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TRAIN CONTROL AND OPERATIONS

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16. Abstract

ATO (automatic train operation) and ATC (automatic train control) systems are evaluated relative to available technology and cost-benefit. The technological evaluation shows that suitable mathematical models of the dynamics of long trains are required before substantial improvements can be made to ATO systems, and the present ATC systems are presently near optimum. The cost-benefit analysis concludes that only railroads which find CTC (centralized traffic control) economically desirable will also find that ATC offers improved operating economies. ATO does not seem economically or politically practical in the general railroad environment.

A brief evaluation is made of both the contribution of the railroad locomotive to air pollution and the possible means of controlling this pollution.

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TRAIN CONTROL AND OPERATIONS

INTRODUCTION

During the past year, the Train Control and Operations program was revised. The primary objective at the outset was an evaluation of the technology required and available to implement a large demonstration of automatic train operation (ATO) in the general railroad environment. The task was modified to include an evaluation of the economic benefits afforded by ATO. Finally, because of the expertise available at TSC, we were asked to develop an outline for an FRA pollution abatement program.

As each of these tasks was completed, an interim report was written. These reports, which constitute the bulk of this final report, appear in the first three appendices. The fourth appendix is a referenced report which might otherwise be difficult to obtain.

PRESENT TRAIN CONTROL SYSTEMS

Evaluating train control systems currently in use or available to the railroad industry can be approached several ways, such as:

a. ATO system operation on a closed railway system which was designed and constructed with the ATO system in mind.

b. The operational and cost savings of an ATO system on an average U.S. railroad which operates passenger and freight trains simultaneously.

c. The impact on safety implied by the modification or removal of certain train control safety devices on specific railroads under specific conditions. Such studies would have to be evaluated on an individual basis.

There are other cases of train control which may be evaluated, but these three serve to show the diversity of problems. The case chosen was in fact the second where state-of-the-art ATO was evaluated in the general railroad environment. This problem seemed to be of the most general interest to the railroad industry and also allowed TSC to make the best use of its aerospace background.

The results of this study showed that with the constraints of the present railroad equipment inventory, crewless trains are not practical and may not even be technically possible.

It will be shown that crewless trains are operating under conditions so restrictive as to preclude such operation in the general railroad environment. Maximum safety can be found in the general environment when the train is driven by an engineer who is protected from making gross errors by an electronic monitor. This system allows the engineer to use his train handling skill to operate the train and make fine adjustments to compensate for equipment problems, weather conditions and train consist, yet he is protected from speed limit violations. Such a system is presently available as a CTC (Centralized Train Control) system plus automatic overspeed control. Details of the technical analysis of ATO systems are found in the interim report which is reproduced in Appendix A.

The economic advantage of a CTC system plus automatic overspeed control clearly depends on the individual railroad. A rough rule is that if the railroad will benefit from the advantages of CTC or already has CTC installed, then the cost of installing and maintaining the overspeed control is justified. The details of the ATO cost/benefit study are found in Appendix B where an interim report specifically concerned with this topic is reproduced.

It is generally assumed that any form of automatic train control will improve safety. After all, the earliest form of automatic train control, the intermittent automatic train stop, was required by the I.C.C. as a safety device. The assumption of improved safety is often, but not always, justified provided that the control system is designed to fail safely. The idea behind many train control systems is that the engineer is likely to fail (make errors) and therefore he should be taken out of the control loop as an unreliable component. This sort of reasoning leads to the dangerous syndrome where technology attempts to solve all safety problems. It may be more efficient to adjust the system so that the engineer is less likely to fail. For example, one of the conclusions made during the present program was that at the present time it is far more efficient and probably safer to augment the engineer's decision making ability than to eliminate the engineer. As a rule, all safety problems and solutions should be evaluated to determine what human factor aspects are involved. Human factors are one of the engineering parameters.

FUTURE TRAIN CONTROL SYSTEMS

It has been noted above that the most advanced train control systems, crewless ATO, are presently in operation only in the special case of railroads with unit trains, special equipment, and predictable handling characteristics over very restricted territory. Typically, these systems operate ore trains associated with mining operations. It is interesting to note that many of the modern rapid transit systems could be operated in the crewless ATO mode, but are not because of the need of a crew for surveillance purposes and because of the general public distrust of completely automatic machinery. The Morgantown Project at the University of West Virginia will be a precedent setting departure from this rule.

ATO is popular in mining operations because it saves crew costs and guarantees precise control during the loading and unloading operations. Rapid transit ATO has been installed to increase operational safety and to handle special problems in the logistics of moving commuters during peak load times. As diverse as these two classes of operation seem, they have several things in common which are important to the successful operation of ATO:

a. The access, protection and control of the right-of-way is good. This is important because the sensitivity of ATO to vandalism is high in relation to normal railroad operation.

b. The trains are run as relatively short units which are rarely uncoupled or reclassified. This eliminates one of the more critical train handling problems as well as the hazardous job of making and breaking couplings. Couplings with automatic air connections and the use of shorter trains would go a long way to reducing the importance of this point.

c. The cargo flow and destination within the system is predictable.

d. The responsibility for maintenance is centralized so that rigorous inspection and maintenance schedules can be kept. Also, a defective train does not have far to go to a repair shop. This is important because ATO operation is more likely to be delayed by faulty equipment than normal railroad operation.

e. The territory is completely signaled and the block lengths are short to accurately locate the train. The ability to locate the train and/or individual train components is particularly necessary in areas such as stations and terminals.

