildup from interfering with the scanner door. A fourth heater, mounted under the door, provides an 80 degree F above ambient reference target temperature for the detector.

5. Line Driver:

An encapsulated line driver, located inside the scanner cover, matches the output impedance of the radiometer

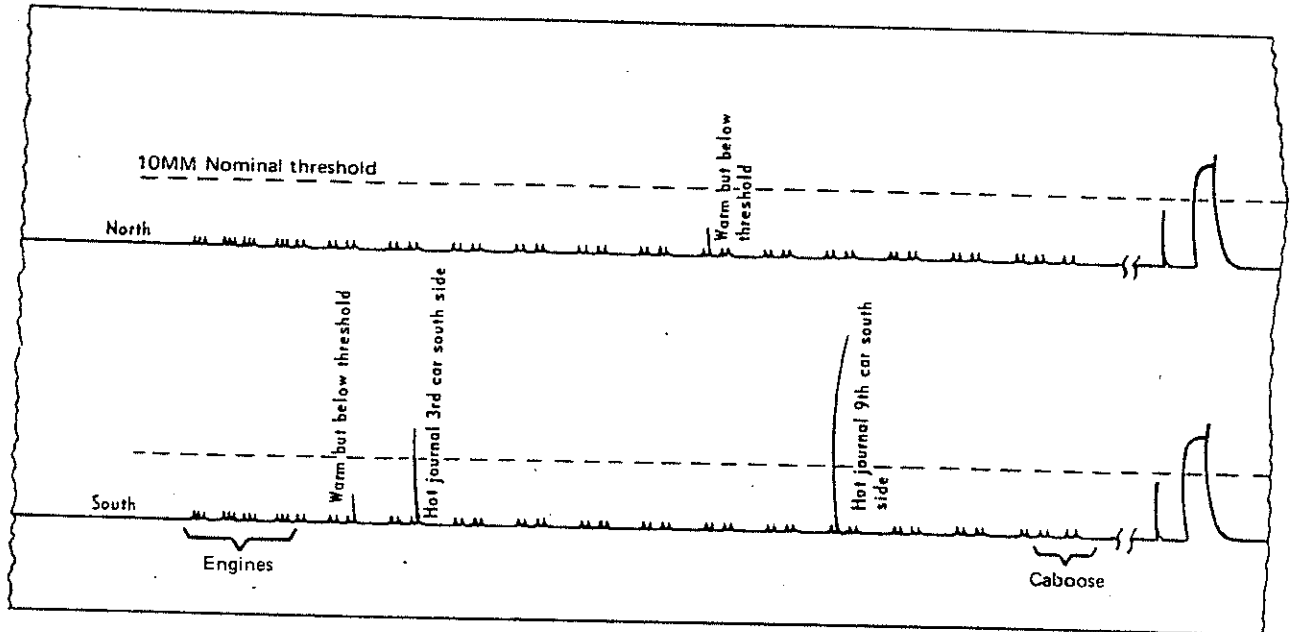


Figure 3. Section of a typical pen recorder tape.

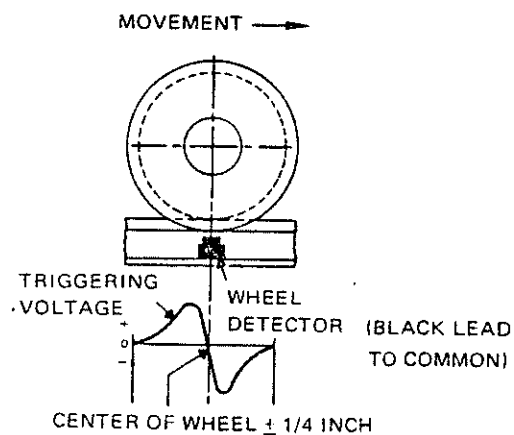


Figure 4. Wheel detector output current.

to the impedance of the line that runs to the wayside housing.

### Blower

The blower pressurizes the scanner with filtered air to keep out snow, rain or foreign objects during the passage of a train. It also partially clears the path extending part way toward the wheel hub to help reduce snow blockage. The blower operates only when the scanner door is open.

