THE FOLDED TWO STAGE RAILWAY CLASSIFICATION YARD

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PREFACE

The primary purpose of this analysis is to present a railroad classification yard of a different basic design. The yard has been designated the folded two stage yard - two stage because of its functional characteristics, and folded because of its physical characteristics.

To present this new yard, the analysis has been divided into two independent parts. Part I is intended to explain to those not familiar with railway operation the need for classification yards, what they do, and how they do it. In addition, each of the existing types of yards is discussed in some detail so that those unfamiliar with classification yards can comprehend the inherent problems, inadequacies, and limitations.

In order to make the latter analysis concise railway terminology must be used. Hence an important function of part one is to introduce the non-railway oriented reader to the language of railroading.

Railroad personnel and those familiar with railway operations, particularly classification yards, can omit part one and proceed directly to part two in which the folded two stage classification yard, or as it is called, the two fold yard, is introduced and discussed in detail.

The two fold yard has been designed to eliminate most of the inadequacies and limitations in existing yards. In particular, it is a rebuttal of the present predilection of the railroads to build large, expensive hump yards where cars simply set for hours and hours.

The two fold yard sorts cars by arithmetic progression. The facilities required are minimal but each car must be sorted twice. However through an analysis of existing yards the bottlenecks are identified and evidence presented to support the claim that the two fold yard can sort each car over twice as fast as present yards. In addition to sorting the cars rapidly, the two fold yard leaves the blocks in a pattern that reduces train assembly time; it can be built in more places and at less cost. The final result is a lower cost per car classified and a reduction in yard put-thru time.

Part two analyzes these advantages, explains how the yard functions and how it can be built.

As in any analysis which deals with an entirely new concept and for which there is very little published, I have called upon numerous people for advice and criticism. First and foremost I wish to thank H. B. Christianson, Jr., Director of Industrial Engineering, Chesapeake and Ohio Railway-Baltimore and Ohio Railroad, who originally conceived the idea of a folded two stage classification yard for allowing me to pursue this development. To him I respectfully dedicate this analysis. In lengthy meetings through this project he has given continual and invaluable assistance.

I would also like to acknowledge with gratitude the help of the Industrial Engineering, Research, and Engineering Departments of the Chesapeake and Ohio Railway-Baltimore and Ohio Railroad in providing much of the factual data; to the men of the Eastside Yard of the B&O in Philadelphia for allowing me to roam through the yards asking questions;

to Neil Benson for reading the manuscript in its early stages of preparation; to my mother for translating my pencil scratchings into typewritten words for most of the paper; to my father for turning my sketches into the final drawings; and to Mrs. Ruth Baldwin for typing the final manuscript on extremely short notice.

TABLE OF CONTENTS

PART ONE EXISTING CLASSIFICATION YARDS

PART TWO THE FOLDED TWO STAGE CLASSIFICATION YARD

PART ONE

EXISTING CLASSIFICATION YARDS

CHAPTER I

THE FUNCTIONS OF RAILROAD CLASSIFICATION YARDS

The year is 2001. At the shipping platform of the XYZ Corporation a self propelled, fully automatic railcar has just been loaded with widgits for delivery to a customer. The foreman takes a card giving the destination, routing and commodity being shipped in the car and inserts it into the holder on the side of the car. He then opens the door covering the control panel and sets a switch to "close." All doors and hatches close and lock and the "ready to depart" light flashes on. The foreman then pushes the "start" button and in a few seconds the car smoothly leaves the platform. It pauses briefly at a point not far from where the siding joins the mainline until another freight car goes by on the mainline. The turnout then opens and the car of widgits goes onto the mainline and proceeds to route itself to the siding of the receiver where it comes to a stop at his inbound platform.

The national car fleet has nearly the same tonnage capacity as the fleet of the mid-twentieth century but it carries many times the ton miles; solely because the cars go directly from shipper to receiver as individual units and do not enter railroad yards where they formerly spent over 70% of the time they were under the railroads' control.

The automated self-propelled cars have a high initial expense but the railroads are able to pay for them and increase net return on investment because they permitted abandonment of the classification yards.

A. Primary Function of Classification Yards

The above may sound a bit far out, but it indirectly points out the function of railroad classification yards. If each car were self-propelled there would be no need for such yards. However with the present state of technology, economics dictates the operation of trains rather than individual cars.

Except in rare instances there are not enough cars at any one point at any given time that are destined for any other single point to constitute a train. Hence a railroad collects all the cars in a given area and takes them to some central point where they are sorted into groups. This is called classifying or blocking the cars (the two terms are synonymous). The point where the cars are classified is the classification yard and the groups into which the cars are sorted are referred to as classifications or blocks.

The cars are classified by any or all of the following criteria: direction of travel, type of car, or commodity carried. An example would be a railroad that has tracks leaving a city toward the north, west and south. A very elementary classification procedure would be to sort the cars into three groups, with one classification going in each of the three directions. If the city were Philadelphia, the train going west would contain all the cars destined for Harrisburg, Pittsburgh, Chicago, St. Louis, Detroit, the West Coast, etc. At the first stop, say Harrisburg, all the cars for that vicinity as well as those bound for points on lines north and south would be sorted out of the train and left. All those that had collected at Harrisburg and destined west would be added to the train and it would then proceed on its way. The cars northbound from Harrisburg would later be put on a train going north, etc.

This process is no different from an individual going from one part of a large city to another via public transportation. The fastest and most direct way is usually by taxi (analogous to the self-propelled freight car) but it is often more economical to take a bus, subway, trolley, etc., in the general direction of travel, transfer to another route and thus eventually reach one's destination. The transfer points are analogous to classification yards.

As a railroad example, a car from Staten Island in New York bound for Macon, Ga., might be put in a train at New York whose destination is St. Louis. At Washington, D.C., it would be sorted out and put on a train for Richmond. At Richmond it could be put on a train heading for Tampa, Fla., then at Hamlet, N.C., the car would be sorted out and put on a train for Birmingham, Ala., via Atlanta, Ga. At Atlanta, it is once again sorted out and put in a train for Savannah, Ga., which finally sets it off while passing through Macon.

The sorting of cars and assembling them into trains is the primary function of classification yards. Until the self-propelled freight cars imagined at the beginning come into existence, classification yards will be necessary.

1. Blocking policy

Which cars are sorted (classified) where and into what blocks is specified by each railroad's blocking policy. The optimum blocking policy for Railroad A may not be best for Railroad B. Blocking policy can range from extreme deferment to extreme anticipation.

a. Extreme deferment

Extreme deferment, the blocking policy most common in the early days of railroading, is still used in some instances. It is the practice of always sorting cars at the last possible yard. If a yard were the last yard before a railroad line split to go in two different directions only then would the cars be separated into three blocks; one going in each of the two directions, and one consisting of the cars for the area that yard itself serves. The yard would not group together the cars for the area served by the next yard down the line. Thus, instead of merely taking a block out of the train, the next yard would have to sort through the whole train to collect the cars.

Formerly, railway practice was to dispatch freight trains only when the maximum tonnage a locomotive could haul over the ruling grade to the next yard had accumulated. Such trains are called tonnage trains or drags. At each yard each car had to be classified.

Eventually customers demanded better service. This resulted in freight trains as well as passenger trains being operated on schedules. If trains left yards by schedule and not only when there was a tonnage train, there was no longer any reason for running trains from only one yard to the next. Trains began to operate between such distant points as New York and Chicago. This necessitated a different blocking policy. At the other end of the blocking spectrum from extreme deferment is extreme anticipation.

b. Extreme anticipation

When all cars are classified at their origin yard into blocks that contain cars only for the yard of their destination, the blocking policy is called extreme anticipation. Reconsider the example of the train leaving Philadelphia for the west. If it were blocked in accordance with extreme anticipation, it would be completely ordered; all cars for Harrisburg would be in a group, all those for Buffalo to be left at Harrisburg would be in another group, all those for Pittsburgh in another group and so on. In the extreme case a 100 car train would consist of 100 blocks with the 100 blocks arranged in a specific order from locomotive to caboose.

Between the two extremes of complete ordering and extreme deferment there is an infinite variety of possible policies.

2. Set offs and pick ups

One of the in between blocking policies popular with the nation's railroads at the present time is picking up and setting off blocks. The blocks do not necessarily consist of cars to a single destination. A train destined from New York to Chicago may set off a block at Pittsburgh that includes cars for Columbus, Indianapolis, Cincinnati and beyond. The following example of an actual train and its blocking is an illustration of picking up and setting off blocks.

The Baltimore and Ohio Railroad (B&O) operates a scheduled freight train designated the "Chicagoan" from Jersey City, N.J. to Chicago. Leaving Jersey City the Chicagoan consists of only a single classification. This classification is designated Y83. Y83 is the symbol the B&O has given to all cars of unrestricted freight, except piggyback, destined for the Northwest. Examples of restricted freight are open top cars, tank cars of flammables, oversize cars, etc.

At Elizabethport, N.J., the Chicagoan adds a group of cars previously sorted out of all the cars at Elizabethport that meet the criteria of block Y83. This is called a fill out.

At Nicetown, Pa., (North Philadelphia) the Chicagoan picks up a complete block designated Y81. This is called a pick up. The Y81 block consists of all unrestricted freight destined to Cumberland, Md. and beyond. Hence, leaving Nicetown the Chicagoan consists of two blocks: Y83 and Y81.