There is little question that the benefits enjoyed by the limited railway systems presently using ATO could be extended in part to the whole railroad industry. This will require an investment of money and technology to change the present right-of-way and equipment so that the characteristics of the extended railroad system resemble those of the present ATO operated railroads. The difficult question is whether the investment is worth the return.

TRAIN MODELING

Computers are finding a wide application throughout the railroad industry from classification, to MIS, to signaling. As computers assume a larger share of the signaling responsibility, it becomes more and more tempting to have a computer replace the man at the interface between the signal system and the individual train controls. This change would be relatively simple to implement on a railroad which was equipped with continuous cab signals with as many aspects as the wayside system, providing that the results of the control commands are fully predictable in all cases. The problem is that at present the reaction of long freight trains of arbitrary consist over varying grade are not always predictable to the degree necessary for completely automatic command and control.

The heart of the problem rests on the poor understanding of the longitudinal dynamics of long freight trains. It has become a *modus operandi* of the aerospace industry to computer simulate a system which has poorly understood dynamics when it is necessary to design controls for the system. This same approach will be effective for the design of train operating controls. The results of such train dynamics simulation will, however, have a much wider application. A similar program was used by Canadian National to design grade on new sections of track. The effect of draft gear performance can be studied. The handling properties of any consist configuration can be predicted so that unmanageable configurations can be avoided. This last benefit alone could justify the dynamics simulation through improved safety and reduced L&D costs.

It has been proposed by TSC that in FY72 the TSC train control program be directed towards the solution of the train dynamics problem. The Center has experienced personnel to write the program and operate the computer. TSC also has EDP equipment and facilities designed specifically for computer simulations. Although the motive for the dynamics simulation is to design and test train controls, the simulation and computer service will be available for other train and equipment problems as the need might arise at the FRA.

RAILROAD POLLUTION CONTROL

The pollution problems associated with the railroads extend to almost every phase of the operation. A good review of the total problem and measures being taken to cope with it can be found in the minutes of a recent meeting of the National Industrial Pollution Control Council[1]. This review is reproduced in Appendix D. Public opinion, however, requires that the problem of exhaust noise and emissions be treated before the other problems.

It is instructive to review the operational features of railroad diesel engines to understand the exhaust problems peculiar to this generic class. Probably the single most important feature is that unlike the gasoline engine, the diesel is a stratified or heterogeneous charge engine. Moreover, the fuel is burned almost immediately as it is injected into the engine so that the burning rate of the fuel is almost completely controlled by its injection rate. A second important feature is that nearly all these engines contain an air compressor in the air induction system and use the compressed intake air to scavenge the exhaust gasses in the cylinder. The use of compression ignition and low volatility sulfur containing fuel are of less importance.

The stratified charge, injection controlled burning allows high efficiency, low pollution power for three reasons:

a. Very lean, i.e., air rich, air/fuel ratios are possible at idle or full load. A lean mixture encourages full oxidation of the fuel and greatly reduces hydrocarbons and CO in the exhaust.

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1. National Industrial Pollution Control Council, Railroads and Railroad Equipment Sub-Council, Maine Commerce Building, Washington, D.C., June 26, 1970.

b. The flame burns centrally in the cylinder so that little of the burning fuel can approach the cylinder wall and be extinguished. This reduces the hydrocarbons in the exhaust and is the major reason for the general rule that the larger the cylinder horsepower, the lower the relative pollution per horsepower.

c. The burning of the fuel as controlled by injection can be nearly optimized for all power levels.

The diesel engine would seem to be an ideal source of low pollution motive power. This is true provided that the engine is maintained and operated properly. A mechanic who is too zealous in his attempt to wring maximum horsepower from an engine he is tuning may set an air/fuel ratio which is too fuel rich. It is expected that this practice will be common until some extinction standard is set for exhaust smoke. Injectors which are damaged by using poor quality fuel, questionable operating procedures, or contain manufacturing and remanufacturing defects can also be a major source of diesel smoke.

The type of smoke produced by the defects just mentioned is black in color and is caused by the pyrolytic cracking of the fuel in a fuel rich section of the engine. Black smoke is usually emitted only from an engine which is near the hot end of its normal operating temperature range. When an engine is cold, it can smoke, but the smoke color is white. White smoke is produced by condensed fuel droplets. White smoke, which might be more accurately described as a fuel fog, is a normal emission during the starting and warm-up operating phases of a healthy engine.

The major liability to diesel engine smoke is public indignation. However, black smoke is indicative of incomplete fuel combustion and is accompanied by a marked increase in carbon monoxide. The increased carbon monoxide can cause an additional hazard to train crews. As a rule, a crew will complain about the condition and maintenance of an engine which is smoking, but they are not likely to bring it in for repair unless it has lost power or is smoking so badly that they are suspicious of its reliability. This situation may indicate that the train crews are unaware of the increased hazard, or it may be that they consider the hazard small compared to their other problems.

A pollution monitoring and control work statement for the FRA has been proposed by TSC and is found in Appendix C.

CONCLUSIONS

Under the conditions of the general railroad environment, automatic train operation appears to be neither technically feasible nor economically desirable. On the other hand, automatic train control systems which augment the engineer's train handling skills and protect him from gross errors, such as speeding, are both feasible and cost effective. Some of these systems are in operation in the railroad industry today, and it is likely that technology will improve them in the future. It appears that these train control systems are presently nearly optimized for safety, but technological innovation may increase their reliability, lower their cost and increase their utility.

The principal technological deficiency in automatic train operation is the poor understanding of the dynamics of long trains. The study of train dynamics is well suited to computer modeling, and it is suggested that this problem be undertaken soon.

