"Muzzle Not the Ox That Treadeth Out the Corn"

BY ROBERT S. BINKERD
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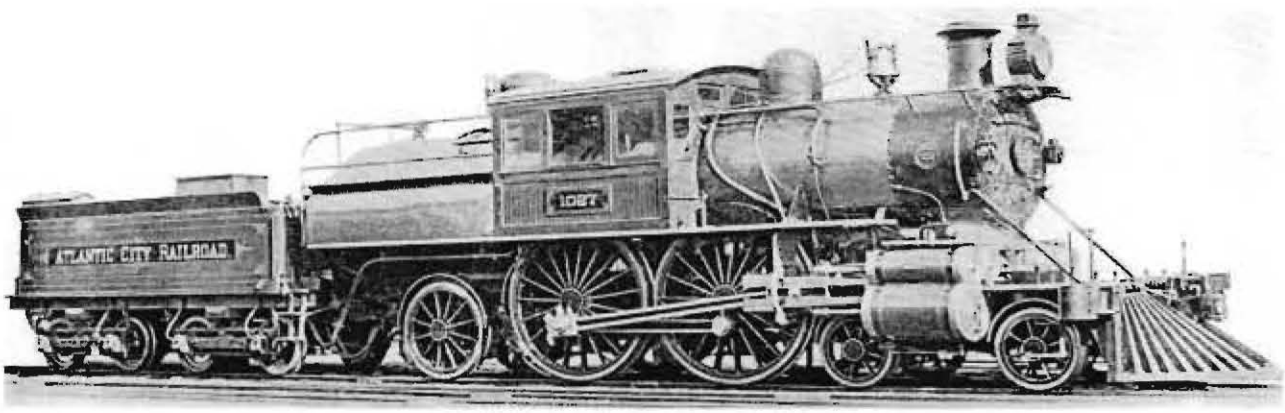
From an address delivered before the New York Railroad Club, New York City, on the evening of April 25, 1935

TONIGHT, I propose, as far as our human frailty will permit, to speak without prejudice. I think I am in a position to do so; and when I say this I say it not only on behalf of The Baldwin Locomotive Works, but on behalf of the three recognized locomotive builders in this country. Each of us has the engineering brains and the manufacturing ability to build any kind of a thing that moves on wheels. We build a number of different products, and we are not in the position of having to recommend any particular product for uses and purposes for which it is not well designed. Each of us is in a position where, when a client comes to us and wishes the benefit of our knowledge in developing what his policy should be, we want to give that client sound and intelligent advice free from the fads and fancies of any given moment—advice that ten or fifteen years from now he will have been glad to have received and acted on. And it is from this point of view that I propose to talk. Now it was only about thirty years ago that the railroads in the United States were just about to be completely electrified. Yet today, as we approach the completion of the greatest single electrification in the history of American railroads, I do not think I am giving away any secret when I say that the expectations of our big electrical companies with regard to future railroad electrification are not very sanguine. Certainly I give up no secret when I say that from a plain dollars and cents point of view the steam locomotive today is a more serious competitor with electrification than it was thirty years ago. Today we are having quite a ballyhoo about stream-lined, light-weight trains and Diesel locomotives, and it is no wonder if the public feels that the steam locomotive is about to lay down and play dead. Yet over the years certain simple fundamental principles continue to operate. Some time in the future, when all this is reviewed, we will not find our railroads any more Dieselized than they are electrified, and in each case a substantial portion of those operations will not be based upon what will produce the highest return on the investment, but on aesthetic considerations or compulsion of public bodies. It was not so long ago that the movie magnates thought it would be a good thing to interest the movie public in the personal lives of the movie stars. And that was all very well for a while, until finally they woke up and found this public trying to dictate what the lives of these stars should be. So when we start out to advertise something, it is a pretty good thing to know that the something that we are advertising today is a something that we are going to want to sell tomorrow. The impressions which are being produced today are going to become the public demands of tomorrow. If those demands are for things which cannot be justified, then we and our friends, the railroads, are going to be faced some time in the future by demands for large additional capital investment on which no economic return can be earned.