### Wheel Detector

The wheel detector detects the presence of a wheel and provides an electrical output at the instant the wheel is within  $\pm 1/4$  inch of the center of the wheel detector. See Figure 4.

### Modular Equipment Cabinet

The modular equipment system cabinet, usually installed in a wayside housing, has space for the plug-in printed circuit boards used in the system. The number and arrangement of the boards depends upon the requirements of the installation. For carrier operation, the Data-Tran transmitter is housed in a separate modular cabinet.

A mother board in the back of the modular system cabinet contains plug couplers to receive the printed circuit boards. Terminals on the back of the mother board enable jumpering additional functions between boards and provide for input-output cable connections.

### Operation

As the train approaches the scanner 1 location it first passes over either advance wheel detector 3 or 4, Figure 1. This announces arrival and readies the system for operation.

It also establishes train direction, which is used to select the scanner wheel detector preceding the centerline of the scanner. For example, if advance wheel detector 3 is actuated, scanner wheel detector 1 is selected. This direction is referred to as direction 1-2, with reference to the scanner wheel detectors.

The train next actuates WD1 which causes the scanner to scan the journals and convert radiated heat energy to electricity on a proportional basis. The electrical analog of the wheel heat profile is carried by cable to the housing where electronic equipment extracts the information desired.

The activation of an advance wheel detector and selected scanner wheel detector operates a 14-second timer which keeps the system in operation. When the train slows and stops at the scanner installation, the timer times out and the scanner reverts to standby operation. If a track circuit relay contact is available, or if an overlay transceiver is provided, the direction of train movement is retained. If, however, no track circuit information is available, the train direction is lost. For this reason, track circuits are recommended where trains may stop. When the train starts again, the first wheel over an active wheel detector reactivates the system which continues to scan the remaining wheels until the last wheel passes. After 14 seconds, the system again reverts to standby operation and, when the track circuit clears, the directional memory is released.

#### System On Standby

During the absence of a train, the Wheel Thermo-Scanner system is on standby. Standby operation involves a self-calibration feature, which once every minute, opens the radiometer

shutter. The normal optical path of the radiometer is, however, blocked by the door, which is closed during standby operation. As previously described, the target on the inside of the door is heated to a temperature above ambient which is indicative of an overheated journal (hot box). This temperature is usually set to between 60 and 80 degrees F above the ambient (outdoor) temperature. Thus the radiometer reads the temperature of the target. In the wayside housing, the amplifier gate board analyses the output voltage; if it is at a level other than that expected from a hot box, the gain of its amplifier is changed to bring the output to the proper level. This gain is controlled by a 32-step digital counter.

The heavy lines on the block diagram, Figure 5, outline this operation. Starting with the heavy lined block, the normally running pulser produces pulses once each minute. The pulses pass through the gate control circuits and open the shutter in the radiometer. With the door closed, the radiometer reads the target temperature which is translated by the preamplifier to a potential of about 1 volt. The heat pulse is fed by the line driver in the scanner back through the cable to the test unit board in the modular equipment cabinet where an electronic circuit clamps the output pulse after a predetermined time. The clamp circuit terminates the heat pulse about 6 ms following the opening of the shutter. The heat pulse is fed to an amplifier and a peak storage device (a capacitor with isolation circuitry). The device stores the highest voltage attained from the time the shutter is opened until the signal is clamped.