The ecological impact of railroad pollution is small. However, social and political pressures require that every segment of U.S. industry, including railroading, reduce its pollution contribution. Two of the most conspicuous forms of railroad pollution are the noise and smoke from diesel locomotives. Both of these problems can be relieved through equipment design and maintenance procedures and, therefore, are prime candidates for an FRA engineering program.

APPENDIX A

AUTOMATIC TRAIN CONTROL AND OPERATION

State-of-the-Art Technology

INTRODUCTION

An ATO (automatic train operation) system is a railway system where all the train operations, such as accelerating, braking, switching, etc., which are normally performed by railway personnel, are performed automatically by electronic and electromechanical devices. A little over a decade ago, such completely or nearly completely automatic systems began to appear. As one might expect, these early systems were used on railroads dedicated to highly specialized traffic and conditions. The choices have been limited to closed systems which are either rapid transit for passengers, (e.g., EXPO 67, PATCO, BART) or ore trains (e.g., Carol Lake, Great Slave Lake, Muskingum Electric).

The problem now is to determine whether the present technology which was developed for such specialized ATO systems is sufficient to allow the fabrication of an ATO system which will operate in the general railroad environment. Such a system would have to handle a large variety of trains with many priorities and destinations. The ultimate goal of this study is a demonstration test of an ATO system over a 100 mile section of track under the conditions of the general environment. This report is the result of a study of the state-of-the-art ATO technology and its applicability to the general ATO problem.

GENERAL RAILROAD ENVIRONMENT

Since it is clear that ATO is practical on specialized railroads, it is first necessary to determine the difference between these conditions and those of the general railroad, and then to evaluate what additional technology is needed to cope with the additional constraints.

a. The performance (acceleration, deceleration) of the individual trains varies widely.

b. There will be a variation in train priorities.

c. The stopping schedule, train route and destination must be flexible so that it is a characteristic of the individual train.

d. It is clear that the previous requirements will require train meets, passings, and the insertion and removal of trains at interlockings along the route.

e. The large variation in train lengths require both the head end and the end-of-train indications.

f. There is often a voice communication link between the engineman and the dispatcher. ATO should provide a similar link between a computer on board the train and the CTC (Centralized Traffic Control) computer. This link will provide the central computer with information concerning the individual operating condition of the unit trains.

PRESENT ATO TECHNOLOGY

The equipment available today for ATO systems can readily provide six or more commands between the wayside and locomotive, and can program train movements among an almost unlimited number of units through an almost unlimited number of switches. The problem of locating head end of trains can be accomplished through the conventional system of wayside signals, and a last car indication can be provided by simple passive equipment presently available. This last car passive indicator can also be adapted to give positive identification of the train. This locating system will only indicate blocks entered and left by the train. Finer indications can be provided by an undulating track wire, but at considerably increased cost.

It is convenient to think of the ATO system as divided into a subsystem for solving problems of train movements and a subsystem for reducing these solutions to detailed commands on board the individual unit trains to produce the train movements. The general problem of train movements will be handled by a large centralized computer used for CTC. In a normal CTC system, this computer will generate speed commands which are transmitted to the engineman through track circuits to cab signals. It would be possible for the CTC computer in an ATO system to generate specific commands for the trains such as braking and acceleration schedules and transmit them to the unit trains. This, however, would require the communication system between the central computer and the unit trains to have a much larger data rate than a simple CTC system. Such a large capacity communications system would be much more expensive and probably less reliable than the basic CTC communications system. It makes more sense to keep the ATO communications system the same as for CTC and provide a small computer (which shall be called the train computer) on board the unit train to provide the specific and detailed control functions for the unit train. This approach seems reasonable since the data from CTC which is sufficient to provide unit train control with an engineman should also be sufficient for control in an ATO system.

The data rate for transmitting information as to the condition of the train from the train computer to the CTC computer is very low. It is expected that this task can be handled through the system of track circuits and wayside stations. The more difficult and expensive problem is instrumenting the unit train so that the train computer can determine the condition of the train. Of course it can be rightfully assumed that if the train computer is to successfully control the train, then the train is so instrumented and the computer is informed in real time of the condition of the train. The problem then is what train condition inputs are necessary to the train computer for the computer to successfully operate the train. This area appears to be the only area in which the technology required for ATO may be deficient.

It is generally agreed that the occupation of being a good engineman requires a high degree of skill. Among the many attributes comprising this skill are certain intangibles which some would classify as a unit called "feel" of the train. In engineering terms, this syndrome indicates that the system being operated is not understood. This appears to be the case with railroad trains. The interaction is unknown between such system components as roadbed, rails, wheels, suspension, couplers, load distribution, braking distribution, and shifting loads. One approach to this train control problem is an attempt to adapt the train computer to "feel" the train condition through input sensors presently unspecified. The object would be to determine what sensual inputs the skilled engineman uses to determine train conditions and to duplicate these inputs with electromechanical devices to the train computer. The problem with this approach is that it will take as long to "educate" the computer as it does a man and will be far more expensive as well.

A more direct approach is to attempt to develop a mathematical model of a unit train. Once this model is available, the dynamics of any train configuration can be simulated and studied. This approach will lead to the definition of those train parameters which are most critical to the operation of the train. Then it will be possible to control the train through the measurement of these parameters.

The principal problem with this approach is that the mathematical modeling of a railroad train is difficult. It is not possible at the present time to accurately estimate the effort required to produce such a model or to guarantee its success. The existence of such a model, however, would produce effects on the railroad industry far beyond the ATO problem, and for this reason the model should be attempted.

