Railway Signaling & Communications

TORONTO RAILWAY CONFERENCE

The feasibility of automatic freight train operation was proved by the successful operation of a test train on a 10-mile section of CN track near London, Ont., in 1960 (RSC Nov. 1960, p. 20). Some of the problems encountered in the design of locomotive and train controls for such automation were discussed by R. G. McAndrew, control engineer, General Railway Signal Co. Major problems are:

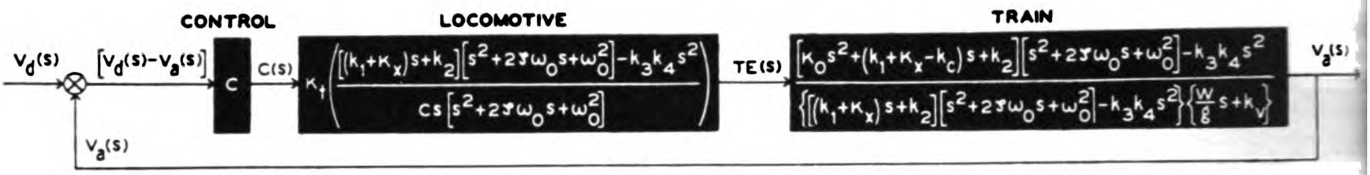
- Representation of the train and its controls so that response and stability characteristics may be examined.
- Choice of a parameter for the control.
- Suitable control at very low speeds.
- Train handling without damage to draw-gear or lading.
- Vibration effects on locomotive-carried control equipment.

Present day control design techniques are applicable to train automation, Mr. McAndrew said. He made extensive use of mathematical analysis in studying the major problems of control. One approach, he said, is to investigate a closed-loop system where the difference between demand and actual train speed provides actuation to a control, the output of which is applied to the locomotive. The output of the locomotive is applied to the train, the output of which is the controlled variable —speed. The "loop" is closed by unity feedback of velocity to the system input where it is compared to the desired speed. The advantage of "closing the loop" lies in the fact that many undesired disturbances can be handled satisfactorily with little loss in inherent accuracy of the control system.

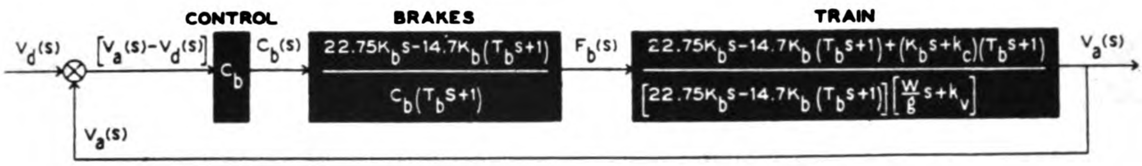
The parameters upon which to base a control is a speed-error system. A problem involved is that velocity or its derivative is involved. The matter of sensing accurate values of velocity brings in the problems of progressive change of wheel size and wheel slip. The use of acceleration as a basic parameter requires that a knowledge of proper level of acceleration for a number of circumstances be known. It would appear that acceleration would be better used as a modulating signal.

A matter which has come up in recent years which was expected to be a considerable problem has resolved itself with little or no trouble. There is oftentimes demand for extremely low controlled speed. When a locomotive is proceeding at a speed of less than one mile per hour, one's immediate reaction would be concern for overheating the traction motors in view of expected high current values. It has been determined during some recent tests conducted by General Railway Signal that speeds of the order of ¼ mph are perfectly feasible and controllable for a single 1,750-hp unit on level tangent track, or up to about a 0.2% grade (ascent) with a nominal tonnage of 2,500 tons. The horsepower requirement was of the order of 20 to 25. The tests were conducted such that manual control was used to simulate speed error. Timing with a stopwatch, together with knowledge of rail length provided the speed. No overheating of traction motors could be observed during a test period of about 30 min.

With regard to the problem of the transmission of shock through a train and draft gear response, an accelerometer was mounted in the caboose of the CN train during the London, Ont., ATO tests. In this case the train had 1,827 trailing tons, caboose weight was 22



Control block diagram - increasing throttle



Control block diagram - 7 psi brake pipe pressure reduction.

Some idea of the complexity of the mathematics involved in automatic freight train operation is shown above.

tons; 32 cars total; train braking ratio was 34.8%; and the train was pulled by a 1,750-hp locomotive.

Up to the present time, it has been very nearly impossible to obtain shock data for each car in a long train. The plot on the accelerometer chart (mentioned above) indicated that a damped sinusoid represents the acceleration of a caboose responding to slack action. It is suggested (from curve form) that a simple relationship involving viscous friction may be used, even though the draft gear in the caboose was of the variety theoretically requiring use of Coulomb friction relationships, as are most interchange cars.