A fixed voltage pulse (called a pedestal) is added to the heat pulse. The pedestal serves to mark, on the pen recorder, the

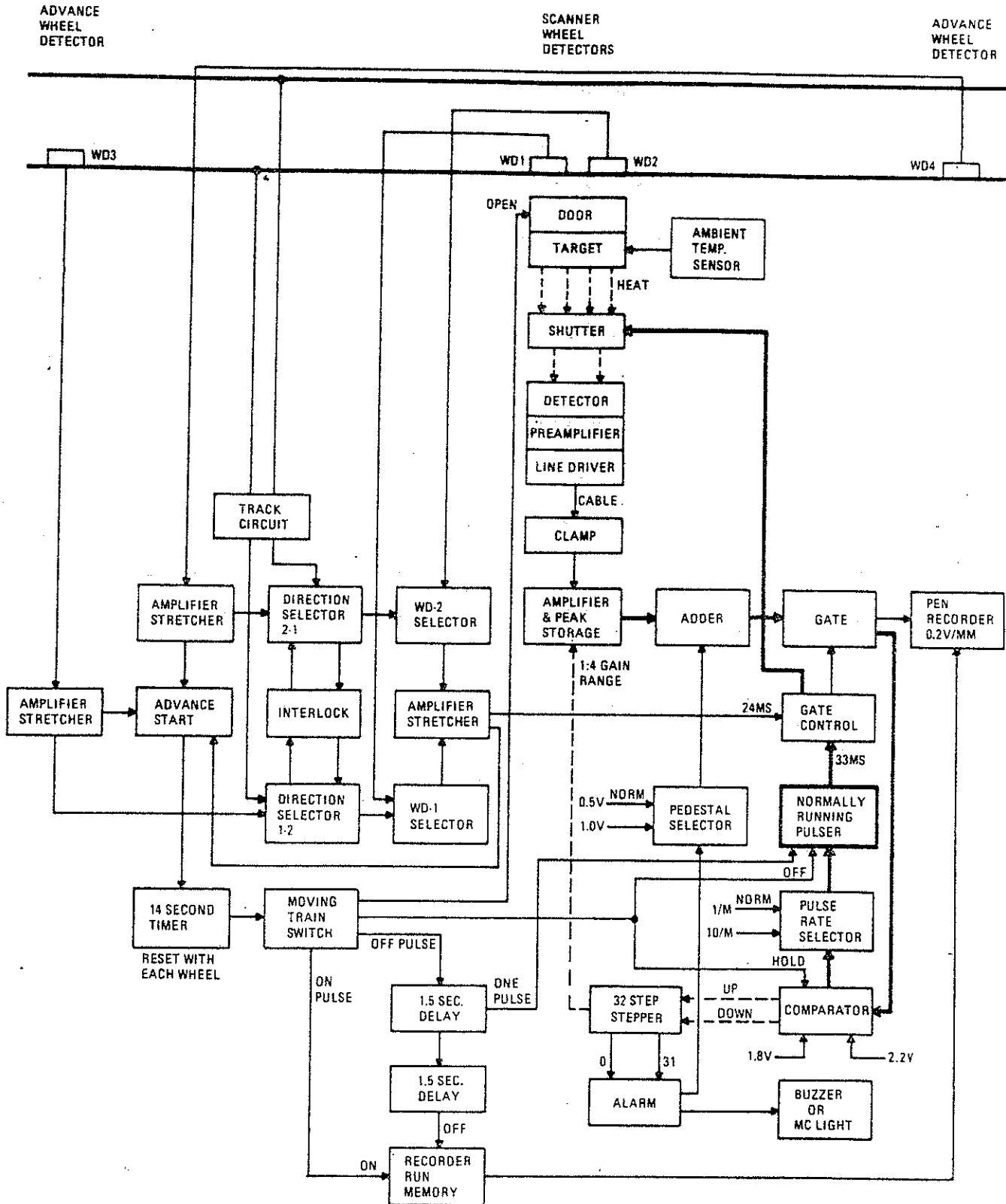


Figure 5. Block diagram, bidirectional system operation.

the passage of a train wheel which generates little or no heat pulse if the journal is cool or cold. The pedestal is normally 0.5 volt in height. The combined heat pulse and pedestal is fed through a gate circuit (controlled by the same gate pulse that originated the shutter movement) to the comparator.

