A smarter breed of defect spotters

By JOHN H. ARMSTRONG, Associate Editor

Hotbox detector on the Santa Fe. New trackside devices now in use or under test monitor other types of mechanical failures that can cause costly accidents.

Start with a bottom-line number such as net railway operating income—whether the 1977 nearly catastrophic $343 million or 1979's moderately healthier $794 million—and it's clear that lopping off any significant fraction of such dead-loss payouts as last year's $328 million for freight L&D or $314 million in direct train-accident damage to equipment and track would show up vividly in the ROI percentage for the whole U.S. rail system.

Exactly half of last year's L&D total (*RA*, June 30, p. 34) is in the shadowy "additional damage not otherwise provided for" category. Within the train-accident drain on profits (see table on page 27), there are several specific categories that represent big enough chunks of the whole to suggest that attacking them with doses of modern technology could pay off in more concrete ways than just the general social benefits of a smoother-running, less-dented railroad. Focusing on the $76 million of equipment-failure-caused costs, we find that items amounting to $2 million or more each account for well over half of the total, confirming intuition that savings might in fact support development and deployment costs for specialized detectors if they can in fact find and forestall events that lead to these big-ticket accidents.

Track geometry cars detect likely sources of major accidents, and the ultrasonic/magnetic rail inspections conducted by today's fleet of detector cars certainly fit within any broad definition of "detector." So do many items of factory or shop quality-control and inspection equipment; block signals detect the presence of trains to allow safe operation of the railroad. However, this review of some of today's developments in "detector" technology is arbitrarily confined to *the use of sensors in the field to detect mechanical conditions in rolling stock that may lead to a train accident*—usually, derailment—*from a sudden failure or event*.

● **The stake in detector deployment.** Reportable accident damage includes only direct costs of repair or replacement of rolling stock and track. Railroad costs for operational delays, detouring and other disruption, damage claims for lading, and any societal costs are not included, nor is there any allowance for wreck clearing, casualty, compensation, or such indirect effects on the railroad balance sheet as loss of competitive position in the transportation marketplace. Their $313-million total is more than the tip of the proverbial iceberg (if nonreportable wreck costs were in fact seven or eight times that big, there would probably be no railroads left to worry about by now). But we do know that the L&D payout for train accident damage to lading last year was $86.3 million, and in some studies of potential savings from accident reduction the FRA has postulated a three-to-one ratio of total to reported costs. For individual derailments where hazardous materials are involved, the ultimate total cost limit is in fact very near the sky, as the current investigation and prospective litigation on the Mississauga hotbox/derailment/evacuation dramatizes.

As the table shows, a few specific items account for a very significant fraction of the total. All that wheel-tapping and hotbox-sniffing over railroading's century and a half represents well-founded alertness to hazards that have still not disappeared. Running-gear components account for the vast majority of equipment-caused derailment costs; at the same time, perspective requires the observation that some *17.4 million car-miles were run for each of the 1,815 equipment-failure accidents*.

There is a definite limit to the frequency, intensiveness, and expense of *profitable* surveillance, and any false-alarm rate that adds significantly to train delays can quickly price a technology out of the market. Within the $46.4-million "other" cause category are additional major items worth considering in connection with "detector" possibilities: shifted, improper or falling loads—$8.8 million; lateral/vertical force interactions—$5.8 million; obstructions on track, natural or otherwise, $5.5 million. Add in the $42.6 million in accident damage attributed to rail and joint bar defects, and a reasonable guess at the total tab for accidents associated with mechanical-part problems in keeping those flanged steel wheels carrying commerce over those steel rails could be $200 million to $300 million a year.

● **From the wayside...** Slow-developing difficulties such as worn-wheel contours are found rather adequately by inspection and gauging as indicated by the relatively low toll ($2.2 million) they exacted in 1979. For much of this inspection, rolling the train past trained eyeballs, as at the hump inspection pit, is the cost effective way to go.

Failure modes that develop only or mostly on the main line are something else again. Granddaddy of the more formal wayside inspection devices is probably the break-bar dragging equipment detector (DED) installed by the Pennsylvania Railroad in quantity prior to World War II and still in service at some Conrail locations. Cast iron bars—carefully de-

At Pueblo: Probing the principles of defect-spotting systems

Alongside the 14-mile Railroad Test Track loop at the Department of Transportation's Pueblo facility (with its own double-ended research siding) sits the well-instrumented research van of FRA's Wayside Detection Research Facility. Operated by the Office of Research and Developments system management contractor, Aerospace Corp., the WDRF has been set up under a multiyear program initiated in 1977 in response to Administrator Sullivan's expressed concern for detection of defective rolling stock components that contribute to accidents.

Initial planning called for about $2-million-a-year federal support of this program, but that figure has been cut by about 60%, and the program to demonstrate the CAR-SCAN (Composite Analysis of Railcar Safety and Components with Automatic Notification) concept has been stretched out to 1983.