Diesel Versus Steam Schedules

A couple of months ago I was out in Kansas City. When I got through my day's work I had a few hours left, and I bethought myself that here the Burlington Zephyr and the first Union Pacific aluminum train were both operated, and so I thought I would go down and look into the matter. I was particularly interested because I had just previously made a

study of a steam versus Dieselized operation of another locomotive run, and had been surprised to learn that there was no terminal expense connected with one of these light-weight Dieselized trains. But when I got down to the Kansas City Terminal, I found, in order to turn these trains around, they had to route them on an irregular elipse over three miles in the Kansas City yards, but in order to hold the expense of that down as far as possible, they did not put a yard crew on the train. Of course, that is one way of holding down terminal expense; but obviously it has not much to do with the Diesel motor in the front, or the stream lining of the train or the weight of the cars. And then I was interested in looking at the schedule. Naturally, in common with most other members of the public, I had an idea that this first Zephyr was splitting the ozone out West there. Imagine my surprise to learn its scheduled speed for the 251-mile run was 45.6 miles an hour! When I got back to my hotel in Kansas City I found a telegram asking me to be in Portland, Maine, at the earliest possible moment. So I hurried back to St. Louis and had just half an hour to catch the poor old Southwestern Limited out on the New York Central. I hope my Pennsylvania friends will not take any notice of this fact. So here I got on this poor old train that nobody talks about. It was hauled by a dumb steam locomotive that one day takes ten cars, another day twelve or thirteen cars, and provides through service from St. Louis to Boston, New York, Washington and Cincinnati. And this poor train did not know any better than to make a schedule of 51.5 miles an hour, and on the New York Central time table I did not notice any caption reading: "This train is limited in its equipment and passengers can be accommodated only to the extent of its seating capacity." Nevertheless, not only as a locomotive builder but as a railroad investor and one who has served the railroads to the best of his ability in times gone by, I feel that the railroad and equipment industries both will owe a debt of gratitude to developers of Diesel power and light-weight trains, not because these are going to supersede steam and standard equipment, but because they are stimulating constructive thought and effort. At the same time, I refer to the dangers of conveying false impressions to the public mind, and at the present time a false impression is certainly being created with regard to the improvement of passenger schedules. The truth is that this new Twentieth Century development of Dieselized lightweight trains has not yet touched Nineteenth Century performance with steam, and hardly more than parallels the daily performance of many modern steam trains of today. With this in mind I proceeded to make up a very short list of schedule trains moving today in the United States. But first look at this picture of a little Atlantic type compound locomotive built by Baldwin in 1896 for the Reading Railroad.



(Slide No. 1) Vauclain Compound Locomotive which made a notable record for consistent high speed operation between Camden and Atlantic City in the summer of 1897.

This poor little thing, beginning in the summer of 1897, hauled the Atlantic City Express of the Reading Railroad SS1/^ miles from Cam-den to Atlantic City in anywhere from 48 to 461/2 minutes, or at a scheduled speed from start to stop of from 69.3 to 71.6 miles an hour. And after it got outside of Camden and before it got to the corporate limits of Atlantic City it only averaged from 82 to 85 miles an hour!

Some Typical Schedules

Here is my list, which does not pretend to be exhaustive:

Miles per hour Start to stop

19th CENTURY STEAM (1897)
Before the days of the all-steel passenger coach
Atlantic City Express (Reading)
Camden to Atlantic City—55.5 miles..... 69.3

MODERN STEAM (1935)
With interchangeable all-steel passenger coaches substantially reduced in weight
The Hiawatha (Milwaukee)
Chicago to St. Paul—410 miles. 63

MODERN STEAM (1935)
With interchangeable all-steel Pullman and passenger
coaches of standard weight
The "400" (Chicago & North Western)
Chicago to St. Paul—408.6 miles..... 58.8
Twentieth Century Limited (New York Central)
Broadway Limited (Pennsylvania)
New York to Chicago—961.2 miles via New York Central 56.5
The Columbian (Baltimore & Ohio)
New York to Washington—223.6 miles..... 55.9
Wall Street Special (Reading)
Philadelphia to Jersey City—90 miles. 55
Empire State Express (New York Central)
New York to Buffalo—435.9 miles..... 52.8
Southwestern Limited (Big Four)
St. Louis to Cleveland—535.9 miles..... 51.5
Yankee Clipper (New Haven)
New York to Boston—229 miles..... 50.9
The St. Louisian (Pennsylvania)
New York to St. Louis—1,051.7 miles..... .50.1
The Miamian (Atlantic Coast Line)
New York to Miami—1,388 miles 49.7

MODERN ELECTRIC (1935)
With interchangable all-steel Pullman and passenger coaches of standard weight
The Congressional Limited (Pennsylvania)
New York to Washington—225.2 miles..... 57

DIESEL STREAMLINED (1935)
With rigidly limited carrying capacity, non-interchangeable with any other form of passenger equipment
The Twin Zephyrs (Burlington) .
Chicago to St. Paul—431 miles..... 66.3
The Streamliner (Union Pacific)
Kansas City to Salina, Kansas—187 miles..... 53.4
The Zephyr (Burlington)
Kansas City to Lincoln, Nebr.—251 miles..... 45.6