If each car in a train is now represented by an oscillating RLC circuit and these circuits arranged such that the output of one becomes the input (with suitable time delay to represent slack) to the next, it may be possible to simulate slack action. Should this plan prove feasible, one could observe the reaction of each car to control outputs on the locomotive in order to select optimums which provide least disturbance to lading.

The mass is analogous to inductance; energy storage and release ability of a spring is analogous to the same for a capacitance, and damping may be represented by resistance. A check is provided if one has available the total time from first movement of locomotive to first movement of last car.

Another large problem that it might be well to bring out is the matter of vibration aboard a locomotive. A number of excitation functions can be identified; however, it is felt that little has been done to take into account their result in the design of locomotive-carried control equipment. There has been no serious need in the past for such investigation. However, with the advent of electronic and servo control with their attendant refinement, careful attention should be paid to environment which could destroy them or render them inaccurate. In the design problem, we must consider the normal rotary unbalance of the diesel engine-generator combination, the possible longitudinal excitation caused by the firing order which may be necessary in the diesel engine, the transverse "hunting" of the wheels on the rails, and vertical excitation from passing over rail joints. This is a formidable combination and the range of frequency involved is considerable. Particular difficulty may be expected (this is from qualitative observation) when the locomotive is standing still with the engine idling. No doubt locomotive vibration data will be taken and published before very long.

Floor discussion following Mr. McAndrew's paper indicated general agreement that velocity is a good parameter, especially because velocity detectors are now available which do a good job. It was brought out, however, that there is doubt that the present day detecting equipment has the precision required when braking a train on descending grades. One listener said that the dead time parameter—the shift of the transfer function along the time axis—should be considered. This is the time lag that occurs between the time a control is "told" to take effect and the "action" takes place. It varies with the locomotives used in the automatic train, and also varies with each car, particularly depending upon the distance of the car from the locomotive (the well known occurrence that the locomotive starting a long train moves several feet before the caboose starts moving). It was predicted that the first application of ATO will be on a captive railroad. RSC

INFRARED HOTBOX DETECTORS

Three aspects of hotbox detector performance appear to be of major importance in assessing the use of these detectors, stated E. G. Menaker, manager-railroad equipment engineering, General Electric Co. One aspect, he said, is called efficiency, but in many respects it is a misnomer. Whatever it is called, it is calculated as the percentage of hotbox indications given by the detector for which hotboxes were found, or:

$$\frac{\text{Hotboxes found}}{\text{Hotboxes indicated}} \times 100 \text{ percent}$$

Experience seems to show that percentages vary from 50% to close to 100% with entrance-to-yard percentages running somewhat higher than line-of-road. However these figures must be used with understanding, since they are greatly affected by many factors.

For one thing, some railroads include with hotboxes other heat generating defects such as sticking brakes, steam leaks, etc., while others do not. Some statistics are based on inspections by train crews, who are not necessarily specialists in bearing inspection while others derive from observations by specialized car inspectors. In addition, many of the other factors affecting performance described below will modify such statistics quite drastically.

A second aspect of performance is the reliability of detectors from the maintenance standpoint. While this is fundamental to any economic evaluation of the use of hotbox detectors, it is not so readily measured in quanative terms. I should like to suggest here, though, that easures having considerable validity could be applied. is possible to establish such ratios as: (1) Maintenance an-hours per detector per month. (2) Percent of trains r which detector was operating satisfactorily.

The third aspect is the very essence of any evaluation hotbox detector performance. This measure might be pressed as the percentage of hotboxes passing the tector which were indicated by the detector, or:

$$\frac{\text{Hotboxes detected}}{\text{Hotboxes passing detector}} \times 100 \text{ percent}$$

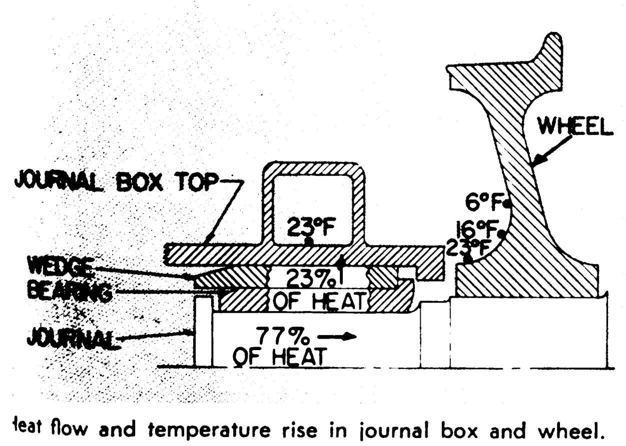
nce hotboxes can develop rapidly, it is difficult to es- blish with certainty whether a hotbox found some dis- nce beyond a detector did or did not exist when the ain passed the detector. Another difficulty is that cri- ria are not always clearly established for defining a otbox. In spite of these difficulties it should be possible express quantitatively this third aspect with as much alidity as the first one discussed above.