A third approach is to provide the train computer with a visual readout of the desired speed and to allow the train to be operated by an engineman. If the engineman does not comply, the computer will undertake to make the speed adjustments itself. This would not be ATO in the strictest sense, but it is an expedient alternative since it circumvents the problem of duplicating the engineman's operating skill while preserving most of the advantages of ATO.

CONCLUSIONS

A large portion of both the hardware and technology for an ATO system suitable for the general railroad environment exists today. A system for scheduling train movements is embodied in the computerized CTC system. This system also provides for suitable communication to a small computer which is on board the unit trains within the system. Equipment also exists which can transform the train computer outputs into specific acceleration and braking actions. However, the technology necessary to specify this instrumentation and software is not available today. It is probable that this technology must be developed before an ATO system can be designed which will be reliable under all the extremes of the general railroad environment. A hybrid ATO system is proposed as an alternative where the engineman and his skill is preserved as an operating component in an otherwise ATO system.

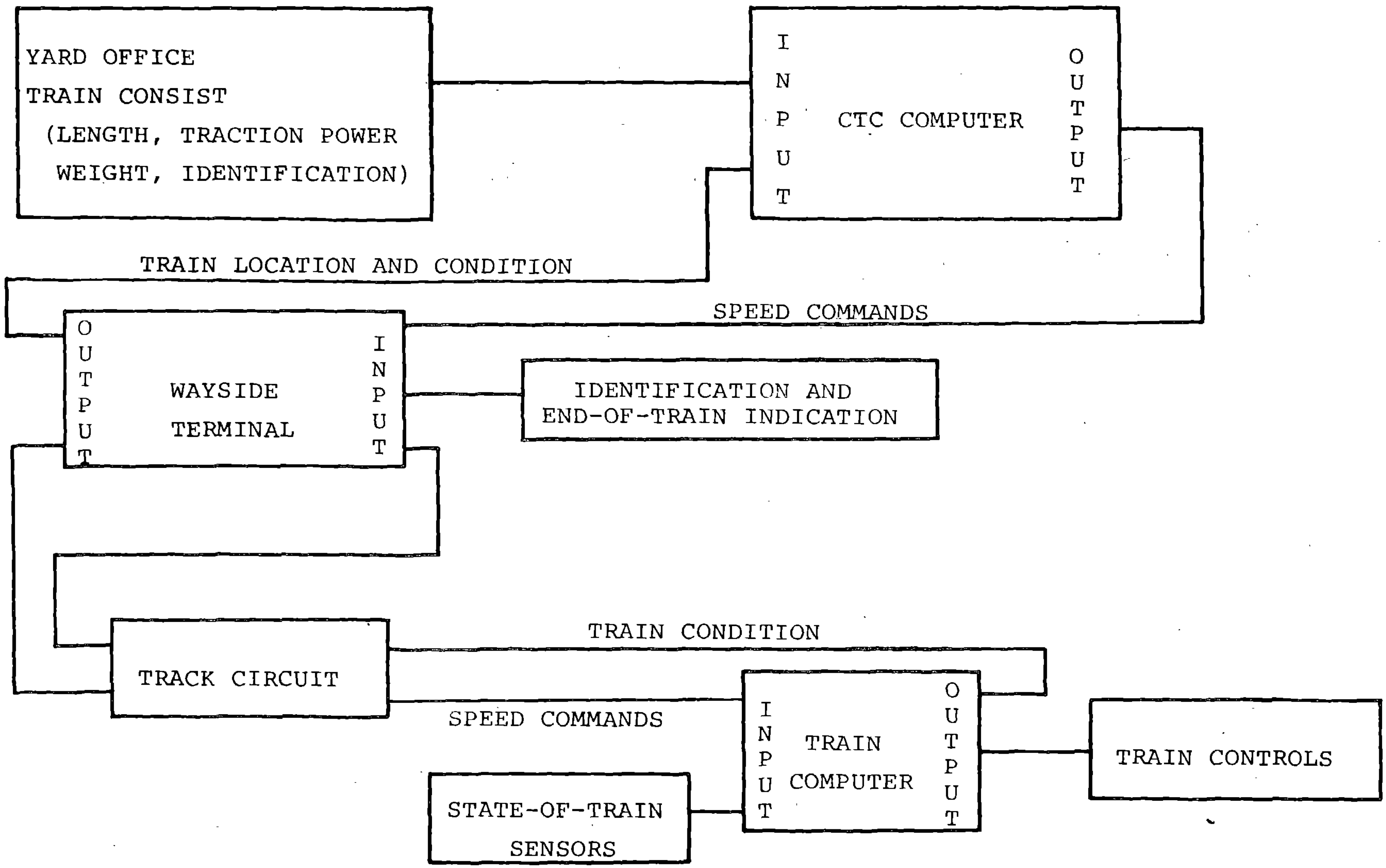

Figure 1. Schematic of ATO System

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EQUIPMENT COSTS

The following estimate is made for an "average" railroad environment which does not have extremes in switching complications, density of passenger stations, noisy track circuits, grade crossings, etc. Any of these extremes will in general raise the costs over those of this estimate. These estimated costs should be considered rough; accurate costs can only be estimated by considering a specific system as applied to a specific section of railroad.