Now you know the foregoing steam schedules are made by trains carrying interchangeable all-steel Pullman and passenger coaches; performing through service from many different points; having terminal delays which are a part of furnishing this service; supplying a much larger seating capacity and more facilities; and still most of them make better time than any of these new Diesel stream-lined, light-weight trains except the Twin Zephyrs. These latter go 431 miles from Chicago to St. Paul, making a schedule of 66.3 miles an hour. It just happens that the Milwaukee's mileage from Chicago to St. Paul is 21 miles shorter than the Burlington's. Otherwise the scheduled speed of the steam-drawn Hiawatha would be identical with that of the Diesel-drawn Burlington Twin Zephyrs.

Speed and Diesel Not Synonymous

The speeds that are being made with these Diesel stream-lined trains are not because of any fundamental characteristics of the Diesel engine, but in spite of them. As I will develop shortly, a fundamental characteristic is a rapid loss of drawbar pull at speed, so that at 70 or 80 miles an hour a Diesel locomotive can hardly exert one-tenth of its starting power. The only way in which this characteristic of the Diesel engine can be overcome is by trimming the weight to be hauled down to a negligible relationship with the motive power available at starting. But the price of this trimming down is the creation of rigidly limited trains incapable of expansion or variation, and absolutely non-interchangeable with any other form of passenger equipment. Do I need to argue that this development cannot possibly be the means for general passenger service to the people of the United States? I am one of those who believe that passenger service in this country can and will be substantially accelerated and that this can be done at a profit to the railroads. But in the main, this improvement in passenger schedules is not going to be brought about by running 110 miles an hour, except in isolated spots and for very brief spaces of time. It is going to be brought about by a safe reduction in the dead-weight of trains—and here let us note that, with all

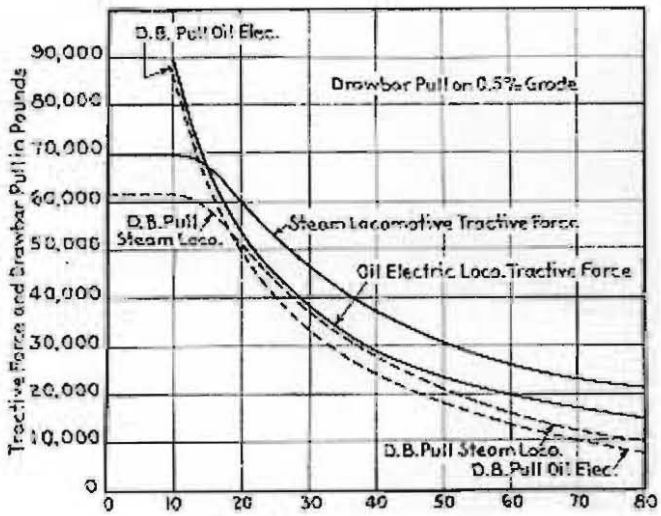
the ballyhoo about stream-lining, a reduction of 50 tons in the dead-weight of a train is worth more than all the stream-lining — by faster acceleration, by better time on grades, and in general, by a substantial increase in that portion of the running time which is spent at speeds of 60 to 80 miles an hour.

The Dead-Weight of Trains

You know what has happened since 1900. The development of the all-steel car in the interest of safety gradually doubled and then finally trebled the deadweight of cars. Most of the fleets of passenger locomotives in this country — largely Pacifies — were designed about midway in this process. They were supposed to be adequate for 10-car trains when the average weight per car was 65 or 70 tons. Today the average weight of these cars is around 85 tons. Instead of getting ten 70-ton cars, these locomotives are given eleven, twelve, thirteen or fourteen of these 85-ton cars. So instead of having 700 tons in dead weight back of the tender, these locomotives now have 1000, 1100, 1200 tons. When you consider that the acceleration of a train depends on the ratio between the tractive force of the locomotive and the dead weight to be moved back of the tender, you will realize why it takes longer to get these trains up to speed; why the top speed has been materially reduced; and why, in short, steam passenger speeds such as those of the Reading in 1897 have disappeared. What the manufacturer of these new lightweight trains has done is to seize control of the load that can be given to the motive power unit and to so rigidly regulate it that you fellows can't monkey with it. That is what he has done. But the same result can be accomplished with steam through your own intelligent direction. The truth of the matter is that the poor old steam locomotive, being capable of taking a substantial overload, has been consistently and persistently abused by giving it dead loads for which it was not designed, thus creating in the public mind the idea that modern speeds and steam power are inconsistent. The passenger schedules of the future are going to revolve around some control of average or maximum dead weight back of the tender. As new passenger train cars are built there will be substantial reductions in dead weight without losing any of the standards of safety which have been established out of past experience, and these cars will be completely interchangeable with existing equipment. As a result, the dead weight of a train can be made up of a number of combinations of new and old cars and the capacity of any train can be increased without increasing the dead weight by the simple expedient of increasing the proportion of new and lighter cars in the total train load. Unless this is the policy followed in improving the passenger service of the United States generally, the entire existing investment in passenger equipment will have to be scrapped. But the evolutionary is the method by which every other great improvement in railroad service has been brought about. Scarcely ever have the railroads taken a wild leap in the dark. They have taken a step forward and gradually that forward step has become a standard. With each passing year most new equipment purchased has embodied that standard, and the railroads have gradually achieved an ever-growing percentage of savings that can be effected over a reasonable term of years without the loss of existing capital investment. If this policy be followed — and in my judgment it is the only safe one—you will see that it is essential that the locomotive should be kept separate from the train, because only by keeping the locomotive separate from the train can you be free to make up the train load out of an infinite number of combinations of new and old cars. And with air conditioning moving forward by leaps and bounds the drawbacks of smoke and cinders are removed from the steam locomotive, and the last objection to the use of steam in passenger service is destroyed.