At Cumberland the entire train is reclassified, that is, the entire train is sorted into new classifications. When the Chicagoan leaves Cumberland it consists of seven blocks. These are designated DM, Y25ND, Y25, Y21, Y31, Y79, and Y17. The blocks would be arranged from locomotive to caboose in the order given. That is, the DM block would be directly behind the locomotive and the Y17 block directly in front of the caboose. The cars in each of the blocks are defined as follows in the Freight Schedule and Classification Binder of the B&O.[1] DM = Hamler - D.T.&I. - Detroit. In non-railroad terminology this means that the block is set off at Hamler, Ohio, and that it contains cars that are going toward Detroit on the Detroit, Toledo and Ironton Railroad (D.T.&I.). Y25ND is the block for the Twelfth Street and Downtown districts of Chicago. Block Y25 is for the Robey Street and Homan Avenue Districts of Chicago and

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[1] Freight Schedule and Classification Binder, Transportation Department, The Baltimore and Ohio Railroad Company, 1966, p. 53.

includes Chicago and Great Western Railway loads, Soo Line loads, Illinois Central loads, and Chicago and North Western loads. Y21 is loads for the Chicago, Burlington and Quincy (to be interchanged in Chicago). Y31 is loads for the Milwaukee Road. Y79 is loads for the Santa Fe; and finally the Y17 classification designates cars for Willard, Ohio, and beyond, including Columbus.

At Willard, the whole Y17 block is set off. The reason for having the block just in front of the caboose becomes apparent: Willard is where the crews change (division point) and there is also a classification yard there. Thus a switch engine merely couples to the rear of the caboose and pulls it and the Y17 block off and sets both in the yard at once. In the meantime, a new caboose with the new rear end crew already in it is added to the train and the Chicagoan is ready to depart. At Hamler the DM block is set off. Figure 1-1 represents the crossing of the D.T.&I and the B&O with a siding between the two called the interchange track. Since there is no yard and no switch engine, the locomotive of the

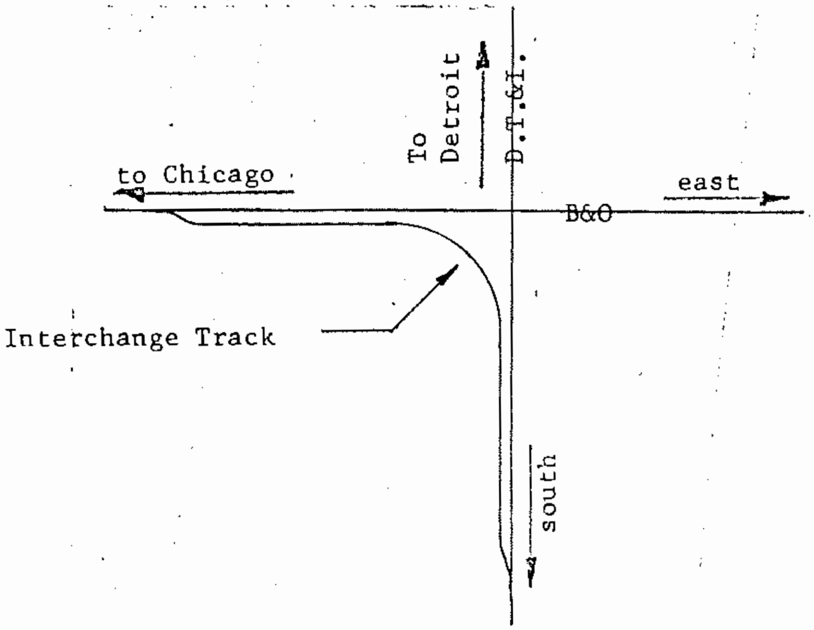

Figure 1-1 D.T.&I. - B&O Interchange atHamler Ohio

Chicagoan must take the DM block and back it into the interchange track. This is the reason the DM block is directly behind the locomotive.

At all other division points between Jersey City and Chicago where the Chicagoan did not enter a yard, the train was "maintracked". The crew simply changed while the train was on the maintrack and with a new crew the train continued on without rearrangement, subtraction or addition of cars.

B. Locations of Existing Yards

Because 100 miles used to be a full day's work for freight crews, and is still considered as such under union contracts, most classification yards were originally located at 100 mile intervals (division points) and new yards have tended to be built at or near the same locations. However, in recent years the construction of new yards has resulted in a consolidation of facilities and the deterioration or elimination of the yards at some division points.

C. Auxiliary Functions of Classification Yards

As mentioned, most trains were formerly operated from division point to division point and only when there was a tonnage train available. Since other functions could most easily be performed where the train ended its run, they came to be considered as yard functions. These auxiliary functions included the repair of damaged cars (called bad orders), the inspection of cars, re-icing or adding heaters to non-mechanical refrigerator cars, cleaning cars, weighing cars, storing cars, and servicing the locomotives and cabooses.

Later, trains began to operate over more than one division. However, each crew had its "own" cabooses (on some railroads they still do) and this had to be changed when the crew changed. Since the caboose had to come off at the division point it was just as easy to pull off the rear block along with the caboose and put on a new block and/or add more cars (fill out) the rear block at the same time the new caboose was added. Thus, the practice of pick ups and set offs of pre-blocked groups arose.

D. Time and Money Involved in Yard Operations

Investment in yard facilities is substantial and fixed costs are high. Labor and motive power are expended in a function which does not in a literal sense move the cars toward their destinations.

Even if cars don't move an inch there is an expense. If the cars are foreign owned there is a cash payment (per diem) to the owners, and if the cars are home owned there is depreciation to say nothing of opportunity cost. Yards are indeed an expensive bottleneck.

A study made by the American Railway Engineering Association (AREA) in 1956 revealed that for the average trip of 167 hours a loaded freight car was under railroad control for 82 hours, of which it spent 63 hours or 77% in yards. Of these 63 hours, 24 hours or 38% were in intermediate terminals, 16 hours or 25-1/2% were at the origin terminal, 16 hours at the destination terminal and 7 hours, 9%, was spent waiting for interchange. Thus the in-motion time toward destination was only 19 hours or 23% of the total time a car was under railroad control.[2]

This division of transit time has not improved substantially to the present day. This is indicated by the average daily car milage. In 1956 average daily car milage was 48.3 miles; in 1965 it was only 51.7

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[2] - American Railway Engineering Association Proceedings, 1956, Volume 57, American Railway Engineering Association, Madison, Wisc, 1956, p. 321

miles.[3]

As an approximate indication of the terminal costs consider the carload unit costs for a boxcar on a 300 mile trip with a load of 30 tons in the Eastern Region in 1956, the same year as the AREA study, as determined by the Cost Finding Section of the Interstate Commerce Commission (ICC). The total cost of transporting the car in a through freight train on the Commission's fully distributed cost basis was $108.88; of this $73.55 or 67% was classed as terminal costs. On the ICC's out of pocket cost basis the total cost was $79.20 and the terminal charges were set at $56.33 or 71%.[4]

Since railroad management is well aware of the high costs and great amount of total elapsed time spent in terminals, terminals are increasingly being examined as areas where significant time and money savings can be effectuated. The purpose of this paper is to introduce a totally different design of classification yard which will require a lower initial investment, permit a reduction in operating costs, speed up the classification process itself somewhat, and greatly reduce the total elapsed time a car spends in terminals.

[3] - Yearbook of Railroad Facts 1966 Edition, Association of American Railroads, Washington: 1966, p. 51.

[4] - "Rail Carload Cost Scales by Territories as of January 1, 1956" Cost Finding Section, Interstate Commerce Commission; 1956, p. 59.

CHAPTER II

TYPES OF YARDS

The process of classification consists of receiving trains, taking the trains apart by separating the cars, grouping the cars in some predetermined order and reassembling the groups into trains. This process, along with the repairing of bad order cars, can be represented by the block diagram of Figure 2-1.

There are two general types of yards to perform the classification operation. One type, which uses a locomotive to separate the cars, is called a flat yard. The other type depends on the force of gravity to separate the cars. Technically it is called a gravity yard, but is more commonly referred to as a hump yard. This is because the cars are pushed up and over a small man-made hill, the hump, and allowed to coast into appropriate tracks on the other side.

In addition to the common flat and hump yards there are two different track layouts that can use either a locomotive or a hump to separate the cars. The first type is commonly called the herringbone because the track pattern viewed from above resembles a herringbone. The second is called the two stage yard because the cars are sorted into one yard, the primary stage; and then are sorted into another yard, the secondary stage.

In order to fully understand the new type of yard proposed in this analysis, it is necessary to have a good understanding of the operation of existing yards. Therefore, each of the four yards will be discussed in some detail.