The comparator checks that the voltage of the combined pulse (representing a hot journal) is between 1.8 and 2.2 volts. If the voltage is not within these limits, sensing circuits within the comparator step the 32-step stepper one step in the direction required to correct the situation. The 32-step stepper controls the gain of the amplifier through which the heat pulse was fed before the peak storage. When the heat pulse is low, the comparator causes the stepper to increase the gain in the amplifier so that after one or more steps the pulse is of the expected height. This ensures that, during normal operation, heat measured from an overheated journal (at the same temperature as the target) displays a 10-mm pulse--the hot journal threshold.

A supplemental comparator circuit, the pulse rate selection, governs the pulse rate of the normally running pulser by increasing the rate from one per minute to ten per minute any time the comparator detects a pulse out of tolerance. This ensures prompt correction of any gain change and is especially valuable during initial start up and test. Things which might cause a change in the heat pulse output are dirt on the optics, component aging, ambient temperature changes, and faulty system alignment.

A second supplemental circuit in the 32-step stepper is an alarm circuit. It senses when the stepper has stepped either to the top or bottom of its range. The circuit then causes the pedestal selection to double the pedestal voltage. This doubles

the height of the pedestal displayed on the pen recorder and switches on a transistor relay driver (for external alarm) to warn the person reading the tapes that the system is no longer able to compensate for whatever condition is causing the heat pulse reduction. When such a condition is corrected the comparator steps the gain back down again to get the heat pulse within tolerance. The comparator does not operate during normal system operation; just during standby.

### Train Approaches

As the train approaches the scanner site it occupies the track circuit (if one has been provided) so that the direction established when the train first actuates the advance wheel detector is maintained during the train's presence. This may be a spare contact on an existing track relay, if such is available, or it can be a series overlay. GRS can furnish a series overlay on boards which plug directly into the modular equipment cabinet. Referring to the block diagram, Figure 5, the occupied track circuit furnishes energy to maintain (stick) the direction selector.

### Train Actuates Advance Wheel Detector

The train, after occupying the track circuit, passes over the advance wheel detector. The electrical pulse generated by the wheel detector coil is fed over a cable to the wayside housing where it is amplified and shaped by an amplifier-stretcher which picks up an interlocked relay on the direction unit board (the direction selector) to establish train direction. The relay is held by the track circuit. The activated direction selector selects the proper wheel detector for operating the scanner.

The gate generator associated with the advance wheel detector and the selected scanner wheel detector have a second output--

to provide an advance start for taking the system out of standby and readying it for operation. The advance start circuit actuates a 14-second timer which is reset to zero when a wheel passes a wheel detector. The timer, in turn, operates a moving train relay as long as wheels keep resetting the timer and turns off 14 seconds after the last wheel pulse. While the relay is energized, a pulse is delivered to the recorder run memory which activates the pen recorder and/or unmutes the carrier to operate the office recorder. A second function of this relay is to open the scanner door, removing the calibration target from the view of the detector. A third function is to stop the normally running pulser and hold the comparator and, therefore, the 32-step stepper in the position it had attained at the time the train arrived.

The distance between the advance wheel detector and the selected scanner wheel detector must be long enough to allow the door to open and the recorder to start before the train reaches the scanner. For high speed trains (up to 85 mph) this distance is 45 feet. With Data-Tran carrier and no overlay track circuit, the one second squelch time requires an advance distance of 200 feet.

#### Train Actuates Scanner Wheel Detector

When a wheel passes the selected scanner wheel detector, the associated gate generator applies a 24-ms pulse to the gate control circuitry in the same manner as the normally running pulser did during standby operation. The gate control circuitry opens the shutter allowing the detector to view the passing wheel hub, which has in the meantime moved into view. The heat received during the wheel scan is converted into electrical

energy in the same manner as described under standby operation. The heat pulse is gated, amplified, stored, stretched, and added to the pedestal through the gate circuit to the pen recorder where it is displayed. This activity is repeated for each wheel of the train.