ITEM	UNIT	COST
Complete CTC System	Per Mile	$ 20,000
Programmed Stop, Passenger Station	Per Station	2,000
Passenger Train Computer and Controls	Per Train	17,000
*Freight Train Computer and Controls	Per Train	20,000
Train Identification and End Detection, Wayside	Per Block	3,500
Train Identification and End Detection, On Board	Per Train	250

*Does not include state-of-train sensors

Table 1. Estimated Component Costs

These component costs can be used to estimate the cost of installing an ATO system on a railroad. For example, assume a railroad has 100 miles of track divided into 50 blocks with ten passenger stations, and the equipment to use the road will be five passenger trains and ten freight locomotives.

The estimated costs will then be:

CTC System	$2,000,000
Programmed Stop Equipment, Wayside	20,000
Passenger Train On Board Equipment	85,000
Freight Train On Board Equipment	200,000
End-of-Train Equipment, Wayside	175,000
End-of-Train Equipment, On Board	3,750
TOTAL -	$2,483,750

These costs are for a completely debugged system and, as such, do not include the cost of engineering support which will be necessary for the field tests of the first system assembled.

APPENDIX B
ATO COST/BENEFIT

INTRODUCTION

The principal motivations for equipping a railroad with an ATO system are to increase safety, to allow the railroad more economical operation, or to improve railroad customer service. Although it is clear that the installation of a full ATO would improve the safety of operation of some railroads, this improvement may be minimal on a railroad which has continuous cab signals and is equipped with automatic train stop. Statistics indicate that the majority of derailments are the result of faulty equipment while the majority of train collisions result from human error. Therefore, the gratest improvement in safety would be in the reduction of train collisions. This might be offset by an increase in derailments caused by an increase in the complexity of the railroad equipment, a decrease in the number of visual inspections of the right-of-way, and the difficulty in designing automatic machinery which adapts to abnormal conditions as well as a human being adapts. For example, it is probable with today's technology that a deteriorating roadbed would be detected earlier and the operation of the train more appropriately adjusted by a skilled train crew than by an ATO system.

The impact of ATO on the operating economy and customer service of a railroad is a very difficult question. The installation of ATO will effect all levels of railroad operations from administration down to the section crews. This report will evaluate the changes expected in railroad operations when an ATO system is installed and estimate whether the economies thus affected can justify the expense of the ATO system.

ATO DESIGN

Since the term ATO is not very explicit, it is necessary to describe in some detail the system to be considered in this report. The principal design parameters have been to provide multiple speed control with automatic train identification and positional information for CTC (Centralized Traffic Control) routing using present state-of-the-art technology and off-the-shelf components. The system will consist of a CTC computer which programs train routing and speed, keeps track of train position, adjusts headway, and sets switches. The communication system routes CTC commands to local wayside terminals.

These terminals translate the commands to coded track signals and communicate these signals through the tracks to the train. There is a small computer on board the train to translate the coded track signals into the various control functions required to operate the train in the manner prescribed by the CTC computer. This system is specifically designed to minimize the communication system data rate because the communication system appears to be the least reliable and most expensice component in the ATO system.

One of the more serious limitations of this system is that coupling and uncoupling operations require manual action by a trainman. This means that if it is necessary for cars to be set off or picked up during a haul, a human must be present. This constraint becomes particularly critical when a car on a crewless train develops trouble over the road which is serious enough to require the car to be set off. Such a circumstance will halt the train until a crewman can be sent out to remove the defective car.

The cost of installing this ATO system clearly depends on the individual railroad. The estimated cost of the individual components installed are shown in Table 1. The cost for any given railroad to install the ATO system can be calculated by determining the numbers of each component needed and totaling the aggregate cost. This cost will be substantially lower if the railroad is already equipped with CTC and continuous cab signals. The cost will be higher if the ATO requires additional improvements such as better grade crossing protection. Therefore, the figures in Table 1 should be used with care when estimating the ATO installation cost on any particular railroad.

THE OPERATIONAL FUNCTIONS OF TRAIN CREWS

Since an ATO system in effect usurps the train crew in some of its tasks, let us study the duties of the train crew and estimate how many of these tasks ATO can manage.

One of the first duties of a train crew when accepting a train for operation is to inspect it. This inspection consists of a cursory visual inspection of the engine, wheels, brakes, electrical switch positions, indicator lights and so on, and also a leakage test of the pneumatic brake system. This inspection can, of course, be performed in the yard by a yard crew if there are no changes to be made in the consist while the train is on the road.

The inspection duties of the engineman and fireman, however, continue after the train is underway. Conditions of the track, roadbed, bridges, and passing trains are noted and dangerous conditions are reported. Since this procedure is usually unofficial, its performance is bound to vary widely between crew, but it exists to some extent among all crews. The usefulness and need of such inspections can be minimized by requiring high maintenance standards for the right-of-way and equipment and performing frequent separate inspections of the right-of-way. This procedure, of course, will increase maintenance costs.

Train crews also serve an additional purpose which is difficult to define, and can best be understood by comparing human reactions to electronic and electromechanical control system. An electronic system within broad yet bounded limits can perform precise, repeatable, predictable, correct and almost errorless control functions. When the system, however, is presented with a situation beyond its bounded limit, its performance is either unpredictable or predictably bad. A human being, on the other hand, is not nearly as reliable, precise or predictable in his performance of the ordinary control functions. However, his adaptability and reasoning power make him irrreplaceable as a control element in the extraordinary situation which is beyond the capabilities of the electronic system. These extraordinary situations are common while the train is underway and range from mechanical equipment failures to vandalism.