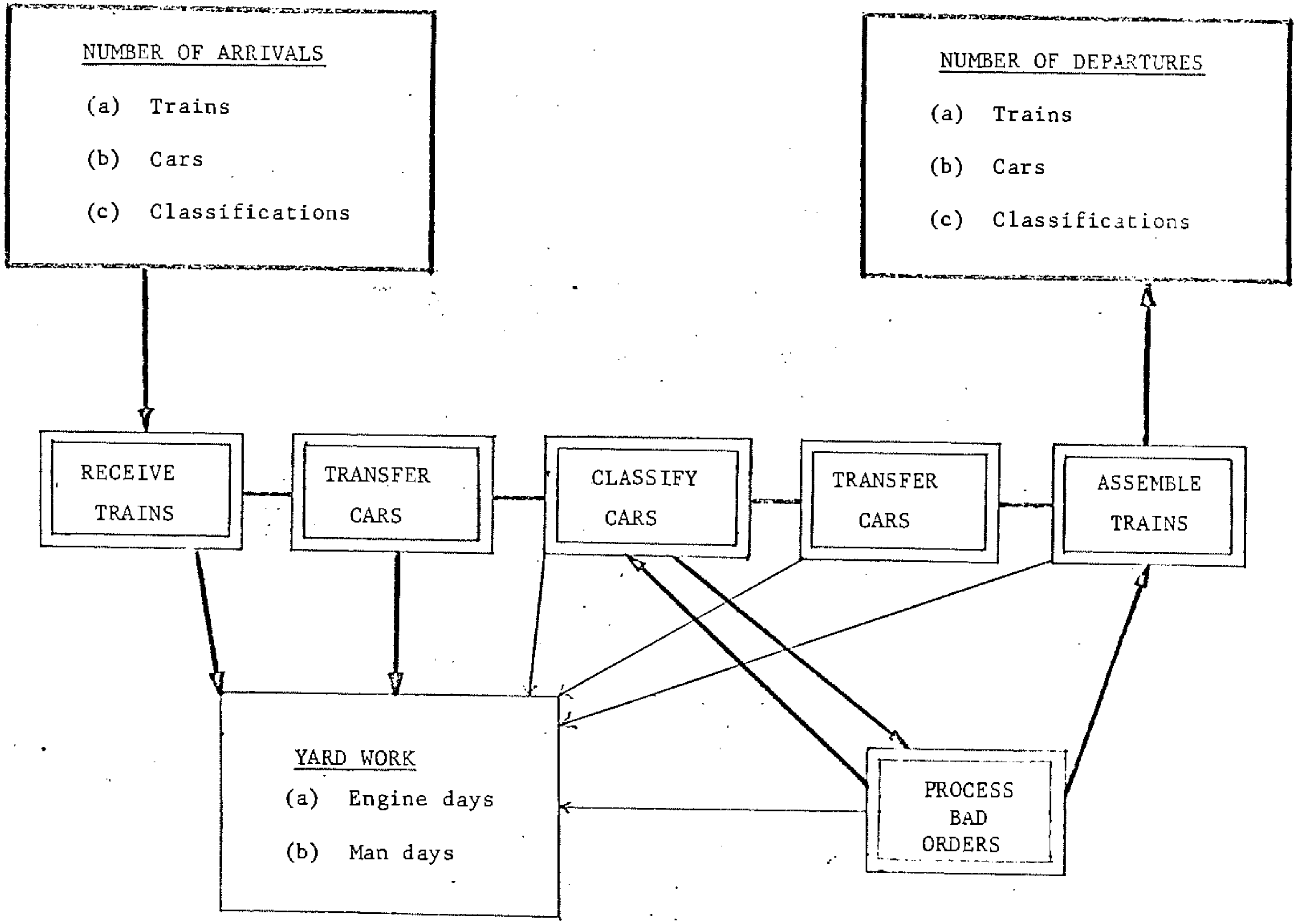

FIGURE 2-1 Block Diagram of Yard Operation

A. The Flat Yard

By far the most common type of yard is the flat yard. The term flat merely means that the yard does not use gravity for car separation. It is not necessarily perfectly flat, depending on the lay of the land. Some flat yards slope gradually, while others may be slightly lower in the middle or at the ends.

1. Physical characteristics

The distinguishing characteristics of the ordinary flat yard are the general track pattern and mode of operation. A typical flat yard is illustrated in Figure 2-2. In its simplest form it consists of a number of parallel tracks, called class tracks, for forming the various classifications.

The track at either end of the yard is divided into two sections. The portion containing the turnouts which form the class tracks is called the ladder and the remaining part that extends away from the class tracks is called the switching lead or simply the lead.

It is more economical for an engine to take a whole string of cars from a track and sort them into other tracks than to take one car out of a track, sort it into another track, go back into the first track and get another car, sort it into a class track, etc.The function of the lead is to hold the engine and the string of cars while they are being classified into the class tracks.

Some high volume flat yards have a few tracks, usually longer than the class track, set aside from the main yard for parking incom-

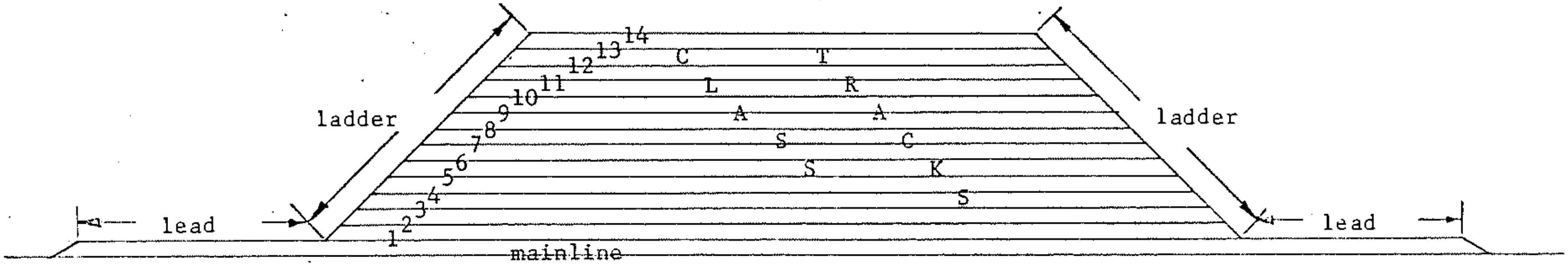

FIGURE 2-2 Track Pattern of Typical Flat Yard

ing trains and assembling outgoing trains. These are termed the receiving and departure tracks and in a very large yard could be two separate areas. They would then be the receiving yard and departure yards. They will be more fully discussed in connection with the hump yard.

2. Operation

The typical small flat yard does not contain special arrival and departure tracks. The inbound train is left on one of the class tracks. Often a train is too long for a single class track and is left on several of the class tracks.

Before a car leaves a yard it must be inspected. It is better to locate a defect before the car is classified so that it may be sorted out and taken to the repair shop (called the rip track) during the regular sorting process rather than when it is buried in the middle of a train ready to depart.

The car inspectors make a detailed check of wheels, flanges, journals, roofs, hatches, doors, couplers, draw bars, grab irons, ladders, all safety features, brakes, shifted load, etc. of every car in the train.

Air pressure holds the car brakes off. When a car uncouples, the air hoses pull apart, immediately releasing the air in the airline. This causes the car brakes to go on very hard, the so-called emergency stop. When cars are being sorted they, of course, must be uncoupled but still roll freely. Therefore the brakes are designed with a device called a triple valve. As its operation is quite complicated and really irrelevant for this analysis it is sufficient to note that on each car there is a lever which can be pulled to release part of the air in such a way that the cars can roll freely without air in the airline. The inspectors perform this function also; it is called bleeding the cars. It takes about 15 seconds to bleed each car and so inspecting and bleeding a train takes considerable time. Many studies have been made of this process and significant improvements effected.

Today, flat yard switch crews generally consist of three or four men although five man crews are found occasionally. The classification of a string of cars can be described as follows: Assume a string of 40 cars which has been left on track number four of Figure 2-2 by an incoming road train must be sorted into a number of classifications. Assume also that a single classification will be formed on each track. As the first step, the yardmaster, the man directly in charge of yard crews, gives the crew conductor (foremen) a switch list. This list identifies each car on number four track and the track to which each car will be moved. The engine may then enter the yard from the left in Figure 2-2 coming in the lead, down the ladder and into number four track where it is coupled to the cars. If the air brakes are on, the ground crew (all the crew except those in the engine) will walk along bleeding the cars and releasing any hand brakes which are on.

Once the brakes are released, the engine will pull to the lead as many cars as it can control with the engine brakes alone, probably 15-

20. It then pushes the cars down the lead. A man signals the engineer who applies the engine brakes, slowing the train. At the same time the man pulls the coupler pin of the car on the engine side of the first cut. A cut is any number of consecutive cars that go into the same class track and is frequently only one car. The cut, free to uncouple, continues at the original speed down the ladder where the one or two other men have set the turnouts to direct it into the proper class track. It gradually loses momentum and couples with the cars already there.

If there are no other cars on the track, a man rides a car, applying the hand brake to stop the cut by the time it reaches the end of the track.

Meanwhile, the engineer has again accelerated the train, and the pin has been pulled for the next cut. As the train slows, another cut coasts toward its class track with the turnouts properly aligned for that cut. Eventually, after several such cuts have been made, the engine and the cars still coupled to it will have gone so far down the ladder that the next cut is beyond the turnout to the track into which it is to go. The engine then pulls the cars back to the far end of the lead and repeats the process until all the cars that were first brought out of number four track have been sorted. The engine then goes back into number four track, getting more cars to continue the process. This method of classifying is called kicking or tail switching.

If a car contains very fragile merchandise or explosives or for a number of other reasons, it is not kicked into the class track but gently pushed in all the way and uncoupled. The engine with the remaining cars pulls back out. This is much more time consuming.

When all the cars for a train have been sorted, the blocks must be placed one behind the other to make up the train. As an example, assume the train consists of five blocks and these are on tracks 1, 2, 3, 6 and 8 of Figure 2-2. The road locomotive is to be at the left end of the yard and the train is to have the blocks in the following order from engine to caboose: 2, 6, 3, 8, 1. Block 2 has 10 cars, block 6 - 29 cars, 3 - 16 cars, 8 - 6 cars and block 1 has 19 cars. The five blocks consist of a total of 80 cars and the class tracks of Figure 2-2 hold only 45 cars so the train must be made up on two tracks.

The switch engine, if working from the right end of the yard could go into track 6, couple to the cars and pull them onto the ladder. It would then push the cars into track 2 and couple to the block there. This is called doubling. It would then double the remaining three blocks onto another track in the same fashion and add the caboose. The train would then be assembled on two tracks. The road engine can then double the one track to the other thus completing the train.

Before the train can depart, however, the air brakes must be again actuated and a standing brake test made. Generally the inspectors start at the engine and walk toward the caboose connecting the airhoses and making sure all angle cocks are open. The engineer then pumps up the brake system. When the brake pressure reaches a given level in the caboose the inspectors walk back along the train checking to make sure all brakes have released and are properly adjusted. When the inspectors signal the engineer that everything is all right, the train is ready for departure.

There are many possible variations of when, how and where many of the preceding functions may be performed. For example inspecting and adding the caboose is handled in many different ways. Also, in some yards where the road crews cannot make the final double because of the union work rules, a yard crew must do it.

3. Improvements made to flat yards

There have been some technological improvements to flat yards. The most notable is the installation of powered switches. The switches for each ladder can then be controlled from a single point somewhere along the ladder. This makes it possible for a three man crew to handle the whole operation on even a long ladder. There would be only the engineer, the pin puller (brakeman) and the man who controls the switches, generally the conductor.