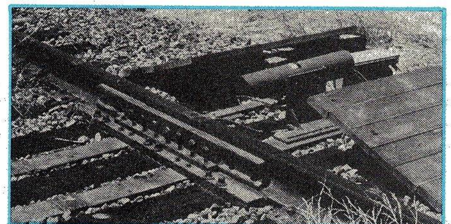
The CAR-SCAN project is an example of FRA's effort to encourage industry to develop individual sensor/detector components and subsystems whose signals can be integrated into microprocessor-analyzed outputs that will make inspection of passing trains more economical by detecting a wider variety of potential hazards than is now feasible. For this purpose, commercial hot wheel, electronic dragging equipment, ultrasonic cracked-tread, hotbox, and wheel flange/loose wheel detectors have been installed for testing on a rag-tag collection of freight cars that have such defects.

FRA is scheduled to report in this fiscal year (1981) technical characterizations of three detector principles as embodied in current hardware:

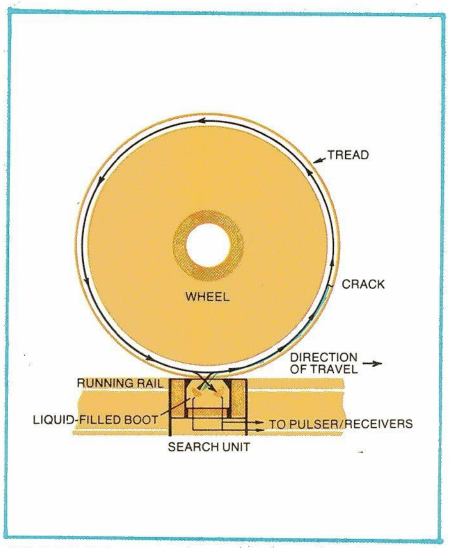
—*Cracked-tread detector*. This is the WHeeLFAX system for ultrasonic scanning of passing wheels (see diagram) developed by Scanning System, Inc. (now FAX Corp.), of Danbury, Conn.

—*Flange detector*. This is the Marine Electric Railway Products Division's multifinger electromechanical "Wheel Checkers" system for detecting missing flange segments and loose or displaced wheels.

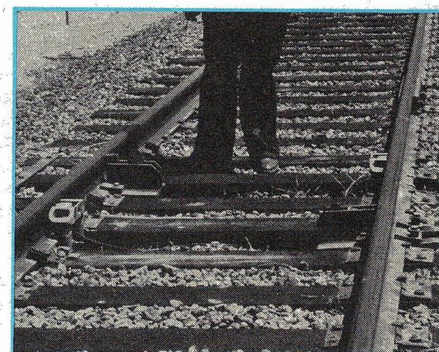
—*Cracked-plate detector*. This is an FRA/Aerospace WDRF embodiment of a mechanization of the time-honored carman's hit-it-and-listen inspection studied at the University of Houston under previous FRA contracts, with lab-type acoustic spectrum analysis gear feeding into a minicomputer programmed to detect wheel plate defects (see photo).



BRAKING INSPECTION SYSTEM sensor. Optical wheel locator correlates motion over sensor with vertical and longitudinal force measurements from displacement of rail segment within the sensor.



CRACKED WHEEL TREAD DETECTOR. A transducer mounted in a special measurement rail injects an ultrasonic signal at the wheel tread, which propagates around the running surface and is received by a second transducer. Depending upon crack size, a crack in the tread will reflect some or all of the injected signal to a receiver in the first transducer. Sensor system logic will determine if the wheel is good (no reflected signal), has an alarm-level crack (partially reflected signal), or has a calamity-level crack (fully reflected signal).



AUTOMATIC WHEEL IMPACTOR used in exploratory development of Cracked-Plate Detector system. Passing wheels flip hammers in the manner of a trap drummer's foot pedal, striking wheel plate to generate sound picked up for good-bad analysis by microphones (not shown).

● **Ultimately—train dynamics?** Farther down the line is the Braking Inspection System (BIS) exploratory development, a system for measuring wheel-rail vertical and longitudinal forces on a passing train in real time. A Transportation Systems Center (Cambridge, Mass.) program with sensor system development by contract with Novatek, Inc., of Burlington, Mass., the BIS uses movement of a section of running rail as measured by linear variable displacement transformers to determine not only single-wheel vertical forces (in the manner of a weigh-in-motion scale) but longitudinal braking forces as well (see photo). At its present state of development it can detect "anything qualitatively out of line" in braking system performance at up to 20 mph and has withstood wheels passing over it at 60 mph with unanalyzed indications that data-taking at such road speeds may be possible.

Obvious possibilities include detecting struck or unreleased brakes and overloaded or eccentrically loaded cars, and wheel-rail force measurements (perhaps including lateral forces) on a real-time, routine basis. BIS might ultimately interact with insights from the Track Train Dynamics program in attacking incipient tendencies toward derailment via dangerous L/V force ratios from whatever cause—track geometry, train handling, train makeup, or suspension design and maintenance—as well as inspecting for failed or maloperating components.