MAINTENANCE

The required increase in maintenance costs of a railroad installing an ATO system have already been mentioned. These costs can be separated into two categories; maintenance of new equipment specifically required by the ATO system and improved maintenance of existing equipment and right-of-way. The ATO maintenance may require a railroad to establish an electronics capability beyond anything previously necessary. The cost of maintenance of the ATO equipment is hard to estimate but should be relatively low. Conversely, the improved maintenance of existing equipment and right-of-way could be a very large expense to a railroad which is in poor physical condition. This does not mean to imply that these improvements may not be a sound investment even in their own right, but their cost might provide a formidable financial barrier to a railroad in poor condition and in some cases could exceed the cost of the ATO system. This cost is also difficult to estimate and clearly is a function of the particular railroad.

SOCIAL ACCEPTANCE

Crewless ATO trains are not likely to be well received by the general public. The public outrage is bad enough when a trespasser or motorist is killed or injured by a manned train. If the same accident occurred involving a computer controlled crewless train, the press would declare it murder by electronics. The public fear and distrust of automatic equipment is legend from the Expo train to Shelly Berman's dry humor about automatic airplanes.

The concern with problems associated with crewless trains may be purely academic. Historically, the Railroad Brotherhoods have stubbornly resisted any reduction in the size of train crews. It is, therefore, unlikely that the trains in an ATO system will be crewless for many years. If this is the case, then reduction in train crew wages will not be an economic factor to ATO. There is a benefit, however, since this obviates any of the other problems caused by crewless trains in an ATO system.

ADVANTAGES OF ATO

The system described above is essentially a CTC system with automatic overspeed protection. The speed limit is sensed through the continuous cab signal circuit and thus has no information in addition to what the engineman has. Although it may be possible to increase the traffic throughput of a railway through the more uniform performance of trains under ATO, it is not safe under these conditions to reduce the train headway. It has been reasoned above that the installation of an ATO system may increase the railroad labor costs. It is clear that any economic advantages to ATO must come from fundamental changes in railroad operations, procedures, and service.

The basis for any change in railroad operation will stem from changes in the interactions between the train, train crews, and the railway system. The interaction of the railway system and the train is primarily governed by the fact that the system has CTC. The effect of ATO is to reduce the interaction between the train crew and the CTC since the crew now needs no routing instructions. The ATO also removes the requirement that at least one of the train crew pay full attention to the train control all the time. The action of the ATO will be in many ways analoguous to an autopilot in an aircraft. This will allow the engineman to perform other duties and reduce his risk of error when he is tired or otherwise incapacitated. It might be possible for the same train crew to stay with a train for 1,000 miles or more by working in shifts, thus eliminating the logistics and downtime problems caused by changing the crews five times during the same trip. The true advantages in the general railroad environment of ATO will only be realize by investigating innovative changes such as this which ATO may allow in railroad operations.

ITEM	UNIT	COST
Complete CTC System	Per Mile	$ 20,000
Programmed Stop, Passenger Station	Per Station	2,000
Passenger Train Computer and Controls	Per Train	17,000
*Freight Train Computer and Controls	Per Train	20,000
Train Identification and End Detection, Wayside	Per Block	3,500
Train Identification and End Detection, On Board	Per Train	250

*Does not include state-of-train sensors

Table 1. Estimated Component Costs

APPENDIX C
RAILROAD POLLUTION CONTROL

SUMMARY

The recent increase in the public awareness of pollution sources in its environment will have its impact on the railroads. The air and noise pollution standards for private autos have recently been expanded to include trucks and eventually will include trains. Trains have an additional problem in spark control since locomotive exhaust sparks are annually responsible for a significant number of forest fires. It is the responsibility of the FRA to provide the Federal Government with advice as to realistic anti-pollution laws. Work must be started now if the FRA is to provide meaningful guidelines for the control of these pollution sources.

PROBLEM

The noise from railroad trains can be classified as coming from two sources: the traction power and the wheel/rail interface. Both these noise sources have been studied to some extent and indications are that the technology exists to reduce them substantially.

Noise

The traction power is either electric or diesel-electric on American railroads. Electric power is almost noiseless, but the diesel engines on diesel-electric locomotives are quite noisy. Although the blowers, turbines, injection pumps and other ancillary systems are substantial noise sources, the bulk of the diesel noise is exhaust noise. There are many accepted methods of muffling the exhaust noise from diesel engines. All of these methods tend to decrease the engine's maximum horsepower by reducing its volumetric efficiency. Since most railroads are critically short of horsepower, it is not likely that the railroads will willingly install mufflers on their locomotives unless required to by legislation or unless such muffling can be shown to have other redeeming features.

Most of the diesel locomotive engines are either blower-scavanged two cycle engines or supercharged four cycle engines. It is probably not widely appreciated that such engines, which have a positive pressure in the intake manifold, will suffer almost no power loss by the addition of an exhaust silencer which increases the pressure in the exhaust manifold.

The problem seems to be to design and fit exhaust silencers to diesel locomotives and then to measure horse power loss due to the silencer. Some modification to the camshaft lobe profile may be required to optimize the peak engine horse power at the increase exhaust manifold pressure.

Wheel/rail noise has been shown to be dependent on the physical condition of the rails and wheels. When the track is rough and pitted and the wheels are in a similar conditon, the wheel/rail noise is high. Refinishing either or both of these surfaces will substantially reduce this noise. Any advances in the reduction of wheel/rail noise will probably be in the form of the design of equipment which will reduce the cost of rail and wheel refinishing.

Spark Arresting

The present locomotive diesel exhaust manifold designs have been based on schemes which will trap or bread up sparks which are emitted by the diesel engine. Engine sparking is a serious problem because the sparks start fires.