4. Sorting capacity of a flat yard

The number of cars that can be switched per day in a flat yard is naturally rather limited. Only one crew can work on each lead. If the flat yard is large it is often broken into several sections with each section having its own lead so that more crews can work at once. Examples of the way this may be done are given in Figures 2-3 and 2-4.

Flat yards typically sort up to 1000 cars per day in addition to making up the trains, switching the industries served by the yard and

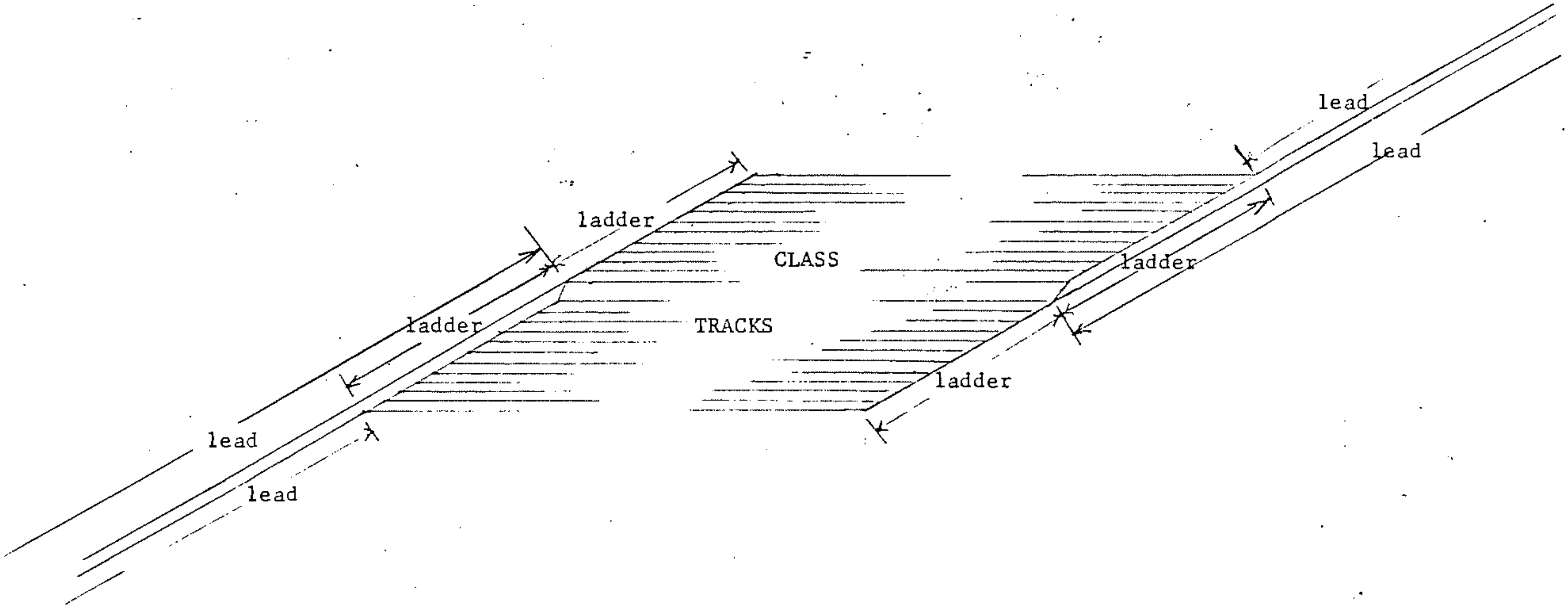

Figure 2-3 Flat Yard with Four Leads

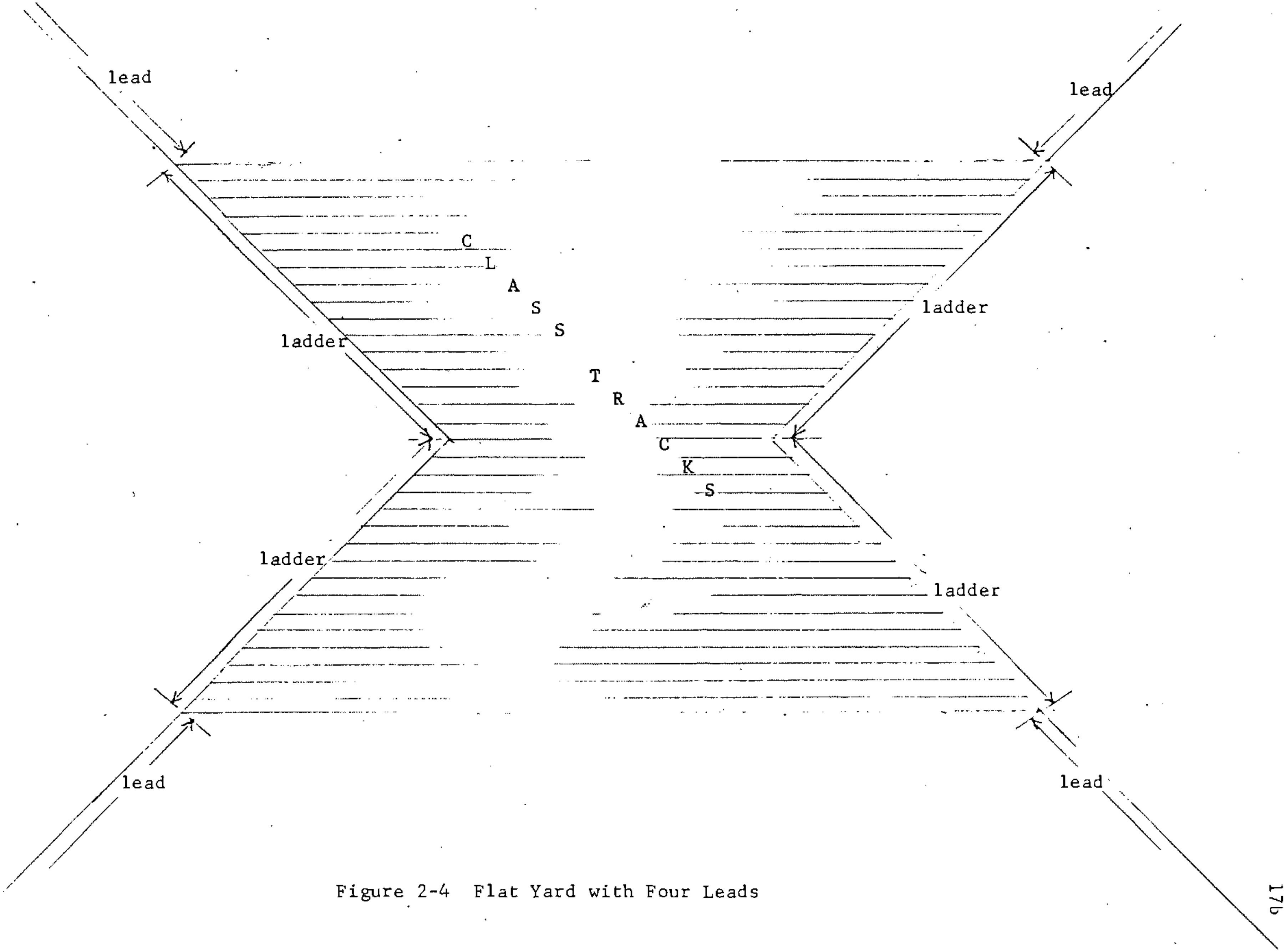

Figure 2-4 Flat Yard with Four Leads

processing through trains. Processing through trains can consist of inspecting, changing cabooses, and adding or subtracting diesel units and blocks.

B. The Hump Yard

Unlike flat yards, hump yards use gravity to separate the cars by enough distance so that the switches can be thrown between successive cuts thus putting the cuts in the various classification tracks. Probably no two hump yards are alike in size and track configuration with the result that capacities and operating characteristics differ greatly.

1. Physical characteristics

The single distinguishing feature of a gravity yard is the hump. This is nothing more than an elevation of 7 to 30 feet. The cars are pushed up one side, uncoupled and allowed to roll down the other side into the classification tracks. In a hump yard individual tracks are commonly referred to as bowl tracks and all of them together are called the bowl because of the general shape.

A typical hump is shown in Figure 2-5 with the corresponding profile shown in Figure 2-6. A complete hump yard is shown in Figure 2-7. Hump yards are generally very large facilities containing 25 to 75 classification tracks and sometimes two or even three parallel leads up to the hump. However, recently some hump yards have been built with as few as 8 classification tracks.