Fundamental Characteristics of Steam and Diesel Power

Now let us move to the fundamental considerations which affect the use of Diesel or steam power. As you look up to the upper lefthand corner of Slide No. 2 you see the trac-



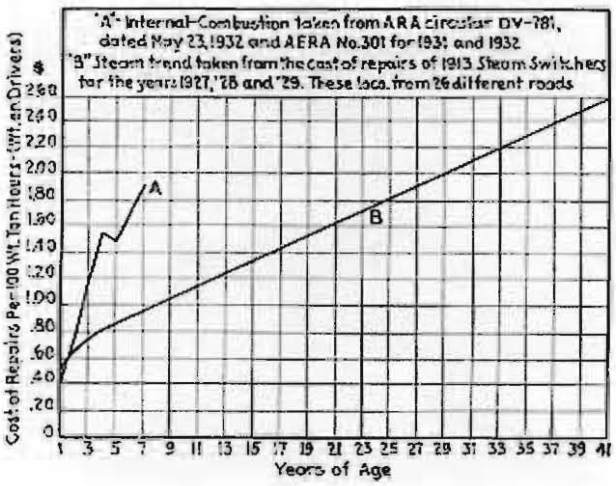
(Slide No. 2) Comparison of the Tractive Force and Drawbar Pull on a 0.5 Per Cent Grade of a 4-8-4 Type Steam Locomotive and a Diesel-Electric Locomotive.

live force curve of a better Diesel locomotive than has yet been built. We designed it, but nobody yet has come forward to pay $400,000 or $500,000 which it would cost to build it. This Diesel locomotive has the advantage of two 1975 horsepower engines that weigh only about IS1/^ pounds per horsepower. It has the advantage of special and expensive electrical and mechanical equipment designed to overcome, as far as possible, that characteristic loss at speed of power delivered at the rim of the wheel. But notwithstanding all these things you see that at 80 miles an hour this Diesel locomotive has hardly 15 per cent of its original tractive force left. When, on the other hand, we turn to the tractive force curve of the Northern Pacific 4-8-4 which we built last year, you will note that it has a tractive force at starting of only 70,000 lbs. But at 80 miles an hour it still has nearly one-third of its original tractive force; and in all the working speeds from 30 miles an hour up it has a constant excess of approximately 8,000 lbs. of tractive force. And lastly, note that this steam locomotive, which gives a better tractive force curve at all working road speeds, would be reasonably priced at not more than one-third of what it would cost to build the Diesel locomotive with which it is compared. The dotted lines give you the drawbar pull of these two locomotives on an 0.5% grade. Even here where the Diesel locomotive has the advantage of greater horsepower at lower speeds, you will note that the drawbar pull of the steam locomotive crosses the Diesel at about 18 miles an hour and above that speed the steam locomotive has about 3,000 lbs. of drawbar pull more than the Diesel. Before I let this slide go off, however, let me point out that this tractive force curve brings out the one place in which the Diesel locomotive has a substantial advantage, and that is in its tractive force at low speed. Of course, that is the reason why Diesel power so far has been mainly applied to switching. But the lower the speeds at which the Diesel locomotive is worked, the greater is its advantage. So far as I know, we are the only locomotive manufacturers in the country trying to sell Diesel locomotives for steady drilling over the hump in big classification yards. But by the same token a comparison of these two tractive force curves should be conclusive as to the undesirability of the Diesel as a road locomotive. Therefore, the field of probable profitable application of the Diesel locomotive is pretty generally indicated at work speeds not exceeding 10 miles an hour. There are many places where such locomotives can show a distinct economy notwithstanding the fact that even Diesel switching locomotives, with none of the expensive elements of the Diesel locomotive which I just showed you, cost approximately twice as much as comparable steam locomotives. But in drilling over the hump of a classification yard; in switching into and out of electrified areas; in protecting the service at outlying points, permitting the doing away with round-house facilities; and in other exceptional places, particularly where one locomotive can be made to do the work of two or three different types, the Diesel can show a return.