The spark arresting property of the exhaust system is probably more important than its silencing. Fortunately, it appears that exhaust systems with good silencing characteristics will also be good spark arrestors. The reverse is not necessarily true. The spark arresting properties of all silencer systems should be measured.

Another approach to the sparking problem will be to reduce the source of sparks. A properly maintained diesel engine running at partial to full power will not emit sparks unless the engine has recently been idling. The sparks are formed from flakes of carbon which are heated to incandescence and break loose from the engine surfaces. Carbon, however, accumulates on the engine surfaces only when the engine is idling for prolonged periods. These idling periods cannot be avoided under normal railroad operations. It may be possible to reduce the rate of carbon accumulation during idling by using fuel additives or through modification of the fuel injectors. Both of these alternatives should be investigated.

Air Pollution

It has been well documented that a properly maintained diesel has lower levels of carbon monoxide, unburned fuel and nitrogen oxides per horsepower than gasoline engines, and in some cases less than electric power generation. The major complaint against diesels is that the engine tends to smoke, producing visably obnoxious products, and that the human nose is extraordinarily sensitive to the particular sort of trace hydrocarbons which are found in the diesel exhaust. Both these problems have recently been the subject of study by the diesel truck and bus industries. This diesel pollution technology developed by these other transport modes should be applied to the railroads. It will of course be necessary to extend certain areas of the diesel pollution technology to solve those problems which are peculiar to the railroad industry. It is expected that this program will show transporting freight by rail rather than by truck can significantly reduce the air and noise pollution contributions to our environment of the freight hauling industry.

ALTERNATIVES

a. Do nothing.

b. Start a program of measurement, test, and design to reduce the noise and air pollution from our railroads.

c. Join with the Coast Guard and the UMTA in assembling and operating a diesel pollution laboratory at the Transportation Systems Center.

PREFERRED ALTERNATIVES

a. This will leave the railroad industry at the mercy of the State and Federal legislation. It is not likely that the legislative bodies which are presently drafting our pollution laws will take the initiative to extensively study the special problems of the railroads before trying to regulate their allowed pollution level.

b. A modest program for the measurement and control of pollution from the railroad industry would be valuable both to formulate guidelines for future pollution control legislation and to advise the industry as to the most effective way to meet air quality and noise standards.

c. The program would essentially be the same as that of alternative b, but its efficiency would be higher. The advantages of pooling specialized equipment such as exhaust analyzers and dynomometers as well as personnel expertise are obvious. In addition, such an arrangement would facilitate the transfer of the advanced bus and truck diesel pollution control technology to the railroads.

APPENDIX D
POLLUTION AREAS RELATED TO RAIL TRANSPORTATION

A. Noise and Vibration (Train and Yard Operations)

1. Noise as a Characteristic of Safety Requirements

B. Dangerous Cargo (Including Contaminants)

1. Dust From Loading/Unloading
2. Tank Car Cleaning
3. Spillage From Accidents
4. Garbage and Trash Haulage

C. Litter and Solid Waste on Rights-of-Way, etc.

1. Defoliants and Clearance Problems
2. Dunnage and Packing
3. Ties, Freight Cars and Air Pollution, Re: Disposal

D. Construction (Including Relocation) and Cleared Land

1. Dust, Erosion and Landslides
2. Drainage and Flooding

E. Oil Drainage

1. Maintenance
2. Refueling Stations

F. Diesel Smoke and Fumes

G. Sparks

1. Locomotives
2. Brake Shoes

Status of Railroad Action on Pollution Problems

Diesel Locomotive Combustion Emission Control

Increasing attention is being given to attempts to improve combustion through additives, as well as through improved combustion chambers, in order to increase efficiency and particularly to reduce smoke. There are no current data available for general railroad use on the contribution to air pollution made by diesel electric locomotives. These data are urgently needed for consideration and study of new regulations and for discussions with labor representatives regarding operations affecting the engineman. Serious smoke problems are being encountered with older locomotives.

Reduction of Pollution From Drainage From Maintenance Shops

More efficient heating and power generation facilities are necessary. Oil and gas are being utilized for this purpose. A variety of waste water treatment plants are being installed to meet limits established by state health departments. Solvents and crankcase oil are very often stored until they can be hauled away by private contractors who retreat or re-process this material. Less toxic cleaning agents are being used. Excessive stack emissions have been eliminated or reduced to an acceptable level. Rubbish is no longer burned. Good industrial practices are being adopted in order to make it possible for railroads to comply with increasingly restrictive state regulations having to do with maintenance shops.

Most railroads have oil separators and other settling basins for the collection of drainage and residues from cleaning. In those instances in which contractors haul and dispose of sludge, some railroads continue to have the responsibility for insuring that the contractors dispose of the sludge at a location and in a manner approved by the concerned governments. Increasing vigilance is required by railroads with respect to tank flushing and cleaning operations.

Collection of spilled oil from fueling operations is a problem for many railroads. Special sumps and pumping systems are necessary to insure that oil is removed from shop and yard drainage. Automatic shut-off fuel line nozzles are generally in use, but these are not entirely satisfactory and, therefore, must be augmented by devices to separate oil from drainage.

Weed and Brush Clearance

Requirements to keep rights-of-way cleared are being more rigidly enforced. Burning, even under controlled conditions, is being discontinued because of new regulations. Restrictions are being introduced on the use of some classes of defoliants which in the past have been acceptable. In almost all areas at least one complete mowing, cutting, plowing or soil sterilization operation is required over the entire right-of-way. The need for research on this problem, directed toward the development of additional techniques, is apparent.