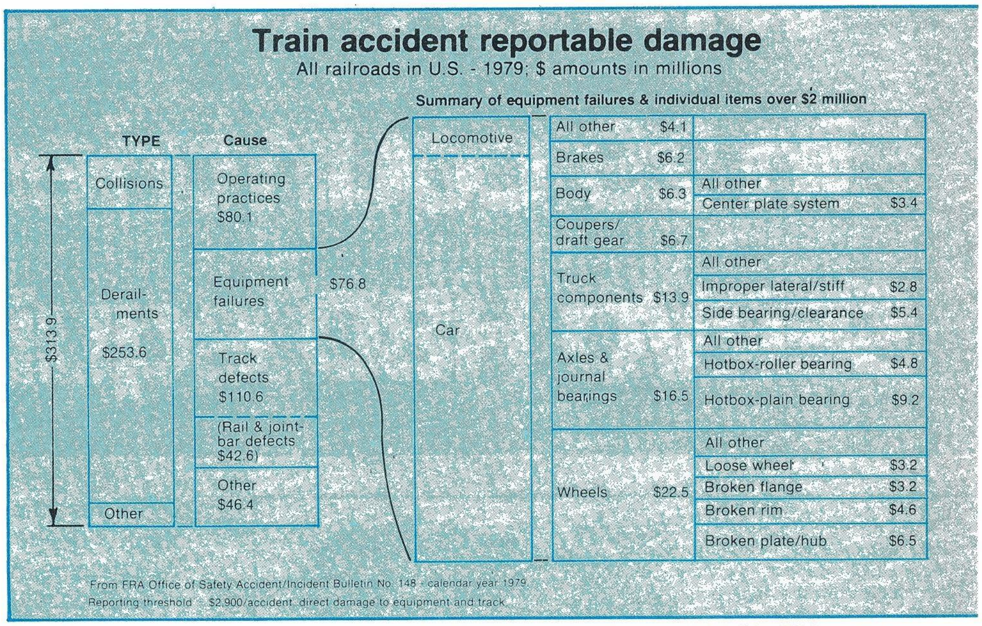
signed to resist fracture from ice clinging to trucks and underbodies but to break when struck by any dragging hardware substantial enough to do structural damage or cause a pile-up—check areas between and beside the railheads at locations approaching tunnels, bridges, and interlockings, where a derailment will have particularly expensive connotations. When these bars are connected in series with appropriate signal circuits, actuation brings trains to a timely halt for inspection.

Development in DED's has proceeded in both directions since then. Opting for economical proliferation, the Denver & Rio Grande Western has installed home-made detectors consisting of a signal circuit wire wrapped around wood lath at each intermediate-signal location on its ctc-equipped main lines. Fracture illuminates a purple aspect at the location, observable from the train in time for an inspection stop before passing the next turnout. In particularly critical canyon areas (also of course protected by extensive side and overhead slide-detector-fence circuits) DED's may be located at intervals as close as a quarter mile, with their signal aspects giving a watchful crew a good idea of where in the train any actuation originates and so reducing the walking and delay after the stop.

In the direction of greater sophistication, latter-day commercial DED's such as the WABCO/Union Switch & Signal SRD-5 are self-restoring; a stout transversely pivoted detector plate flaps over when struck in either direction, breaking the signal circuit. An adjustable spring force provides sensitivity appropriate to the location and returns the detector to its vertical position after actuation. The most recent survey of detector installations conducted by Committee F of the AAR's Communication & Signal Division (1972) found 1,859 installations in service on railroads in the U.S.

Under extreme snow and ice conditions, particularly at high altitudes, moving-part DED's may have problems. Oregon Technical Products (Belmont, Calif.) has introduced its RT-200 Impactor, which senses impacts on its rigid, track-mounted sensor enclosure (fabricated from 1/4- and 5/16-inch steel plate) by acoustic ("earphone") accelerometer outputs, suitably amplified. One MoPac installation was wiped out when a train derailed directly on top of it; other ruggedness complaints are reported minimal.

It is possible for dragging items directly over the railhead, such as brake hangers, to pass through the necessary gaps in mechanical DED sensors; an as-yet-unnamed optical DED system being developed by Marine Electric Railway Systems Division (Brooklyn, N.Y.) uses a light beam immediately above the rail, gated



The damage threshold separating "train incidents" from "train accidents" in FRA reporting, until now adjusted for inflation at two-year intervals, went from $2,300 for 1978 to $2,900 for 1979, accounting in part for a 13.6% decrease in the number of accidents despite a 6.5% increase in revenue ton-miles. Total accident cost, also affected by the threshold change (but less strongly so) and not adjusted for inflation, increased only 2.9% (from $305 million to $313.9 million). For the first time in several years, an actual decrease in accident cost per unit of traffic is indicated.

off and on by each passing wheel, to do the job without this gap. A prototype is located at the Transportation Test Center's Wayside Detector Research Facility (see facing page).

● **Hitting light beams instead of bridges.** Detecting loads or cars made oversize by load shifting or misrouting before they enter a restricted zone would seem to be a straightforward job for a light beam and modern sensing circuitry, and high- and/or wide-car detectors are a part of the scene at appropriate check points. Florida East Coast maintains wide-load detectors at alternate wayside detector locations on its main line, thus checking clearances at about 45-mile intervals.