Not All Economies Equally Certain

But in finding these places it is essential that we keep our feet on the ground all the time. For instance, at the moment, with Diesel oil at 5 cents a gallon, the higher thermal efficiency

of the Diesel affords a distinct economy in fuel. On the other hand, fuel costs are not as important as some other costs; and—more important —fuel economies are far less certain than savings in interest, amortization, taxes, and repairs. Why? Because when one looks to the future, it is reasonable to assume that with our enormous supplies, the price of coal will remain relatively low for generations to come. But the sources of flush production of our oil could dry up in a relatively few years, and an increase in the demand for the various crude oil products might double or treble the price of them within a generation. So that anybody who buys a Diesel locomotive, counting upon the constant repetition into the indefinite future of the fuel economies of today, is taking a gamble. I don't say that they won't exist, but the probabilities are against it. I do say that the economies of the steam locomotive—of interest on a lesser investment, amortization of a lesser investment, taxes on a lesser investment — those savings are real and can be counted on to continue. Diesel Versus Steam Repair Costs But the greatest source of disappointment will undoubtedly come from the cost of repairs. I hate to bring this out, with our good friend Roy Wright sitting right down here in the front seat. But not so long ago he and his able group published a booklet on "The Diesel in Railway Service." On one of the pages of this booklet they listed what the manufacturers claim for Diesel electric locomotives. The sixth of these claims reads as follows: "The cost of maintenance is only a fraction of an equivalent steam locomotive." I have seen studies of switching problems in which some Diesel manufacturers have treated maintenance as though it would be substantially the same for every year of operation. But you men all know that down at Eddystone in the last four years we have analyzed the repair costs of tens of thousands of locomotives in every form of service. We have proved beyond peradventure of a doubt that there is an inexorably rising cost of repairs with the advancing age of any prime mover. With regard to steam this is so definite that we have cost curves from which we can predict within a few cents the probable cost of repairs per mile of a locomotive of any given horsepower, of any given age, with any given intensity of service. With regard to Diesel locomotives, of course, the data is meagre as compared with that for steam. The data which is available, however, has been published as an'appendix to the report of the A. R. A. Committee on Locomotive Construction. The report of May 23, 1932, covers a hundred odd locomotives from one to seven years old. I have had this reduced to a comparable basis on Slide No. 3 showing the cost of repairs per hour for a 100-ton locomotive, and you can read it forward and backward for a locomotive of any other size by simply taking the proportion that it bears to 100 tons; that is to say, a 60-ton locomotive per hour would be 6/10th of the cost shown at the given year of age. Now the curve marked B is the curve which we derived from our study of 1913 steam switchers operated by 26 public service railroads in this country, locomotives all the way



(Slide No. 3) Cost oj Repairs Per 100 Tons Weight Per Hour of Internal-Combustion and Steam Switching Locomotives.