Whereas a flat yard does not necessarily require a receiving yard, the hump yard does. The receiving yard is simply a flat yard with tracks long enough to hold a complete train. An example is shown

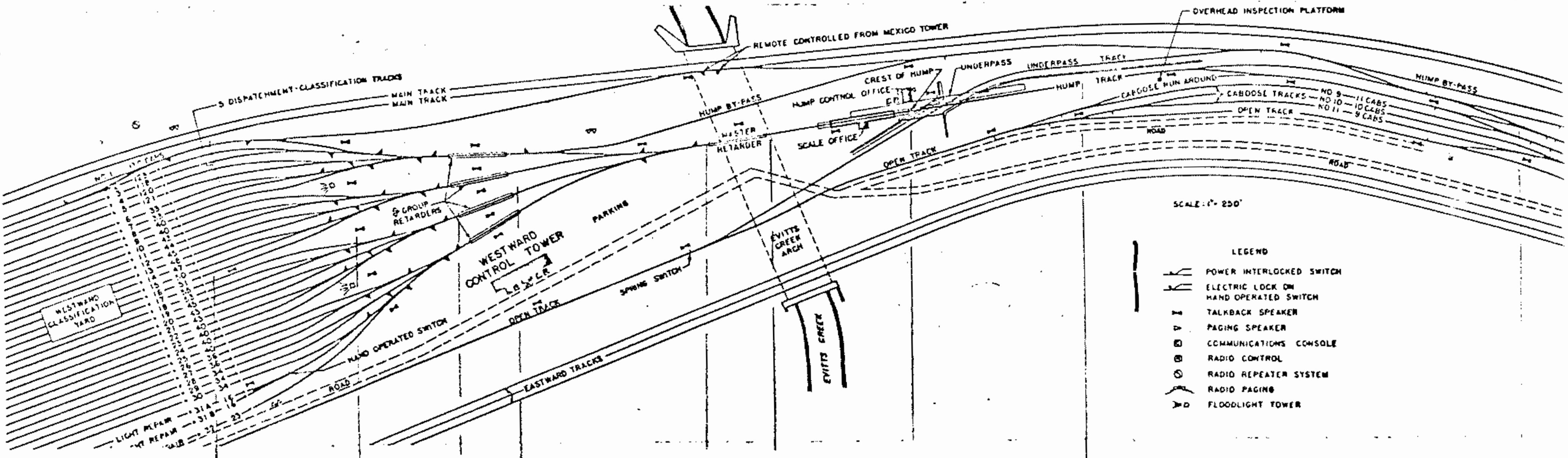

FIGURE 2-5 Track Layout of a Typical Hump

Source: The Baltimore and Ohio Railroad (Westbound Cumberland Yard, Cumberland, Maryland)

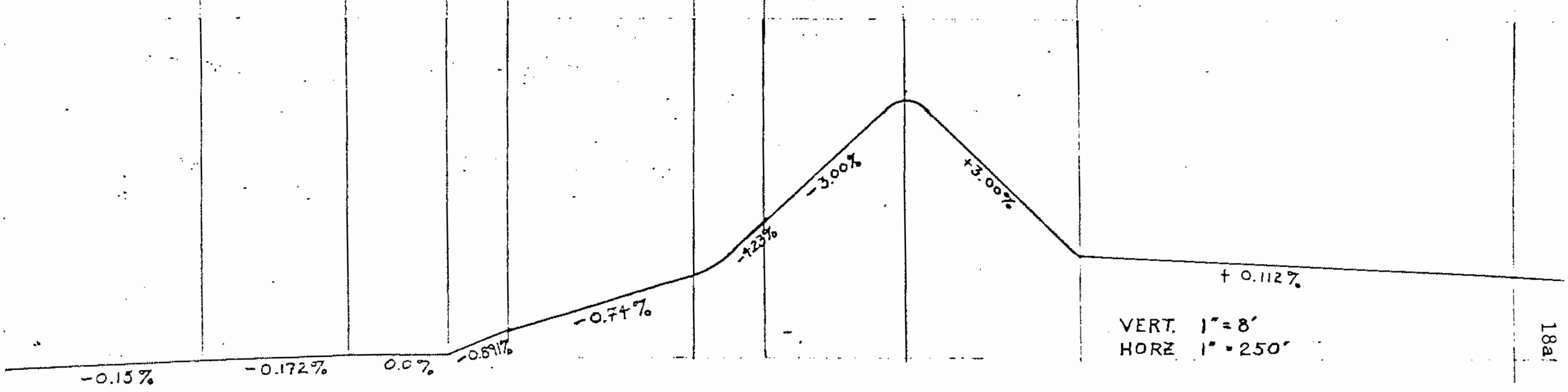

FIGURE 2-6 Profile of a Typical Hump

Source: The Baltimore and Ohio Railroad (Westbound Cumberland Yard, Cumberland, Maryland)

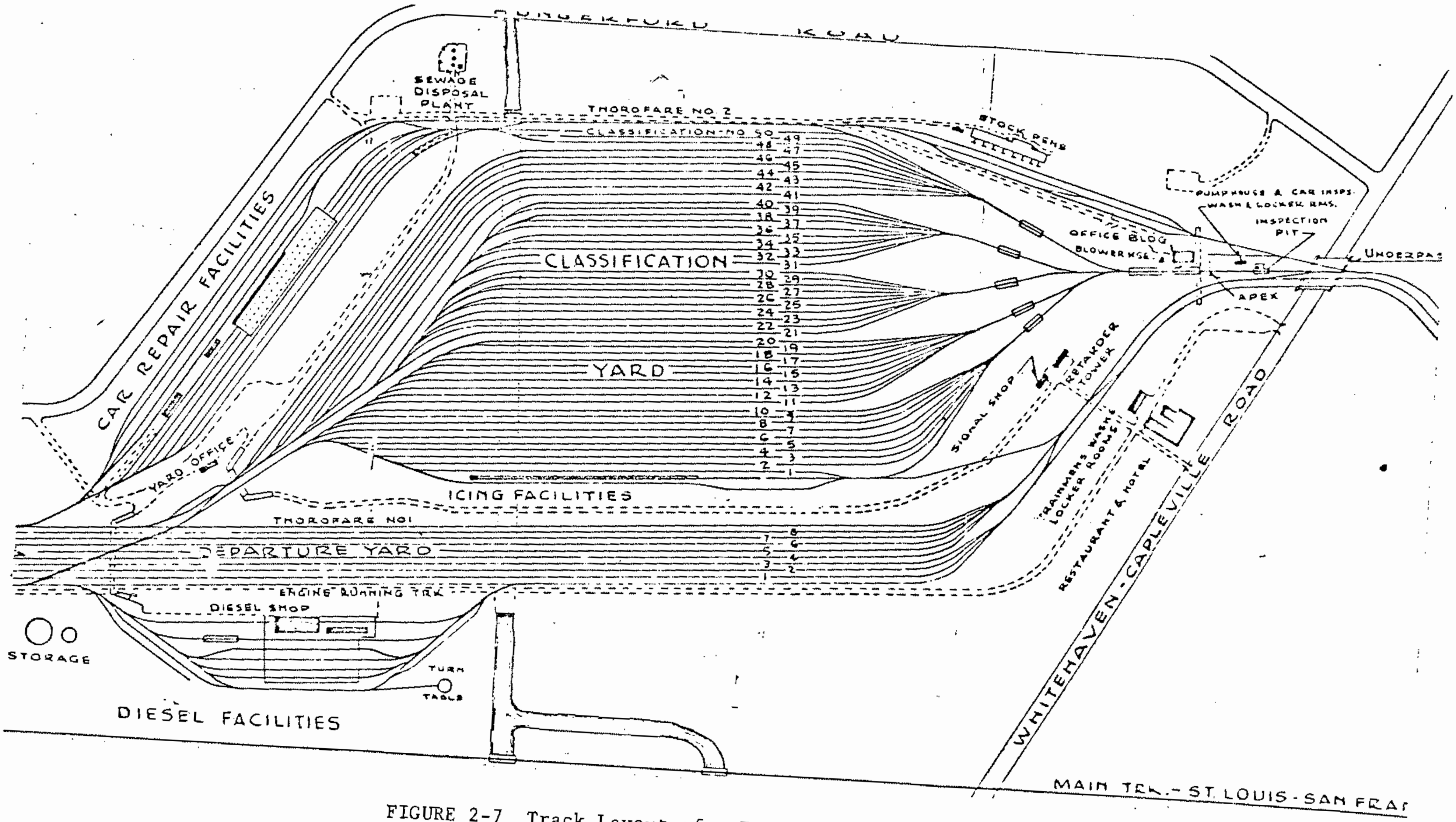

FIGURE 2-7 Track Layout of a Typical Hump Yard

Source: St.Louis-San Francisco Railway (Tennessee Yard at Memphis) in Figure 2-8.

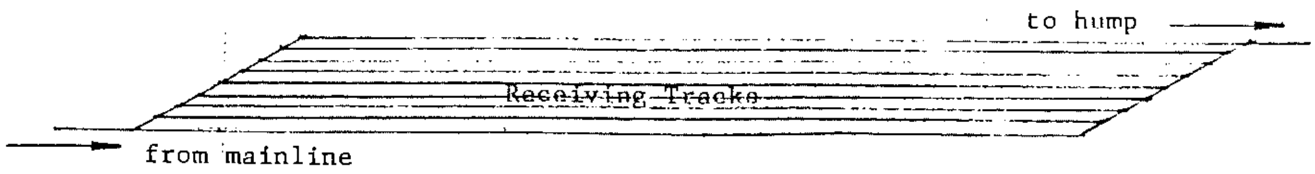

Figure 2-8 Typical Receiving Yard

Some yards are hampered by receiving tracks that are too short, requiring that an incoming train be doubled, i.e. put on two or more receiving tracks. This is expensive. For example, in 1956, Operations Research Inc. (ORI) made a study of the Western Maryland's Hagerstown hump yard and concluded that be lengthening 3 of the 6 receiving tracks from 70 carlengths to 140 carlengths, all doubling could be avoided.[1] The doubling was computed to cost the railroad 1250 man-days per year and 240 engine shifts per year. The standard costs in 1956 were $19.63 per man-day and $29.00 per engine shift. Thus the direct savings would amount to over $30,000 per year.

Hump yards usually have departure yards. These are nearly identical to receiving yards in construction. In some instances one yard serves as both a receiving and departure yard. The whole complex of

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[1] Cook, Emory "Operations Research as a Basis for Improved Design, Operation and Monitoring of Freight Railway Systems." Talk presented at the International Symposium on the Use of Cybernetics on the Railway, November 9, 1963, Paris, France and reprinted in Operations Research Incorporated Technical Paper 23, Silver Spring, Md. P. 8

yards may appear as in Figure 2-9 or may be twisted around to fit the terrain.