### Train Leaves

When the last wheel of the train passes over the selected scanner wheel detector, the pen recorder receives its final wheel heat indication. When the last wheel passes over the trailing advance wheel detector, the 14-second timer receives its last pulse. Fourteen seconds later, the timer turns off the moving train switch which closes the scanner door, thus interposing the calibration target in the detector field of view. The off pulse of the moving train switch starts a second timer which, 1-1/2 seconds later (to give the door time to close), puts a single pulse into the pulser to open the shutter in the usual way. This action displays on the still-running tape recorder one calibration pulse which causes a pen deflection to the 10-mm line. This indicates that the system has been capable of displaying this amount of heat as a hot journal throughout the passage of the train. One and a half seconds after the second timer operates, a third timer operates which turns off the recorder run memory. This deactivates the pen recorder. The action is the same for a train that slows and stops; the recorder shuts off to conserve paper.

Following the scanner shutdown, calibration pulse, and recorder shutdown, the train eventually clears the track circuit. When it does, the directional memory is dropped and the system is ready once more to accept a train from either direction. The

system is now in standby and returns to its self-compensating function.

### Locating The Hot Box Detector

1. The Hot Box Detector site should be located on tangent track at least 500 feet from the nearest curve or switch, in the normal direction(s) of traffic--500 feet will allow the trucks to return to their normal position so that they will not be skewed when passing the detector. On a curve at high speed, centrifugal force will push the flanges toward the outer rail, changing the normal geometry of rail and hub (the hub is scanned). At low speeds on a curve, gravity will pull the flanges against the inner rail, again changing this geometry.

2. The track at, and a suitable distance ahead of, a scanner location should be reasonably level--prolonged braking can cause a false reading.

3. The scanner should be located where the train has been operating at normal speeds for about ten miles--this allows time for hub heating to occur if a journal is defective. A distance over ten miles would be preferred when the scanner density (scanner/100 miles) is less than 10.

4. Track width should be held to gauge at least 100 feet each side of a bidirectional scanner. Gauge wider than 4 feet, 8-1/2 inches should be avoided. Gauge should be properly maintained. Guard rails are not required.

5. The scanner should be located where there is an adequate source of 120-volt a-c power--the line voltage should be capable of staying between the limits of 103 to 127 volts. The circuit should allow one side to be grounded at the equipment

location--an isolation transformer may be necessary.

6. Locate the wayside electronic equipment cabinet within 80 feet of the track-mounted equipment.

7. Ballast in the area of the scanner location should be clean and firmly tamped. The ties should be in good condition.

Detailed circuit plans and a handbook outlining the specific type of installation are available at the location. Instructions for maintenance procedures are available at the location, and in your "A" Book. If questions arise they should be clarified through your Supervisor.

It is important that a hot box detector system be maintained properly. This will include relative position of transducers and scanner to determine that a proper scan angle is maintained. It will also include that certain voltages be kept within specified tolerances and which will be measured at prescribed test points. The method of obtaining these voltages, and points at which they may be obtained, are far too numerous to include within this Chapter, but you should be cautioned that they are necessary. You will also recognize that you should not make adjustments in voltages or other equipment without necessary reason. This will apply regardless of the type or manufacturer of the hot box detector.

The Model 530/531D Frequency Shift Carrier System from Harmon Electronics is used at our hot box detector locations. This is used to relay information to our end locations in the account of a hot journal, or a piece of dragging equipment. (Refer to Vol 1, pp 1-48, on the dragging equipment detectors.) This is done by running two wires each direction from the scanner location, and by carrier we can tell either end of a hot journal which specific wheel is hot and, of course, which rail has the hot journal. In addition, if a

dragging brakeshoe, loose strap, etc., hits the dragging equipment detector, we can alarm the train crew while at the same time checking journals on the entire train. If carrier was not used, we would have to run several line wires in both directions to get all this information to each end location. More information on carrier at hot box detectors can be found in the manufacturers' Manuals, usually found at the hot box locator.

Figure 6 is a map of all the hot box detectors and dragging equipment detectors on the Santa Fe System. See the legend for explanations and information.

## READING HOT BOX DETECTORS TAPES

All hot box detector checks of passing trains are recorded on paper tape. This serves the dual purpose of providing a written record of each train checked and a useful trouble-shooting tool in the event of a system malfunction. Most locations also have a time and date printer which stamps the read out tape with the date and time of each passing train to aid in checking with train operation records for data on specific trains. GRS time and date printers stamp time and date on the upper edge of the front of the tape while the Servo printers stamp the back of the tape.