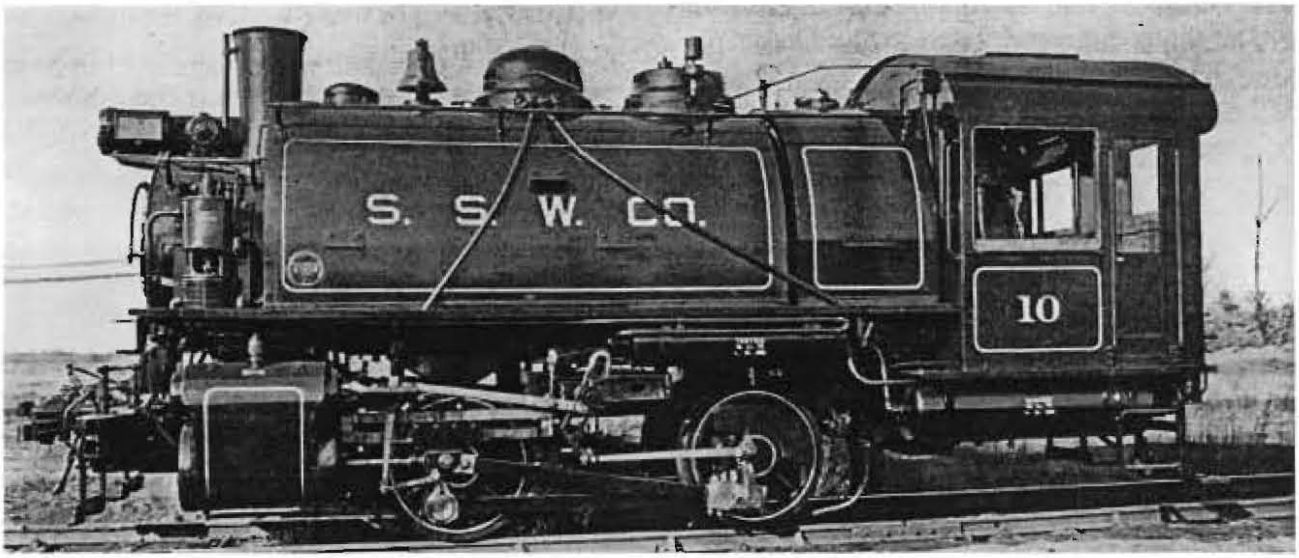
from 1 to 41 years of age. Curve A is merely a placing on the same basis of the Diesel locomotive maintenance cost reported by the A. R. A. Committee on Locomotive Construction. Each of them is the cost of maintenance per hour of a 100-ton locomotive. You notice that a new steam locomotive and a new Diesel locomotive start off at about the same point, a new Diesel a little bit lower. But by the time the Diesel is 7 years old its cost of maintenance is nearly double that of a 7-year-old steam locomotive, and if you projected curve A out to 17 or 19 years, the indicated cost would be far more than double that of steam. At this point I wish to be particularly plain. I want you to understand that I am not claiming that the maintenance cost of Diesel locomotives will be a constant repetition of the curve A which you saw on that slide. It is easy to believe that in this relatively small experience of Diesel locomotives, there has been a lot of stuff that will not be reproduced in future years. But I also wish to point out with equal clearness that no one can predict with any certainty as to what the maintenance cost of a Diesel locomotive may be over a life of 20 or 25 years. And I do wish to say unequivocally that there is not one scintilla of evidence to justify the claim that a Diesel locomotive of equal weight on drivers can be maintained at a cost as low as that of a steam locomotive of the same age after the first year or so. Everything points to the probability of a substantially higher maintenance cost for Diesel locomotives than for equivalent steam locomotives of the same age. The only thing nobody knows is how much higher. Anybody buying Diesel locomotives today and counting upon a substantial saving in maintenance cost to justify the greater investment had better take a hedge at the earliest possible moment.

Checking Claims of Diesel Economies

It is easy to see how this impression has been brought about, however, and I wish to make it plain that I do not believe this misrepresentation is intentional. Manufacturers, eager to sell this new type of locomotive, made studies of existing operations. On many of these operations they found obsolete steam locomotives 25 to 30—and I have even seen them 40— years old. Some of these manufacturers were not aware of the fact that maintenance costs rise rapidly with age. All that they saw was that in the first year of the operation of a new Diesel locomotive they could make a substantial saving over the sums that had been spent in maintaining obsolete steam locomotives. And so they claimed for the Diesel locomotive a saving in operating cost which arose— not out of the Diesel itself—but out of the substitution of a new for an old locomotive. And so I suggest to you that whenever you set out to study the economy of installing Diesels, the greatest safeguard that you can have is to first set up what modern properly designed steam power will do in that operation. If then the Diesel still indicates substantial savings, and those savings would pay a higher return upon the larger investment in the Diesel, then you have a case for Diesel application.

Availability Not All Mechanical

Another claim made for the Diesel locomotive is its presumed high availability. It is claimed that it may be kept available for service 80 or 85 per cent of the working time of the year. This intensity of use is used to reduce the cost per hour by spreading the constant costs over as many hours of work as possible. This is entirely legitimate; and the Diesel locomotive, in the main, has shown a high availability for service. But here again I wish to point out that the chief drawback to a much more intensified use of steam is frequently in the minds of the men who use them and not in the locomotives. Every man in this room can remember the time when division points in the United States were about 100 miles apart,