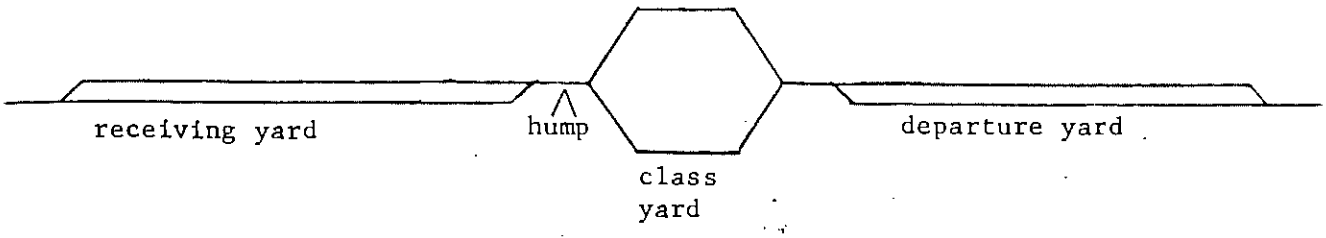

Figure 2-9 Complete Set of Yards for Hump Classification

2. Operation

When a train arrives at the yard it goes into a track of the receiving yard. The locomotive and caboose are cut off and taken to separate places auxiliary to the yard for servicing. As was the case with the flat yard the cars are usually inspected before classification, that is before going over the hump.

To classify a string of cars a locomotive couples to the end farthest from the hump and pushes the cars, at a steady speed of about 2½ mph or less along the hump lead, up the hump and over the crest. When the center of gravity of a cut passes over the crest a man pulls the coupler pin on the first car of the second cut and walks along with the car holding the pin up until the first cut pulls away from the rest of the cars because of gravity. It will then roll down the hump into the appropriate class track.

If the system is functioning properly the engine pushing the cars up the hump (the hump engine) does not stop until all the cars are over the hump. Consequently several cuts roll down the hump at once.

The trains are made up from the end of the classification yard furthest from the hump. Each block to be included in the train is pulled from the class track in order by a locomotive to a track in the departure yard. If the switcher can pull more than one block at a time, it doubles one block to the next until its capacity is reached and then pulls the blocks to the departure track. Only as many trains can be made up at once as there are leads from the end of the classification yard.

The caboose is added and the train is then inspected etc. to prepare it for departure as in the ordinary flat yard.

3. Development and improvements

In the early days all hump yards had men who rode the cars down the hump applying the hand brakes so that the cars coupled at a safe speed. These men were called riders and their job was difficult and dangerous. It is very difficult to judge car speeds correctly. The hand brake wheels until recently (1966) were required to be near the tops of the cars. Climbing the cars in cold and icy weather to apply the brakes and then hanging on a car that is swaying and rocking through the turnouts while simultaneously applying the brake produced many injuries, with resultant indemnity claims against the railroads.

a. Retarders

There are few rider yards left. Now the yards are equipped with mechanical car retarders. There are many types and designs of retarders but most work on the principle of squeezing the wheels of the car as it rolls through the retarder. Retarders are from 10 to 180 feet long. The long retarders are nothing more than several short retarders (section) joined end to end. Retarders in large yards are typically about 150 feet long. Each section of a retarder is essentially two bars on each side of the rail, one or both of which are moveable. End and top views of a retarder are shown in Figures 2-10 and 2-11. As the car enters the retarder the bars move in toward the rail creating friction between the retarder and the wheel to slow the car.

In addition to being safer and more humane, the replacement of riders by retarders is almost always more economical. Again referring to the study of the Western Maryland's Hagerstown hump facility by ORI it was found that by replacing the riders with retarders direct labor savings of 29,000 man days per year (over $550,000) and 3600 engine shifts (over $100,000) could be realized for the traffic then existent.[2] This was primarily due to the higher humping speeds and the reduction of crew from 21-27 to 7.

A rider hump is slower than a retarder hump because the limit on the humping speed is determined by the time required for the rider to board the cut and test the hand brakes.

In addition to savings in labor costs in converting the Hagerstown hump to retarders, the increased capacity thus created would make

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[2] Rosenstock, Henry M., Gary D. Gordon & Emory Cook "System Economics Possible with a Hagerstown Retarder Yard" Operations Research Incorporated Technical Report No. 40, October 1, 1957, p ii

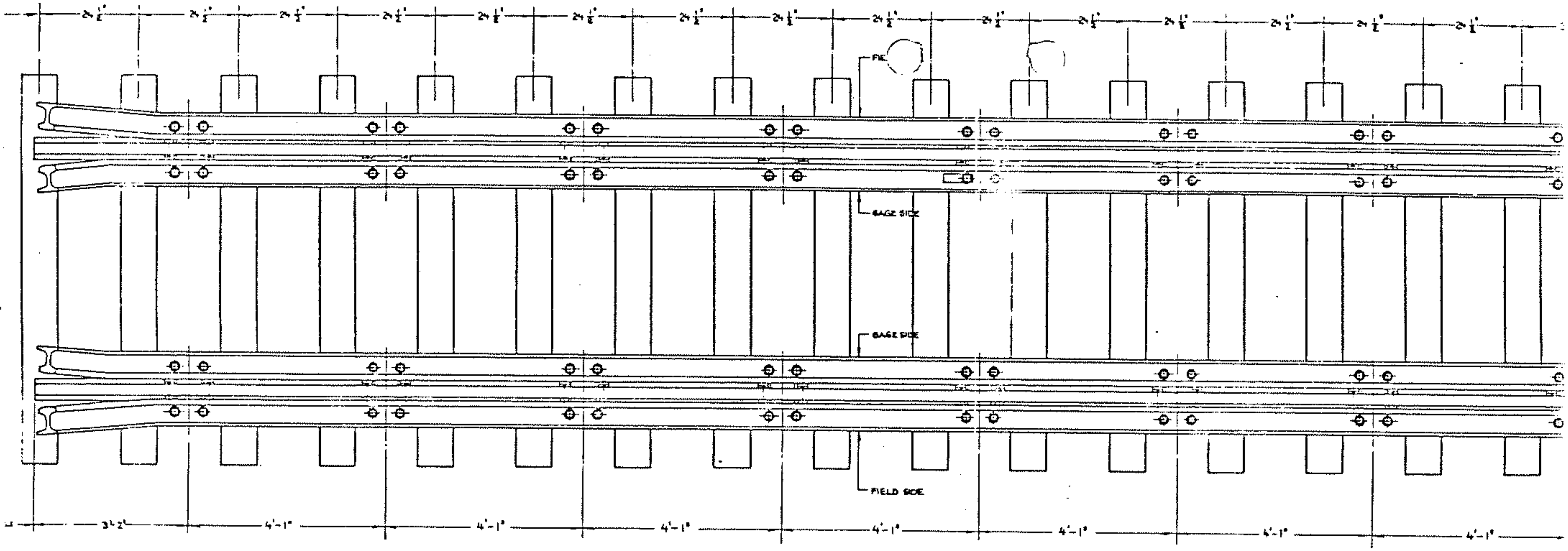
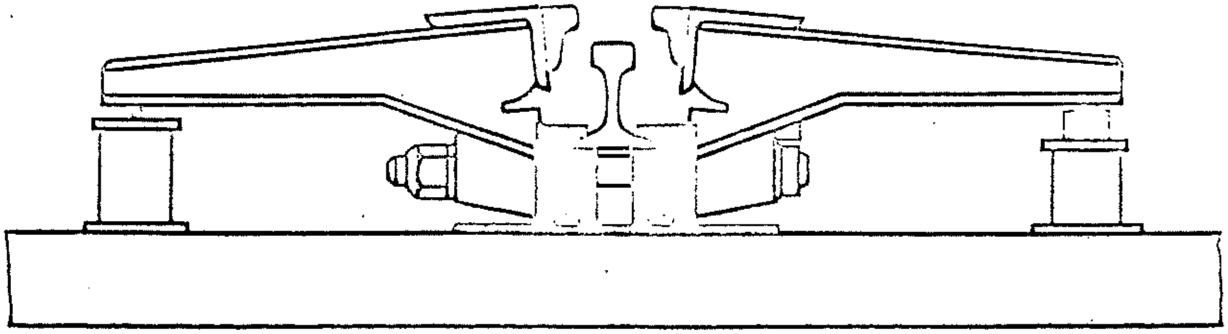
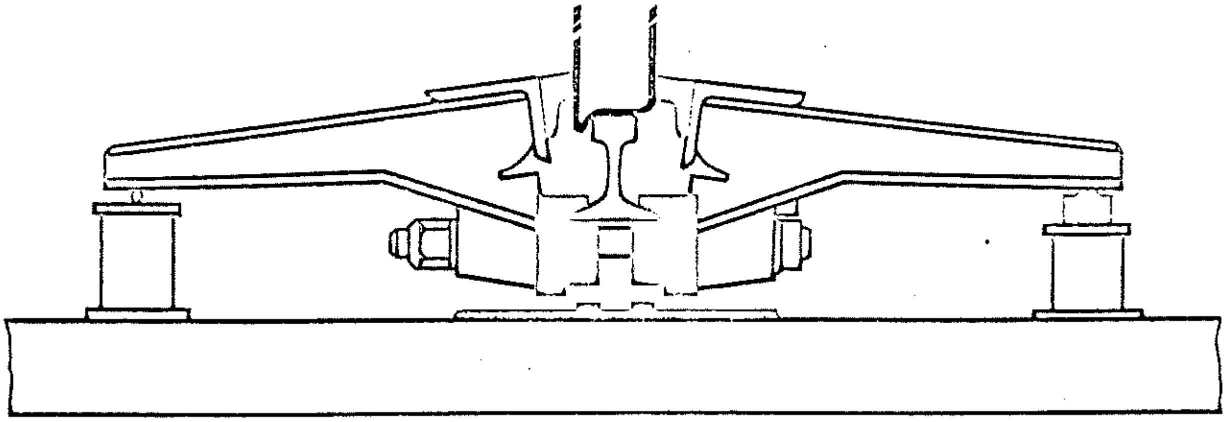