The railroad job is not quite as simple as opening doors in a supermarket; under heavy rainfall conditions, water pouring from the roofs of high cars may result in an occasional false alarm. A redesigned version of the high-wide detector system developed by Erico Products is now Harmon's CCD-1 car-clearance detector with all solid-state electronics. Many systems are of an ad hoc nature, assembled by railroad signal departments to meet their

Harmon CCD-1 Car Clearance Detector uses an interrupted light beam to check height, width or shifted load, and top corners of passing cars. Receiver operator can shift the mode to COUNT for car counting or WALK-THRU to detect unwanted cars in a yard area.

own particular situations.

The largest single-component contribution to train-accident cost is the $22.5 million from wheel defects. Somewhat more than a quarter of this is attributable to wheels with broken flanges or loose on the axle. Based on patents going back almost 30 years, the "Wheel Checkers" multifinger electromechanical detector, which literally feels passing wheels, was in use at over 200 points by 1972 and has continued to increase in numbers as part of the Marine Electric line since 1975. The installations are typically located at yard entrances or other points where the 15- or 25-mph limitation they pose (there are two models, with different finger dynamics for the two limiting speeds) is acceptable. With a guard rail opposite its array of 124 sensing fingers to position the wheel set, it can detect loose-wheel slippage in either direction and any broken-out or missing flange segment more than about a half-inch deep for 3½ inches or more along the circumference. At a cost about half that of today's boxcar, many users consider it well worthwhile.

AAR C&S Committee F (Special Applications) continues to seek promising ideas that would justify preparing requisites for a loose-wheel/broken flange detector suitable for high-speed locations, but to date without avail. A main-line contact-type loose-wheel detector introduced by Raco in the 1960s (now the Safetran LWD-10) can spot a wheel that has moved inward on its axle but may miss one that is hugging the rail as it passes.

● **The elusive crack.** Perhaps the most audacious approach to on-track automatic inspection by any system that has an example in actual service is that of the WHeeLFAX cracked-tread detector (diagram, p. 26). The system installed at the Canadian Pacific's St. Luc (Montreal) yard in 1976 is no longer in service (a government-supported continuation of CP's in-service evaluation, which involved traffic of over 6,000 wheels a day, has not materialized), but Florida East Coast continues its 1977 installation at Bowden Yard (Jacksonville) in service. Unless snagged by something, the flexible boots that contact the passing wheels are reported to last five or six months; inspection is carried out at speeds up to 15 mph. At sensitivity levels used on FEC, 90-to-95% of the wheels the detector identifies by alarm read-out and paint spray are found on inspection to have visible tread defects, 10% of them condemnable in severity.

Scanning Systems Inc. ran out of money waiting for broader acceptance of the on-track WHeeLFAX systems, but its successor, FAX Corp., has sold several dozen hand-scanner WHeeLFAX JR's in the U.S. and throughout the world. Using the same principles to detect, locate, and estimate the size of defects in wheels on or off the train, the JR is in the $7,000 range with readout.

A more fundamental need for ultimately reducing the toll of tread cracks is better understanding of the relationships between residual stresses, detectable cracks, thermal abuse, and catastrophic failure in railroad wheels. Normal-service loading results in plastic surface deformation, so that elastic-range theory cannot resolve the situation, and existing test machines lack the capacity to reproduce all essential mechanical and thermal effects (including vertical rail load) in tests to destruction. Also continuing is the search, still punctuated with the cries of "I have found it" that have been heard at so many times in the past, for a nondestructive method of measuring residual stresses.

● **Mechanizing the car tonk.** Believing that FRA-sponsored work on the automated acoustic detection of wheel plate cracks has shown promise similar to that of hotbox detection by scanner in the early 1950s, investigators in Union Pacific's Research & Mechanical Standards organization have devised an electromechanical in-motion wheel-whacker that is somewhat more sophisticated than the trap drummer's foot-pedal device used to demonstrate the principle. They have rounded up suitable crack-probing and acoustic processing gear and have undertaken reprogramming and expanding of good-bad algorithms from the previous work for use on their minicomputer, with plans to do sufficient work in the laboratory to warrant the installation, somewhere on the railroad, of a prototype field system to try out the technique on cars in general service.

Suppliers are adding to and updating the most widely used detectors—infrared hotbox scanners and their readouts.

From the standpoint of extent of investment and use, the big end of the wayside detector stick is the infrared hotbox scanner. First used routinely in the late 1950s, and in service at 1,842 installations by the time of the 1972 inventory, scanners and their readouts are still being added and updated throughout the industry. With at least four suppliers, it's a competitive field; there are technical differences among the approaches, some of which may make one or another more suitable for a particular situation, but—as in other mature fields—such matters as commonality, service, and replacement-part availability can also weigh heavily in a railroad's choice.

● **What does it look at?** All currently produced scanners sense the temperature of the passing journal bearing assemblies, though they reflect major differences of opinion as to the most informative (and safest) point or angle from which to look; all represent at least two generations of development, require one scanner unit for each side of a track, are compatible with main-line train speeds, and can generate output signals (temperature rise above ambient) that can be processed on the spot or transmitted by communications circuit to any desired remote location.