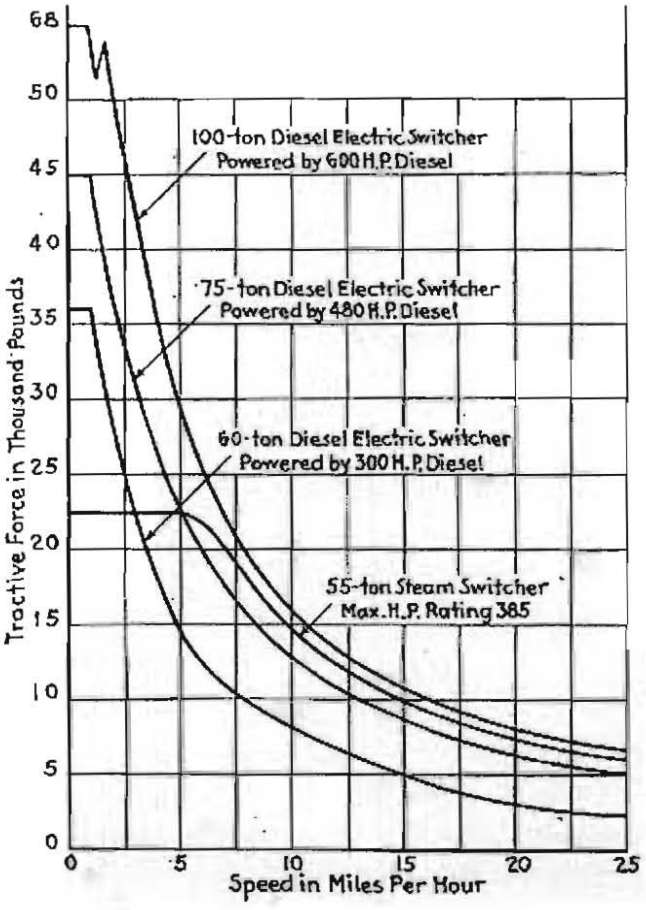
(Slide No. 4) Automatic, Oil-Fired Steam Switching Locomotive.

and no locomotive was ever supposed to run over more than one division. And yet today we run locomotives from 500 to 1000 miles in continuous service. While new locomotives are built better, still it remains true that thousands of old locomotives could have been run over two or three divisions, could have made two or three times as many miles as they did, if only there had been a belief in the human organization running them that they could do it. I have seen a number of steam switchers in this country that are making 7200, 7500 and even 7700 hours of service a year. With a certain amount of time lost for ashes, fuel, water, and so forth, a modern steam switcher can make 24 hours a day, six days a week, just as well as a Diesel locomotive.

One-Man Operation Also Available In Steam

Another and real advantage of the Diesel locomotive has been its mechanical availability for one-man operation. Where such an operation is safe and permitted by law and working arrangements, it has meant a real economy. But we have just proven, down at Eddystone, that this economy can be matched in steam power. Slide No. 4 shows you the first automatic oil-fired steam locomotive. It is a little saddle tank locomotive which we built for our own Standard Steel Works at Burnham. Without discussing certain features on which we contemplate patent application, the fundamental idea is perfectly simple. The fire of this locomotive is regulated by the steam pressure. It never pops, because, when the steam pressure reaches a few pounds below the blow-off point, the fire automatically reduces. We can set the points at which the fire reduces and again increases within a substantial work-' ing range. In this locomotive now before you the fire has three positions; low, intermediate, and high; but we can make it four or five, if necessary. No steam and no fuel is wasted. At the low flame this burns about four gallons of bunker C oil per hour, costing less than 15 cents. The engineer does not have to think about keeping up steam at all. All he has to do is to run the locomotive. Our records indicate so far that in this locomotive we have used only about 35 per cent of the B.T.U.'s we used doing the same work in our old coal-fired switchers. We have even put roller bearings on this locomotive partly as a contribution to lubrication, and partly to avoid time out for adjusting driving boxes. In other words, we have tried to produce a little steam switcher the wheels of which never have to be dropped except for flange wear. Our idea is that the fuel supply should be sufficient for 24 hours'

operation and the water supply for at least an eight-hour trick. And, of course, where saddle tanks would not be sufficient for oil and water, recourse would be had to a tender; and if you agree with us we might put the tender in front of the locomotive instead of behind it. In short, with no ashes to dump, no coal chute to go under, no driving boxes to adjust, we figure that this steam locomotive has just as high availability as any internal combustion locomotive; is just as readily operated by one man; and has at least double the thermal efficiency of the conventional coal-fired steam switcher. Slide No. 5 shows the tractive force curve of this little switcher compared with a 300-horse-power, a 480-horsepower, and a 600-horse-power Diesel locomotive. You will note that it crosses a 480-horsepower Diesel locomotive at about 5 miles an hour, and at 10 miles an hour it can do about 15 per cent more work. We are laying this out in other locomotive sizes up to



(Slide No. 5) Comparison of Tractive Force Curves for a Small Steam Switching Locomotive and Three Sizes of Diesel-Electrics

51,000 lbs. of tractive force. If you will line up on the right after the meeting is over I will be glad to take your orders at 50 cents on the dollar for the equivalent, at 5 miles an hour, of any of your Diesel requirements.