Since the cost associated with a missed hotbox—which ight cause a disastrous wreck—is so high as compared ith the costs associated with "false indications" or with aintenance, it would appear that more emphasis should e given to percentage of hotboxes detected.

Finally it might be possible to derive some figure of erit for a hotbox detector which takes into account all ree aspects discussed above. By assigning realistic cost alues to (1) the investigation of a false indication, (2) aintenance of a detector, and (3) the cost of an un- etected hotbox, a dollar cost or saving might be deter- ined for a detector over a given period of operation.

In addition to the nature of the bearing and side frame ructure plus the characteristics of the hotbox detector, here are several other factors which affect materially he performance of a hotbox detector. Sunlight, snow, lectrical noise and hot ballast are some of the ambient onditions which may modify the performance of a hot- ox detector.

The sun, as the earth's principal source of infrared nergy, is of great importance. When enough of its nergy reaches the detector, it can either produce false ndications of hotboxes or blind the detector to heat ndications from journal boxes. It can reach the detector y being reflected directly from the boxes being scanned, r by being reflected from other parts of the train, by shin- ng directly into the detector or by heating parts of the rain which are seen by the detector. Most of the energy rom reflected sunlight falls in the short wavelength re- ion while most of the energy from the boxes falls in the onger wavelength region. Therefore, most of the effects f reflected sun can be eliminated by the use of de- ectors having the greatest possible sensitivity to the de- ired wavelengths and minimum sensitivity to the short wavelengths. In addition filters can be used to screen out short wavelength radiation.



Heat flow and temperature rise in journal box and wheel.

The heat produced in parts of the cars by sunlight is much more difficult to discriminate against since it re- sults in precisely the same kinds of radiation produced by hotboxes. The commonest occurrence of this kind is the heating of boxes on the south side of a train which travels for an extended period on east-west track. How- ever, another similar example is that of empty gondola or hopper cars, the bottoms of which are heated by the direct rays of the sun. Fortunately, the increase in tem- perature produced in both these cases is not great enough to produce wide deviations from normal performance. It may, though, prevent precise correlation of detector in- dications with actual temperature rise.

Falling snow, or swirling snow caught up by a high- speed train, may if thick enough partially cut off infrared radiation from the train, resulting in indications lower than normal. Accumulations of ice and snow on journal boxes may produce the same effect. On the other hand icicles on the boxes may produce sun reflections and false indications without adequate filtering.

Where hotbox detector information is transmitted to a remote location, it is subject to all the kinds of inter- ference from lightning, radio noise, crosstalk, etc., with which communications engineers are only too familiar. The hotbox detector itself may also produce spurious signals as a result of line transients, lightning hits and intense radio fields. Suitable measures to minimize these effects should be taken in the installation.

Ballast on a hot day may be heated well above am- bient temperatures. The bottoms of cars traveling all day over such hot ballast are undoubtedly heated by radia- tion, and this can distort the readings given by the de- tector.

The most common source of heat on freight cars other than the bearings is brakes. When a detector is located properly and brakes are in good condition, the detector will ignore them. However, a detector may well sense the heat in smoke or sparks given off by applied brakes. Thus detectors should not be installed in locations where brakes will be applied such as on or at the end of long downgrades or close before stopping places such as yards.

Sticking brakes can also give off hot smoke and sparks, but they may also cause the wheel and eventually the bearing to heat up. A large portion of the bearing heat is normally transferred to the ambient air by way of the wheel. When sticking brakes actually generate heat in the wheel, this path for getting rid of bearing heat becomes much less efficient, and bearing temperatures will rise.

Steam and hot water leaks on passenger cars will frequently be detected by hotbox detectors, particularly if they are in the neighborhood of the journal boxes.

Today's hotbox detectors are designed to give normal indications when they view the temperature rise asso- ciated with normal solid bearings. Roller bearings intro- duce some additional complexities in performance. First of all we should distinguish between two applications of roller bearings: those in integral-type side frames (essen- tially identical in external configuration to those used with solid bearings, where the journal box and side frame members are a single unit,) and those in pedestal- type side frames, where the side frame terminates in a fork at each end which mounts over a separate bearing housing. Since the former type appears to the eye and to the hotbox detector to be essentially identical to a solid-bearing truck, it can be classed with solid bear- ings and needs no further discussion. Those mounted in pedestal side frames raise additional questions.

First of all there is a variety of configurations, both internal and external, among such roller bearings. Some are enough shorter than solid bearing housings that a detector aimed to scan solid bearings in optimum fashion may miss such roller bearings, particularly when there is an unfavorable combination of bearing type, side sway, wheel size or rim thickness. Such a bearing will give a detector indication which does not correspond accurately to its temperature rise.