FIGURE 2-10 Top View of Mechanical Car Retarder in Track

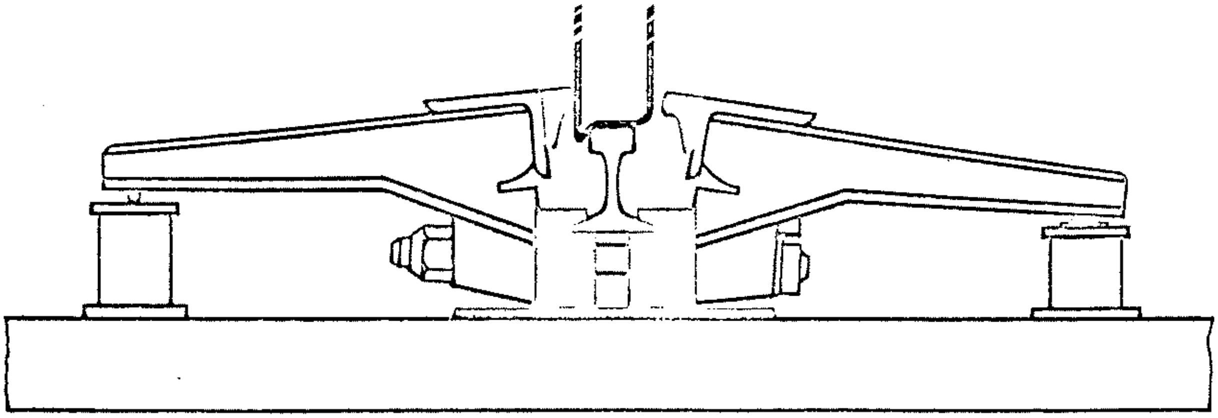
Source: American Brake Shoe Company



NORMAL POSITION. *Retarder Closed—No Car Present.* Ram is extended to close retarder. Retarder rests on tie plate.



RETARDING POSITION. *Retarder Closed—Car Present.* Ram is extended. Brake shoes are spread by the car wheel, causing the retarder to rise from the tie plate. The heavier the car, the greater the retarding force exerted.



OPEN POSITION. *Retarder Open—Car Present.* Hydraulic pressure is removed, the ram is lowered, the outside brake shoe is withdrawn, and the retarder rests on the tie plate.

Figure 2-11 End View of Mechanical Car Retarder

Source: Union Switch and Signal Division, WABCO possible to abandon some yards in another location which would decrease the total system power requirement by four units, reduce by 27,000 car days per year the terminal time of coal cars and cut overhead (not calculated quantitatively) by concentrating supervision, mechanical and clerical forces. These same results could not be expected in every case but because railroad operations are so very interdependent such snowballing effects frequently occur.

It is a common misconception that if traffic volume decreases riders are cheaper than retarders. However, in this instance if traffic volume fell 25%, 22,000 man days would be still saved. During the depression when there was a severe drop in traffic the Pennsylvania (PRR) decided to return a retarder equipped yard to rider operation. They found that the rider operation was much more expensive and soon returned to the use of retarders. However, in the PRR case, unlike the WM, the retarders had been installed.

There are usually two sets of retarders: the master retarders and the group retarders. These are indicated in Figures 2-5 and 2-7. The master retarders release the cut at a fixed speed, usually in the range of 12 to 16 MPH.

Thus the master retarder retards poorly rolling cuts very little but greatly slows these cuts that roll well. This is to prevent them from overtaking the preceding cuts before they are in their separate tracks.

The group retarders release the cut at a speed calculated to let it coast down the appropriate class track and couple gently (2 to 4 mph).

There have been remarkable improvements in retarders over the years. The earliest were set manually by the operator to grip with the desired pressure. Usually only three different settings could be made, e.g., 40, 80 or 120 pounds per square inch. The next modification permitted the operator to simply specify the speed at which the cars were to leave the retarder, the so-called exit speed. This type is widely used and is still being built for use in small, inexpensive hump yards. These are commonly referred to as semi-automatic retarders.

With this type of retarder the operator can usually select one of three exit speeds. The highest speed is used when the cut is to travel to the far end of the class track and when it is a very poor roller. The lowest speed is used when the class track is nearly full and the cut is a very good roller. Each group retarder usually has a different set of three speeds. Those with the highest set of exit speeds are usually in the outside groups where the track curvature from the retarder to the class tracks is most often greatest and thus the resistance is the highest.

Later, the fully automatic retarder was developed. The controls, commonly including a small computer, determine how far down the class track each cut should go and how much track curvature is between the retarder and the desired final position.

Just as the cut starts down the hump its "rollability" on straight track is measured; that is, the computer determines how much the car accelerates in a given distance. The cut is also weighed as it rolls down the hump. This is to help determine how well the cut will roll. Also considered are wind direction and velocity and weather conditions (snow, rain, sleet, etc.) The controls system sets the retarders so that the cut leaves at the proper speed to couple gently in the proper class track.

b. Turnouts

In the early hump yards the turnouts were set by hand. A man tended each group of nearby turnouts. Not only did this seriously limit humping speed and thus capacity but also resulted in misclassified cars and danger to the switch tenders from possible derailment of cars. To overcome these problems the switch machine was developed permitting a single operator to set all turnouts from a remote position. For each cut he set each turnout of the route by positioning an electric switch on the control panel. Still additional developments allowed the operator to merely set a control indicating the desired class track and all the necessary turnouts to get the car there were set automatically. This required the storage of several routes since more than one car rolls toward the class tracks at once. Often the operator can set up four routes in advance. After the cut passes, each turnout repositions itself for the next cut. In the fully automatic yards the computer stores cut routings to the various class tracks for an entire train.

4. Capacity of hump yards

The various types of hump yards combined with the wide range of automation available offers a great range in capacity. For example, Richmond yard at Richmond, California on the Southern Pacific has only eight class tracks and handles only 450 cars per day while Gateway yard near Youngstown, Ohio on the Pittsburgh & Lake Erie has 35 tracks and handles 2700 cars per day over a single hump with a single lead. The new fully automatic St. Louis Gateway yard completed in 1965 by the Alton & Southern with 33 class tracks, a single hump and a double lead has a stated capacity of 3000 cars per day. The Montreal yard of the CN has 84 class tracks in the main yard with a double hump and triple lead which in 1961 was actually handling 2500 to 3200 cars per day. Along with the 40 track single hump, single lead, local yard that was handling 700 to 1000 cars per day, the total complex has a stated capacity of 7000 cars per day.

Several factors limit the number of cars that can be sorted in a given time period. However the inadequacies and limitations of the yards will be discussed in the following chapter. As a rule of thumb, hump yards are generally built when the volume exceeds 1000 cars per day. But the decision to build a hump or flat yard is not dependent solely upon the number of cars to be classified per day, but also upon the number of different classifications to be made at that yard, the average cars per cut and the train schedules. There is considerable overlap in the capacities of flat and hump yards and much has been written advocating the advantages of one type over the other for the same job.

C. The Classical Two-Stage Yard

What is generally referred to simply as the two-stage yard will, for the purpose of this analysis, be called the classical two-stage yard to differentiate it from the folded two-stage yard being introduced in this paper.

The two stage yard consists of two essential aspects, the general track pattern and the method of sorting.

1. Physical characteristics

The general track pattern of the classical two-stage yard is simply two yards end to end so that the first feeds the second as indicated in Figure 2-12. The first yard is called the primary stage yard and the next the secondary stage. Both stages could be flat yards or one stage could be flat and the other hump; however, desired classification speed usually requires that both stages be hump fed.

As in all yards the number of tracks required is dependent upon the number of classifications to be made. However, as will be fully discussed below a particular advantage of any two-stage yard derives from the fact that it can make as many classifications as the product of the number of class tracks in each of the two stages. Thus, if the primary stage and secondary stage contain 10 class tracks each, 100 classifications can be made. A single stage yard with the total number of class tracks used in both stages of the two stage-yard could make only 20 classifications.

The square root of a product gives the minimum sum. Thus if one

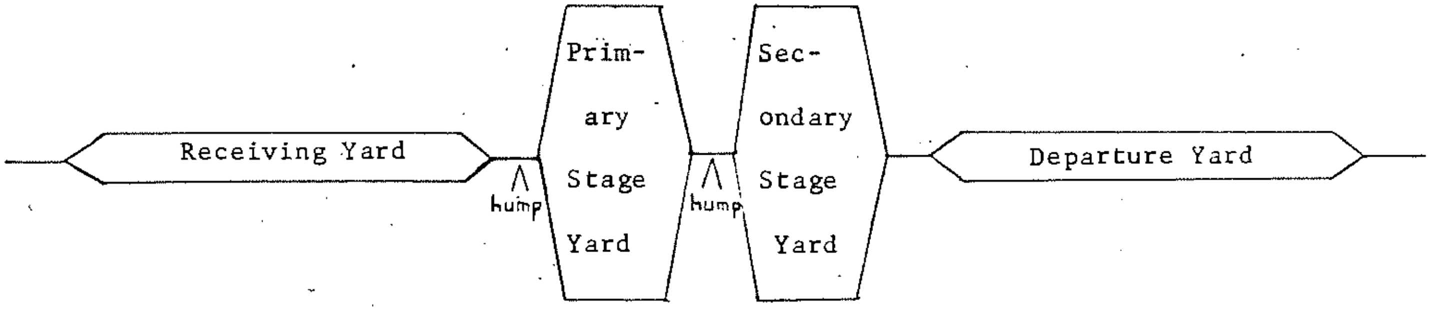


FIGURE 2-12 General Track Pattern of a Classical Two-Stage Yard

wishes the complete two stage yard to contain the minimum number of tracks, each stage should have an equal number of tracks if possible, e.g., 9 and 10 rather than 5 and 18.

2. Operation

To illustrate the method of operation, consider a small yard consisting of only three class tracks in each stage. Such a yard can make nine classifications using only the six tracks.