What Is the Best Investment?

Now, lastly, a word on how to judge the best investment in a locomotive. Is it by the largest indicated gross savings? I have in front of me a report on a certain terminal operation indicating that a fleet of automatic oil-fired switchers such as I have shown you would save, in a period of 20 years, about $4,400,000. A fleet of Diesels in the same operation would indicate a saving of about $5,200,000 during the same period. But the investment required to achieve $4,400,000 worth of savings is only about half that to achieve the indicated $5,-200,000 worth of savings. For every dollar invested in automatic oil-fired steam locomotives of the type I just showed you on the screen, the return on the investment would be approximately 25 per cent, whereas the larger gross savings on the larger investment in the Diesels would return only about 14.5 per cent on their cost. Bearing in mind the uncertainty with regard to Diesel fuel and maintenance costs in the future, which is the better investment?

Summary

So now let me summarize what I have been trying to say to you. It is in effect that there is danger in the ideas which are being put into the public mind today, because they are tending to establish a false scale of values. This is dangerous to the railroads because the false impressions of today will become the demands of tomorrow, coupled with arequire-ment .of capital investment on which our railroads will not earn a return. Diesel motive power and high speeds in passenger service are not synonymous. On the contrary, Diesel power can attain high speeds only by imposing rigid mechanical limitations on

the loads to be carried. These destroy inter-changeability, deny the possibilities of flexible service, and would practically destroy the existing investment in passenger equipment. Steam power has demonstrated for generations its ability to furnish high speed service provided the tractive force of the locomotive is properly proportioned to the dead weight of the train. The proponents of these Dieselized, highspeed trains have firmly grasped the principle of relating the dead weight of the trains to their motive power. It is up to you men to do the same thing with regard to steam. The inherent nature of the Diesel locomotive and its accompanying electrical equipment in the present state of development debar it rom high speed road service because of the physical characteristics of the power itself, its excessive capital cost, and its probable high maintenance cost. Per contra, the outstanding advantage of the Diesel is for work at low speed in switching or hump yard service. Present fuel economies of the Diesel locomotive are real, but their continued repetition in the distant future is uncertain; and it appears more likely that Diesel oil will increase in price than that coal will do so. There is no ground in recorded experience for the claim that Diesel locomotives can be maintained at a lower cost than steam. On the contrary, everything indicates that maintenance costs will be higher, but how much higher no one can say with certainty. When considering the possibility of Diesel versus obsolete steam operation, the first thing to aid good judgment is to set up what modern steam power could do in the same operation, If the internal combustion locomotive still indicates substantial economy, the Diesel locomotive should be seriously considered, provided that the savings on the Diesel operation represent a return on the capital investment at least equal to the return on the lesser investment required for steam.

Conclusion

I wonder if you men realize how much the steam locomotive itself has improved while this Diesel development has been going on? These past ten years have registered probably a greater improvement than in any other decade of the hundred years of life of the steam locomotive. The misfortune is that this goes on in a quiet way; there is nothing dramatic about it. It just goes on. But was not until 1920 or so that we got average steam pressures around 200 pounds, and it was not before 1925 that we began to get them at 225 to 250 pounds and on up. The superheats of today are about twice what they were ten to fifteen years ago. Today's steam temperatures around 700 degrees are 50% greater than they were about ten years ago, and nearly double what they were about fifteen years ago. Larger drivers and bigger boilers give higher speeds and greater intensity of use, so that a modern road locomotive of today at speed can do approximately twice the work of a 10 to 15 year old locomotive of substantially equivalent tractive force. Then people ask how can the railroads most profitably invest what small new capital they can raise, or how can they profitably use what credit they have left? And here they have a locomotive inventory 91 per cent of which was bought before this era of improvement in steam! If anybody wants to look around to find out where the railroads can make the most money, he doesn't have to look around at all. All he has to do is just start out to supplant with modern steam power the oldest part of the existing steam inventory which is being used day by day; and that investment will vastly improve service, pay its interest, amortize the investment within the economic life of the power, and produce a substantial increase in net operating income. If anybody knows where the railroads of this country today can make more certain progress than that, I hope he will stand up this evening and tell us where. And so I say to you, "Muzzle not the ox that treadeth out the corn."*

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* Being a free rendering of the Biblical injunction: "Thou shalt not muzzle the ox that treadeth out the corn." (DEUTERONOMY 25-4.)