Railroad Car Disposal

The majority of cars are sold to scrap dealers for disposition by the scrap dealers. This practice has been introduced because of the restrictions on open burning of cars and the expense of car disposal by individual railroads.

Roadside Fire Control

Most railroads are engaged in special measures to control roadside fires. Track patrols or existing section forces and train crews are assigned responsibility for monitoring fires and responding to those fires. There are many instances of conflict between adjoining land owners. Currently, the law does not require proof of the cause of a fire except as determined in adversary proceedings in a court of law.

Locomotives are now equipped with spark arrestors. New locomotives with turbo-chargers are equipped differently than older locomotives with added centrifugal and screen-type spark arrestors.

Composition brake shoes are being installed more extensively in order to reduce sparking, but this applies primarily to new equipment. Retroactive refitting is not contemplated by most railroads.

Elimination of Pollution From Stacks at Railroad Steam Plants

Almost all railroads are improving their combustion practices at their own steam plants. Most power plants are gas or light oil-fired. Those railroads operating coal or heavy oil-fired power plants are confronted by increasing difficulty in meeting smoke and other gaseous pollutants standards.

Cross Tie and Timber Disposal Control and Removal Practices

The experience of railroads in dealing with disposal of ties is varied. A few communities still permit burning. In some areas, there is a ready local demand for ties for personal use. Some railroads allow ties to remain along the right-of-way to decay in a normal fashion. In other instances, tie disposal machines are being utilized. In these machines the tie is reduced to wood chips which are scattered along the right-of-way. In one case, a contract is being negotiated, at a rate of $3.50 per ton, for use of ties in the production of charcoal. The problem of tie disposal may become of increasing importance if there is more rapid replacement of ties to meet higher standards for right-of-way maintenance and if the trend toward regulations to prohibit burning becomes general.

Human Waste Disposal From Passenger Trains, Locomotives and Cabooses

Most railroads report that they expect new regulations will demand installation of toilets on locomotives and cabooses and, as appropriate, on passenger trains. Electric incinerator-type toilets and chemical toilets with storage and collection systems for haul-away disposal are currently in limited use. Those railroads with short runs do not plan to provide toilet facilities because of the limited space available in their equipment and the fact that there appears to be little need for on-board toilet equipment. Maintenance-of-way cars parked at one location for extended periods are being equipped with holding tanks. Steps should be taken to develop standards for the industry in order to avoid difficulties with equipment operating in interstate service. In view of the variety of equipment available, a standard evaluation procedure is necessary in order to provide a uniform basis for procurement of equipment.

Control of Noise Pollution

Noise pollution is becoming of increasing concern to many railroads because of the spread of residential areas to the vicinity of railroad lines. Although the railroad pre-existed, regulations are introduced that affect railroad operations because of the complaints of the residents of adjacent housing developments. Sparing use of locomotive whistles has been necessary. Diesel engines are operated at partial power and mufflers have been improved. Maintenance shops are also subject to criticism about noise pollution. Riveting has been replaced by bolting or other fastening approaches in order to achieve a reduction in noise. In some instances, ear protective devices are required.

Handling Pollutants Which Result From Railroad Derailments

Emergency procedures have been established by most railroads to deal with the problem of pollutants resulting from railroad derailments. There have been significant spills in the past which have been difficult to control. Active contact is maintained with manufacturers, with the Bureau of Explosives of AAR, and with data furnished by other organizations, including RSMA. However, it is clear that present emergency procedures are not adequate to cover all possible circumstances that may occur. Further study and investigation is necessary in order to cope with this problem.

Disposal of Engine Coolants Containing Pollutants

A majority of railroads use diesel engine coolant additives which do not involve pollution. Those railroads that are still using chromates have a very serious pollution problem. It is not sufficient merely to dilute the chromate in most instances. Instead, it has become practice to hold the coolants for reuse, rather than dispose of them. Further review of this problem is undoubtedly necessary because of the variety of coolant additives that are in use and the response of different locomotives to various classes of coolants. A coolant additive that is satisfactory in one locomotive may lead to cavitation or general corrosion in a different kind of locomotive. It is essential that non-polluting additives become generally available in the very near future so as to eliminate this cause of pollution.

Disposal of Waste Dumped on Rights-of-Way

Private citizens and companies discharge waste onto the rights-of-way of railroads, particularly in older areas. This has been very difficult to control. Some railroads have increasing investments required for policing. Periodically all railroads are forced to collect the trash and dump it. There are no obvious ways to improve this situation. Railroads can expect to be confronted by increasing misuse of rights-of-way as public dumps. Similar problems are involved in collecting, removing and disposing of dunnage and debris from railroad cars at cleaning tracks and other right-of-way locations.

Control of Dust Blowing From Open Top Cars in Transit (Coal, Etc.)

Netting or continuous covers are being introduced by those railroads that have encountered problems in the shipment of fines which are not wet down. This problem is of concern to a relatively small number of railroads but, in those instances where it is a problem, substantial investments are necessary in order to achieve adequate control. Dust control at grain elevators has been a particularly troublesome problem in some instances.

Drainage, Flooding, Erosion and Slides Resulting From Construction Activity or Land Clearing

Local political subdivisions are scrutinizing carefully all construction activities. Restrictions are being imposed against excessive disruption of real property, and requirements made for restoration as nearly as possible upon project completion, for flood and erosion control and in some instances for beautification.