The pens in the GRS recorder receive an impulse from the amplifier gate logic card for each wheel that is scanned by the radiometer. The Servo recorder receives impulse from the pulse processor. This impulse is equal to a scaled pulse determined by the amount of heat detected in the wheel hub plus the pedestal voltage. Thus under normal operation there will be a pulse for each wheel on each car of the train. Generally speaking the Servo Hot Box Detector is set to give an absolute alarm at a 16mm pen deflection and a differential alarm at a 12mm pen deflection while the GRS Hot Box Detector is set to give an absolute alarm at a 20mm pen deflection and a differential alarm at a 16mm pen deflection. However, you must bear in mind that all hot box detectors are very delicately balanced. Their performance is individualistic.

Plate 8-1 from a GRS recorder shows the tape of a normal check (no Hot Box found) of a train with three locomotive units and 101 cars. Notice that a normal train often shows fairly uniform pulses for each journal of the train. Also note the unusual pulse pattern for the wheels on the cars on this train as compared to Fig. 3 Page 8-7. This train is a 10 car piggy-back train using the Santa Fe's new skeletonized "10-Pack" piggy-back cars.

Plate 8-3 shows two tapes, the top of which shows a train consisting of three locomotive units and 60 cars. Note how the space between wheel spaces varies for the different length cars (especially the extra short car). Spacing will also vary with the speed of the train. This train has a Hot Box on the second axle of the first car ahead of the way car. Since the axle count starts with the hot axle, the read out in this case would be 7S, meaning the seventh axle from the rear of the train on the south side (S-7). This is indicated by the trace at the bottom of the pengraph, the trace at the top of the pengraph being the north rail. This alarm is an absolute alarm meaning that the heat detected was high enough to warrant an alarm and an inspection without regard to the reading obtained from the other end of the axle (which would be a differential reading).

The bottom tape (from a different type of recorder) shows a differential alarm on the second axle of the 45th car from the rear of the train, and an absolute alarm on the first axle of the 61st car from the rear of the train. The axle counts on these alarms would be N-179 and N-244 respectively. Also note the lower normal pulses from the friction bearing cars as to opposed to those of the warmer running roller bearing cars.

Plate 8-2 shows two special case tapes. The top tape showing a breaking train. Note the much higher heat pulses due to the friction of the brake shoes against the wheels. In this case the heat is radiated from the wheel tread to the hub where it is "seen" by the scanner. The variations in the pulse height denote the difference in pressure of the brake shoes on each wheel.

The second tape shows a special train with two locomotive units and eight axle special heavy equipment car, two "Idler Cars", a special 16 axle heavy equipment car, and two more cars.

End of train time check

6 Axle  
locomotives

1 "10-Pack"  
Car

Coupler

Dragging equipment detector

11-0314-100

GEAR'S CONTROLS CORPORATION BUFFALO, NEW YORK

This train consisted of  
10-10-pac cars and a  
way car. Only 4 cars  
are shown.

Time / Date

Car with  
Roller bearings

Car with  
friction bearings

Servo

No. 01164-499

RECORDING CHARTS GRAPHIC CONTROLS CORPORATION BUFFALO, NEW YORK

Train consist  
6 locomotives  
107 cars  
Way car  
Locomotives & 33 cars shown

Baring Mo.  
North Tals.  
train moving generator

G.R.S.

No. 01164-499

RECORDING CHARTS GRAPHIC CONTROLS CORPORATION BUFFALO, NEW YORK

T  
O  
P  
O  
F  
T  
R  
A  
I  
N

DRAGGING

HOT BOX

Event 7

No. 01164-499

RECORDING CHARTS GRAPHIC CONTROLS CORPORATI

G.R.S.

Last 21 cars of train

Hot box

Dragging equipment 7

GRE

Event and dragging equipment 7

Absolute

Differential

Hot Boxes

North Rail

Servo