Even if these bearings are scanned properly, they give indications which differ from those of normal solid bearings. Since the roller bearing housing is itself the outer race of the bearing, the scanner sees directly one of the parts which is generating heat. The scanned part of the normal roller bearing therefore has a much higher temperature rise than the scanned part of a solid bearing. Some of these bearings also have a cap bolted directly to the end of the journal and in intimate thermal contact with the axle, which is seen directly by the scanner. This also has a high temperature rise on a normal bearing.

Finally there are some roller bearings which generate somewhat more heat than plain bearings, and on these the journal, wheel hub, and side frame, as well as the housing may have higher temperature rises than on normal solid bearing trucks.

These variations in roller bearing indications have seriously hampered the adoption of automatic evaluation equipment for use with hotbox detectors. The heart of the problem is that different temperature criteria must be used for solid bearings and roller bearings, but there is nothing which can reliably tell evaluation equipment which bearing is of which type. RSC

It is characteristic of the use of hotbox detectors that the various aspects of work associated with them do not fall neatly into the scope of any one department's responsibilities. Car inspectors must check bearings which have been tabbed as overheated, train crews must look for hotboxes when trains are stopped on line-of-road, signalmen must provide maintenance of detectors, men from the communications group must plan and maintain data transmission equipment. The criteria for normal and abnormal bearings must be established by the mechanical department, but the detector performance to meet those criteria must be reached and maintained by electronics people. Close cooperation and interchange of information between the proper groups are essential right from the planning stage for the first installation through the continuing day-to-day operation after units are in service.

The variations in roller bearing indications described above point up the need for more information about the thermal performance of roller bearings, both when they are normal and when they have defects.

The information now available, both analytical and experimental, about the thermal performance of bearings is valid only under steady state conditions. But in the case of most hotboxes, an unstable condition has been created in which the temperature runs away. As the temperature increases, the heat being generated increases, until ultimate failure takes place. In this process the heat capabilities of the wheel, axle and truck members play a major part. A study of what happens during this process would be a valuable contribution to knowledge of bearing performance and of the use of infrared hotbox detectors.

COMPUTER SIMULATION OF CTC

A computer simulation of CTC operations developed by the operations research department of the Canadian National has been close enough to actual train operation so that the technique has been an aid in planning CTC installations and siding extensions and retirements on existing CTC subdivisions. (**Editor's Note:** A full length feature article on this CN project will appear in a forthcoming issue of *Railway Signaling and Communications*.) In the past the installation of CTC involved painstaking and time-consuming work in the redispatching as to how trains would be operated under CTC. This would be necessary to determine the most economic number and locations of signaled sidings which would adequately handle the current and anticipated traffic. C. J. Hudson, operations research analyst, CN, reported that the computer technique of simulation developed by CN's operations research department enables the transportation department to evaluate various siding configurations easily and quickly and to compare alternatives quantitatively.

He said the present program has limitations, some of which are due to the memory size of the IBM 650 computer. At present a section with not more than 38 sidings can be simulated. This will be increased when use is made of the 7070 computer. The simulation program for the 7070 is now being developed.

A more general simulation of railroad operations is also planned. In this it is intended to simulate traffic over a large network, such as Montreal and Toronto to Winnipeg, and to incorporate in the simulation the operation of major yards. This kind of simulation can be applied directly to problems of scheduling between major terminals and could be used to study the effect on operating efficiency of varying the number and length of trains. There is also very little understanding of the theory of traffic flow on a single track. The more detailed CTC simulation will be used to investigate the relationships between over-all interference and the factors of traffic density, siding spacing, train priority and velocity. RSC

TORONTO SUBWAY CAR COMMUNICATIONS

One of the features of the Toronto Transit Commission's new 74-ft aluminum subway cars is the communications system, which will provide: (1) Simplex communication from car to wayside; (2) public address communication from wayside to passengers in all trains; (3) public address communication from the motorman to passengers on his train; (4) duplex communication between motorman and guard on a train. The first two functions are on a shared or party line basis, while the last two are available at all times.

According to I. G. Hendry, TTC, and D. H. Hellmann, Vapor Heating Ltd., the equipment operates on an amplitude modulated carrier frequency of 72 kc. Transmission from the wayside unit is via a special telephone wire pair linked to the contact rail by coupling units spaced at ¼-mile intervals. Coupling units on the cars connect the contact shoes to the transmitter receiver unit.

The train equipment mounted in the motorman's cab includes a portable transceiver unit (comprising transmitter, receiver and power amplifier), a telephone selector unit, and a public address amplifier feeding six loudspeakers mounted above the ceiling. A loudspeaker is provided in the cab which monitors all outside calls. This function is transferred to the handset earpiece when the motorman selects to call or reply. RSC