Servo Corp., (Hicksville, N.Y.). Servo's fourth-generation Model 8909 "Servoscan" hotbox detector is rail mounted, ruggedized to withstand this position where it looks up almost parallel to the face of the wheel at a 45° angle with the horizontal, scanning the portion of the journal bearing inside the side frame on conventional trucks and just catching the wheel hub on inside-bearing passenger car trucks.

General Electric (Electronics Div., Drive Systems Dept., Salem, Va.). GE's detector now uses a pyroelectric (photovoltaic) sensor, eliminating the high-voltage circuitry of the bolometer (thermistor) sensor used in all other systems. Its single ballast-mounted scanner looks at the side of the journal box near the outer end, generating a signal that is converted to a standard-width pulse of voltage that corresponds to temperature above ambient for motion either toward or away from the sensor.

General Railway Signal (Rochester, N.Y.). GRS's scanner is tie mounted, looks at the hub of each wheel near the axle where the temperature (in an unbraked wheel) is a function of the journal bearing heat input (about ¾ of which flows into the axle). Its reading will also reflect abnormal wheel heat inputs. It has recently been redesigned with more compact electronics, easier-to-service access and component packaging, and a powerful blower to keep rain or snow out of the optics during train passage when its viewing port is open.

Marine Electric Railway Systems Divisions. (Brooklyn, N.Y.). Marine Electric's HB-76-1 is pedestal mounted in the ballast near the tie ends, usually with protective ramps at each side; its bolometer sensor looks at the wheel hub but is gated on and off by each wheel for a duration adjusted for train speed so that only 10 inches of scan, centered on the axle, is recorded and wheel plate or rim radiation does not directly affect the sensor.

All of these systems use wheel sensors to sequence various functions and protective devices, incorporate heaters and compensation circuitry as needed to keep their optics clear and electronics in calibration throughout extremes of ambient temperatures, and have some internal or external source of an ambient temperature reference.

● **What do you do with the output?** Here, railroad individuality takes over and brand loyalty, if any, seems to disappear as each road combines components from various suppliers. None of the detector manufacturers builds its own chart recorder, so outputs tend to come out in format compatible with commercially available recorders and alarm panels, and therefore with each other. *Primary* use of temperature data will usually be either to generate an automatic alarm if some criterion is exceeded or to record each reading on a strip chart for examination and decision; as a back-up, many alarm systems also put the data on tape somewhere, and chart readouts often provide an audible alarm for any out-of-line readings.

Since roller bearings normally run at a higher temperature than plain bearings, setting a single temperature as cause for stopping a train for examination isn't usually satisfactory, and a great deal of thought and energy has gone into refining the decision process. A skilled and experienced observer looking at the record of a whole train can do an excellent job of interpretation, so many roads, such as ICG, Southern, UP, and D&RGW, have brought all HBD data into one or a few central locations where decisions are made and instructions transmitted by radio to the train crew involved.

Other railroads rely on some established alarm level, usually on the *difference* in temperature between the two bearings on the same axle. To improve discrimination, Marine Electric offers linear compression as an option; different chart deflection rates per degree allow more selectivity among the cooler-running plain-bearing readings while keeping normal and alarm-level roller bearing readings on the scale. Servo has offered an Automatic Bearing Identification option for the past decade—the differences in *shape* of the scan signature between the relatively uniform external temperature of the roller bearing and the triangular pattern seen by the scanner as its view passes from the cool lower edge of the plain-bearing box past its warmer upper regions is used to classify the bearings on each axle by type; an appropriately different alarm temperature is then applied in evaluating each. ABI thus allows setting alarm temperatures closer to the upper limit of the distribution of normal running temperatures without getting false alarms.

Roads that elect to send alarm information directly to the train crew immediately after passing a detector have several options; a current favorite is the axle-count scoreboard that displays the location of the first alarm indication in terms of position from the rear (or, if desired, the front) end of the consist. Various patterns of auxiliary lights are used to indicate side of train, multiple alarms, and type of defect (in multisensor detector arrays). Harmon, Oregon Technical Products, Servo, and others offer standardized units.

Servo Hot-Wheel Scanner installed at Wayside Detection Research Facility. Diagonal line of sight of infrared scanner scans four wheels of passing truck in turn, obtains ambient-temperature reference from stationary target on opposite side of track between wheel intercepts.

Coming up fast are the "talkers," prerecorded tape units such as Servo's "Servotalk," that can specify the location of up to three alarms per detector type per train, identifying the type of alarm for each as it passes the word by radio to both ends of the train in "any local accent or language desired," while observing FCC protocol and expending only 100 watts in the process. Pioneered by Seaboard Coast Line with hundreds of units, the talkers are now going in on Conrail, BN, and other roads in quantity.

● **Looking at wheels, one at a time.** Less immediately hazardous, perhaps, but far more common, are hot wheels from sticking or unreleased hand brakes. Despite the difficulties mentioned above in quantifying the situation, the thermal abuse they represent has to be a major cause of eventual wheel failures. Flat wheels do the track no good, and even the extra fuel represented by a few restrained wheels over a whole division is not trivial these days.

The same infrared scanner technology used in looking for hotboxes can do the wheel job even more easily, since a diagonal, horizontal line of sight can catch all wheels from one side of the track. A natural companion of the hotbox detector, since some of the same read-out and test gear can be used, the HWD is also suggested for stand-alone installation three to five miles outside the departure yard to catch the draggers as soon as they've had time to warm up.

Already manufactured by Marine Electric ("HW-76-1") and Servo ("Servotherm"), the hot-wheel detector is beginning to represent a major segment of the business, with Canadian Pacific scheduling 60 installations in its current program. Whether found in conjunction with hotbox detection or by the specialized HWD, hot wheels are numerically predominant in today's day-by-day spectrum of indications causing trains to be stopped for inspection.

Illinois Central Gulf pioneered in field testing of the hot-wheel detector and is "very gratified" with results from its two Servo units, but has not been in a financial position so far to add more HWD's. ICG reports the following mix of occurrences at its Chicago Hotbox Detection Center. Sixty-four of ICG's 91 wayside detector locations are monitored in Chicago, where an average of 609 tapes a day are examined in "real time" (while trains are passing the detectors) so that in cases where a critical indication shows up, the word may be passed to the train crew even before the rear end has reached the scanning point. In 1979:

Trains stopped for inspection	4,608
"Valid" stops—specific trouble found	3,303
(Includes 140 cases in which trouble was not found initially but confirmed by later events)	
Cars set out for hotbox	940
Sticking brakes (hot wheel)	1,893
Hand brake unreleased	579
Pressure in brake cylinder	272
Retainer valve on	111
Dragging equipment confirmed	138

The hotbox figures - 1979

	Freight car-miles (AAR)	Set-outs (AAR)	Car-miles/ set out	Overheated-journal train accidents-car* (FRA)	Set-outs/ tr. acc.	Damage (FRA)	Damage/ accident
Plain bearings	6,640×10⁶	10,216	650,000	164	62.3	$8,849,000	$53,960
Roller bearings	26,020×10⁶	1,679	15,500,000	61	27.5	4,666,000	$76,500
Total	32,660×10⁶	11,895	2,780,000	225	52.9	13,515,000	$60,070

FRA figures from Accident/Incident Bulletin No. 148 (1979).
AAR figures from Mechanical Division quarterly/semiannual special bearing-performance surveys.

*Locomotive overheated-bearing train accidents (2pl. brg., 3-roller brg.) omitted. Passenger car accidents (not separately reported) included; passenger-car miles are approximately 1% of freight car-miles.

The percentage of indications judged important by the monitors which were confirmed upon inspection in the field (over 70%) is typical of that attainable with experienced people on a continuing basis, and high enough to lend credibility to the system. The number of hand brake and retainer incidents is also enough to keep up interest in the invention of a practical indicator which would bring prompt attention to such goofs.

● **Is there another way?** Like the slide fence that can do nothing to protect a train from the rock that comes bounding down the slope at the very moment of its passing, the most sophisticated wayside detectors can only find those incipient hazards that exist at the time the train goes by; detecting *all* quick-developing faults involves an inherent trade-off between investment and security.

As perhaps the most thoroughly studied component, the journal bearing should at least provide the most comprehensive body of data to consider the situation. AAR member roads contribute quarterly and semiannual reports to the Mechanical Division; these, in conjunction with the reports to the FRA on accidents that result when the hotbox is *not* found in time, give an overall view of progress in the battle against this particular problem. In the decade ending in 1979, the number of such accidents on U.S. railroads decreased 44% (from 409 to 230) while net ton-miles were going up 19%. Hotbox setouts also decreased 32% as the fleet went from approximately 40% to 75% roller-bearing. The table shows the 1979 situation in terms of catching 'em before they burn off.

For the rare roller bearing that does fail, the well-established tendency to progress from normal running temperature to failure in a much shorter time than its plain-bearing counterpart does is probably the main factor accounting for the fact that less than half as many of those that do overheat are found—by detector or otherwise—and set out in time. The fact that more than 96% *are* found indicates that detectors rarely miss one that's in trouble; spacing between inspections simply exceeds the failure time and distance in some cases. Some roads, particularly where increasing hazmat traffic is involved, are adding and respacing HBD's to improve the odds, but at an installed cost per station of $45,000 to as much as twice that if all optional features are included, there is a limit.

An alternative approach, of course, is an on-board detector that can sound the alarm immediately; in the hotbox case, the maximum theoretically-possible rate of heat generation is such that promptly initiated braking should bring any train to a stop before the axle is fatally weakened.

● **Wiring the Amfleet.** Passenger train hot bearing cases are comparatively rare. However, since inboard bearings of its Amfleet cars are not directly scanned by standard HBD's and regular 120-mph operation will resume on the Northeast Corridor in the future, Amtrak has completed in-service evaluation of two systems of on-train monitoring and is starting installations under a 3-to-4-year program that will see all such existing cars so equipped. A nonproprietary adaptation of principles tested on two pairs of coaches equipped with Marine Electric and Safetran systems developed under previous pilot-production contracts, the adopted system monitors only bearing temperature, and thus does not require multiplexing in using an assigned wire in the train line to transmit information to the locomotive cab. Amtrak decided against monitoring air-bag pressure and disk brake temperature on the basis that these conditions do not affect safety.

A thermistor-bridge sensor at the bearing/adapter surface provides a fail-safe temperature indication, maintaining a green light in the cab unless 260°F is exceeded, when a red light and cancellable audible alarm are actuated; any car not generating its own 24-volt "good" signal will block the signal from cars to its rear, indicate its status by a red light in the aisle, and identify within the electrical cabinet which truck's bearings are to be checked. System hardware is being supplied by low-bidder Safetran.

The 150 Budd long-distance single-level cars now on order will include the system; Amtrak's LRC trains have a similar bearing-monitoring system that is not quite so fail-safe since it uses a temperature-actuated switch as sensor.

● **What about freight?** Monitoring any safety aspect of passenger train or transit vehicle status reasonably economically, and without seriously affecting reliability, certainly can use all available high-technology expertise to good advantage, but with electric power and jumper cables for other purposes already available, it involves no particularly novel technical risk. On freight equipment, where the first piece of wiring represents an infinite increase from that currently in use, there are a lot more questions to be answered.

Assuming that trouble detectors that can meet life, temperature-extreme, and ruggedness requirements are available, there is the matter of getting the word to the locomotive—or to the railroad's communication network, which may be almost as good—where action can be taken. Promising results are reported at Queen's University (Kingston, Ont.) in Canadian Pacific-sponsored work on an inductive link in which transformer coupling within the existing air hose gladhands would provide the equivalent of "hard wire" end-to-end communication with no additional attention in the field. Another possibility is a "leaky coax" trackside cable—for this and other purposes—which, as in existing rapid transit communication systems, would connect any point on a train with the world with only a short and relatively predictable through-the-air link to be bridged.

Such continuous, every-car, communication possibilities, in return for their predictably high cost for general implementation, might reopen such other possibilities as instantaneous brake synchronization going far beyond the needs and benefits of hazard monitoring alone.

● **The RF Bolt.** More specific is the Radio Frequency Bolt bearing overheat detector currently in the engineering breadboard stage of development at DOT's Transportation Systems Center, Cambridge, Mass. It is small enough to mount in the elongated head of a standard roller-bearing end-cap screw, and when actuated by excessive temperature the bolt generates a 900-MHz radio signal that transmits an audio-frequency tone to a receiver in the cab. Powered by a long-life battery, an activated unit will continue to transmit for about three hours, which should be ample for locating the alarm

NEC: A system for fast, dense, mixed traffic

What is the state of the art in wayside detectors as represented by the highest-speed, highest-density territory in the United States, where much trackage is shared by freight and passenger traffic? For the Northeast Corridor Improvement Project, the plan involves purchase of hardware (some of it not likely to be strictly off the shelf) by Amtrak to performance specifications:

Hotbox detectors

—At 35 to 40 mile intervals on main line and at "entrances" to NEC wherever trains have been traveling far enough to warm up bearings.

—Roller/friction bearing discrimination, ambient temperature adjustment, train-average bearing temperature calculation/adjustment.

—Automatic two-level signal:

- "Alarm" level—to signal system to stop train immediaely.
- "Intermediate window" level—to Centralized Traffic/Electrification Control area display for evaluation and action via communication link to train.

—Analog/digital conversion of signal at site to avoid noise problems in transmission.

Dragging equipment detectors

—At all entrances to corridor (stand-alone installations).

—At all hotbox detector locations.

—At locations to protect all interlockings (stand-alones).

—Self-restoring type.

Considered but not adopted because of speed restrictions or discrimination limitations in all known designs: cracked or broken wheel detectors, loose-wheel detectors.

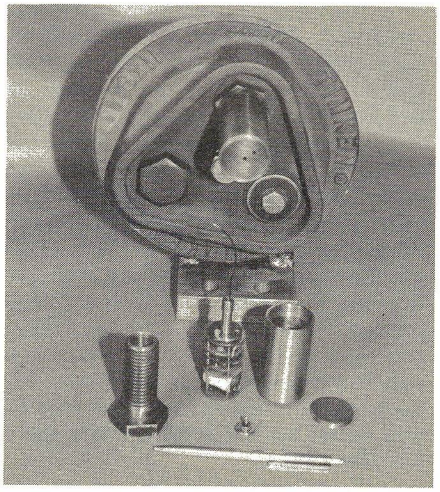
source. Units from TSC contractor Shaker Research, of Ballston Lake, N.Y., were recently tested on the Boston & Maine to verify that the RF pattern they establish should allow reliable reception in a realistic railroad environment at up to one and a half miles. Next step is extensive environmental testing in preparation for exposure to the rough ride of bearings rolling along in service. In common with other individual-car monitoring schemes, such a device can become effective on a percentage-of-fleet basis wherever equipped units may roam, provided that locomotive radios are made receptive to their signal.

Studies of monitorable equipment and roadway failure modes have also indicated that detecting a single-axle or single-truck derailment may be worthwhile. In a small but perhaps significant proportion of such derailments from any source, the train line may not be broken and the train may continue for many miles, chewing up crossties in the process, until a turnout or other obstruction (in turn, likely to be in a populated area) results in a general derailment that could have been at least greatly reduced in consequences had the first wheel on the ground been immediately detected. Where power and communication are available, such monitoring is straightforward; Bay Area Rapid Transit cars have been so equipped from the beginning. A frangible aluminum-alloy member directly over the rail (initially on both sides, now on one side only to reduce maintenance and false alarms, since its geometry will still insure activation) in the door-open emergency circuit will automatically stop the train. BART has experienced only three derailments in its eight years of operation, all at low speed; elimination of the system on the next order of cars is under consideration.

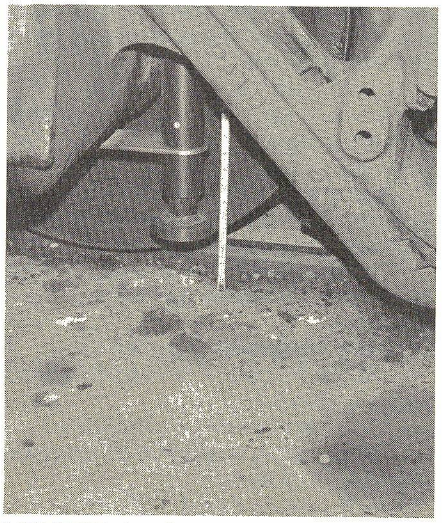
● **DOT-STAR.** It's easy to forget that there has been an inherently fail-safe train-integrity monitoring system in successful use for somewhat over 100 years now—George Westinghouse's automatic air brake, which not only detects a train separation but does something about it, in the vast majority of cases in time and sequence to prevent intra- or inter-train collisions.

DOT's System for Train Accident Reduction (DOT-STAR), also sponsored by FRA's Office of Rail Safety Research, originated with a 1972 "technology transfer" study by the White Oak (Md.) Laboratory of the Naval Surface Weapons Center (NSWC) looking into nonmilitary applications of components, principles, or expertise developed in connection with Department of Defense programs. The system concept that has evolved works as follows in the case of hotbox detection:

A temperature-sensing element of a unique nickel-titanium alloy that, at a desired temperature, undergoes a phase change in which it shrinks in length by several percent is used to release a heavily spring-loaded firing pin and initiate a percussion primer. The primer initiates a hermetically-sealed "thermal" battery of indefinitely long shelf-life by igniting a pyrotechnic material that melts the solid electrolyte. Detectors on each journal are hard-wired in parallel to one self-contained electroexplosive valve per car. Voltage from an activated detector initiates the valve, venting the train line and stopping the train. A loud whistle from the valve as the train line is recharged locates the car; valve location is such that the existing cut-out cock can be used to isolate the car for set-out or other appropriate action.



Engineering model of Transportation Systems Center/Shaker Research RF Bolt bearing overheat detector. Replacing one bearing cap screw, the detector sends an alarm to the train radio if actuated by excess heat.



DOT-STAR derailment sensor element installed on a DM&IR ore car. Upward railhead impact of more than 7,000 pounds on the foot shears the pin, initiating thermal battery generating signal to explosive-powered cutter that vents brake pipe and stops train.

Obviously, a demonstrably zero false alarm rate is essential to the acceptance of such a system. Twenty-four units on "miniquad" taconite ore cars of the Duluth, Missabe & Iron Range, which has been participating in the program since 1974, have been in captive service since 1975 with no false alarms, accumulating more than 100,000 miles with all components in place but with actuator valves not connected. Nineteen of 19 batteries initiated for test after five years functioned properly.

In parallel with the hotbox detectors are wheel-on-the-ground detectors. The initial NSWC proposal was a mechanical accelerometer on the journal that would detect the impact of a derailing wheel as it fell from railhead to roadbed. It was found that elements sensitive enough to reliably detect wheel impact on an empty could occasionally false-alarm under normal conditions when passing over frogs when the roadbed was frozen; the current approach uses long-travel direct-force sensors of considerable ruggedness, which have withstood two years of DM&IR service with no damage or actuations except on one car, which was found to have been derailed in the loading plant, properly actuating one sensor but wiping its neighbor in the automatic rerailing process.

Units with production thermal batteries are now being installed on the DM&IR for all-up (system connected to brake pipe) service test. A thermal sensor for standard roller-bearing journals (Missabe Road ore cars use plain bearings) which allows either hotbox or wheel-on-the-ground sensor to actuate a common thermal battery has passed laboratory tests and is ready for long-term road-testing in the "passenger" (electrically disconnected) mode.

As one developer of a generally technically successful wheel-flaw detection system observed, "It takes a long time to do *anything* in this business." When you must be ready to detect subtle effects occurring with much less than one-in-a-million frequency while living through the railroad's physical, electromagnetic, and emotional environment, and not spending much money in the process, forward motion certainly can be glacial. Better railroading tools ought to help—such as train-action analytical programs that should make it practical to determine whether a service or emergency brake application is the better choice in an automatic monitoring system over a given spectrum of operating situations. Will increasing equipment costs and liability considerations join with new components and techniques to bring detectors into wider use? Maybe so, maybe not. ■