Suppose the following string of cars 6,2,4,8,3,9,2,5,5,4,9,9,7,9, 9,2,4,9,7,7,5,4,9,7,6,1,7,9,2,8,5,9,6,5,8,4,3,7,1,9,5,8,5,1,1,1,5 enters the first stage of Figure 2-12 from the receiving yard with the 5 first, 1 second etc. The sequence used here for illustrative purposes is random having been taken from a random number table.

Assume that it is desired that the departing train have nine blocks, each block containing a like group of cars. Thus one block has all the 8's, another all the 6's etc. Also assume that the train will leave to the east with the blocks in numerical order, that is, with the block of 1's first, the block of 2's next and so on, through to the block of 9's.

After the first sorting the primary stage yard would appear in Figure 2-13. Then by pushing tracks A, B, and C

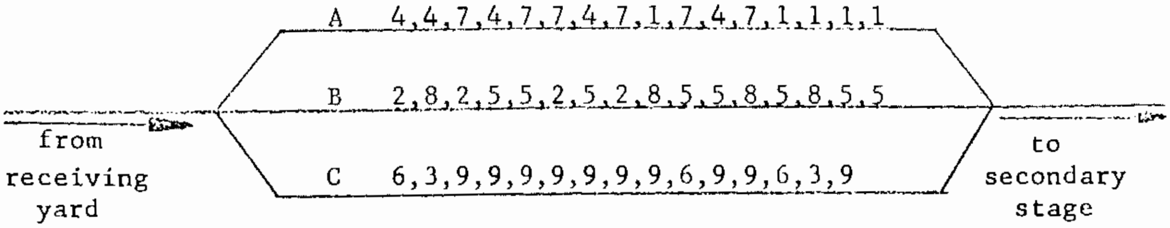


Figure 2-13 Car Arrangement in Primary Stage After First Sorting

in that order over the secondary hump and sorting the cars into the secondary stage, the arrangement of Figure 2-14 would result.

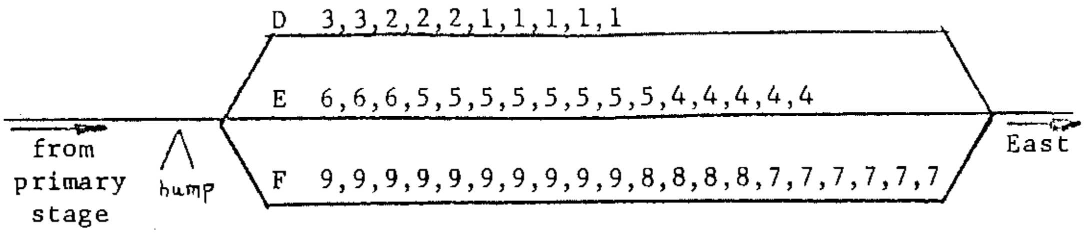


Figure 2-14 Car Arrangement in Secondary Stage Upon Completion of Sorting

To make up a train of the 9 blocks it is necessary for the locomotive to make only two doubles compared to the usual 8. That is, the engine couples to the right end of the cars on track D of Figure 2-14, doubles all the cars on that track to track E and then doubles the total to track F. All other operations are the same as in the ordinary hump yard.

The above discussion is not meant to suggest that the cars cannot be shoved over the same hump twice since they frequently are. This process is called rehumping and is necessary whenever the number of classifications exceeds the number of class tracks. The process will be further discussed in the following chapter.

Also a two hump yard should not be confused with a two-stage yard just because one hump feeds another such as in the Montreal Yard of the Canadian National. In this yard the first yard has 84 class tracks. All local cars are placed on as few of these tracks as will hold the given number of cars. These cars are then put over the second hump into a 40 track yard. Hence in essence they are making only $(40 + 84 - \geqslant 1) \leqslant 123$ classifications. The only advantage of the two humps in this case is that the railroad can be humping two cars at once (one over each hump) and thus increase the total capacity.

3. Capacity

The capacity of a classical two-stage yard is about the same as a comparable single stage even though the car must be humped twice. This is because cars can be going over both humps at the same time.

D. The Herringbone Yard

The herringbone[3], or as it is sometimes called, the trainmaker yard[4], is a relatively recent development in yard design. It, like the classical two stage yard, can be either a flat or hump facility. Its great advantages are derived from the fact that it does not require a departure yard, and several classifications can be made up on one track as in the case of the classical two-stage yard, but with only a single sorting.

1. Physical characteristics

There are several basic designs of herringbone yards of which Figures 2-15, 2-16, and 2-17 are typical. The distinctive character-

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[3] Haranda, Minoru, "New Type Layout of Track in a High Performance Freight Car Marshalling Yard (The Herringbone Pattern)" Quarterly Report of the Railway Technical Research Institute, Japanese National Railways Vol.5, no.2 1964 pp.53-8

[4] Billmyer, George W., 3rd, "The Trainmaster Yard" Trains Vol.XVIII (December 1957) pp.50-3

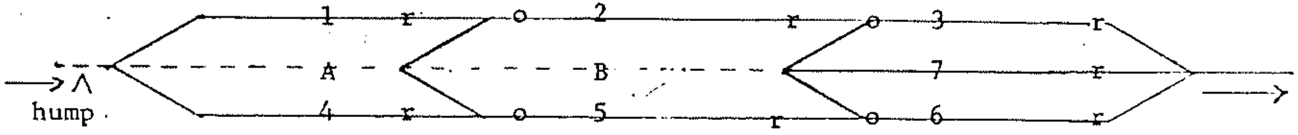

FIGURE 2-15 Herringbone Yard

Source: Adapted from Haranda, p.54

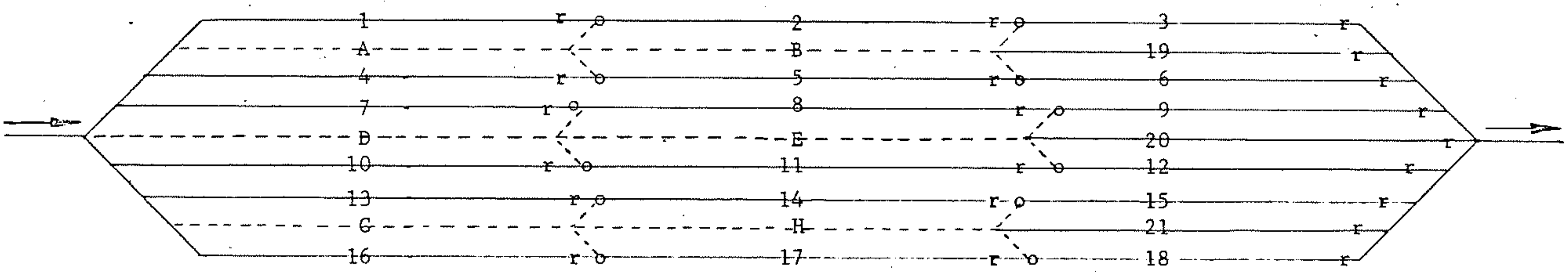

Figure 2-16 Herringbone Yard

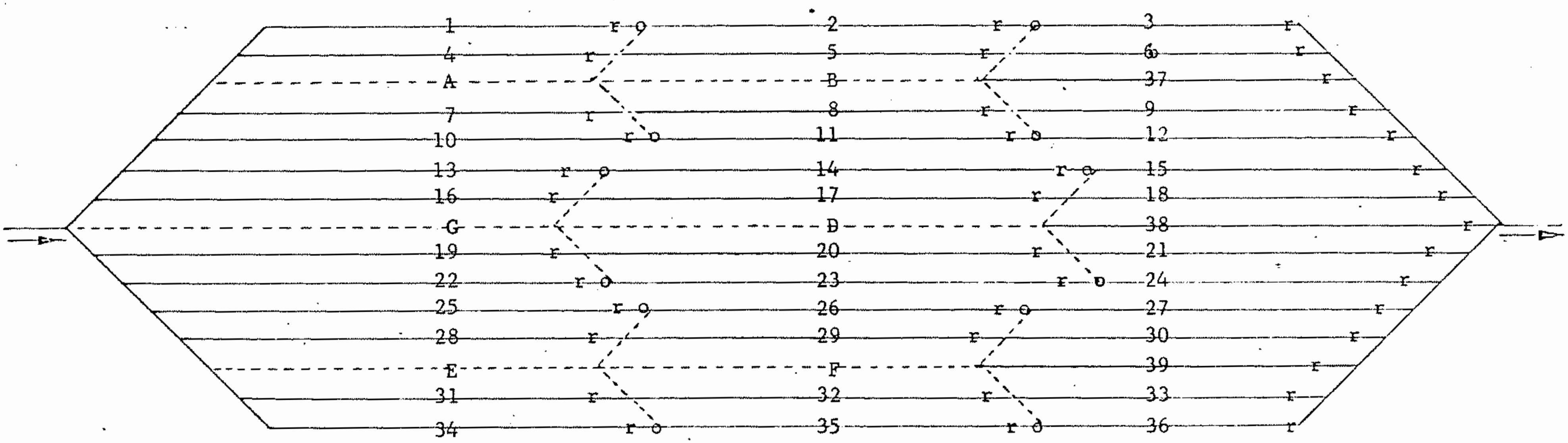

Figure 2-17 Herringbone Yard

istics are the running tracks and the side pockets. The side pockets are used as the class tracks. In the figures, the class tracks have been numbered and the running tracks are represented by lettered, dotted lines. At the end of each class track there is a retarder which can be set in either an on or off position. When in the on positions it stops a car and prevents it from rolling into the next pocket. When it is off it has no effect on the cars. This type of retarder is called an inert retarder; in the figures they are indicated by the letter "r" at the end of each class track.

The small circles represent spring switches. Spring switches allow a car to go through the turnout in the trailing direction from either the main or diverging route but in the facing direction the cars go only in the direction for which the switch is set. See Figure 2-18.

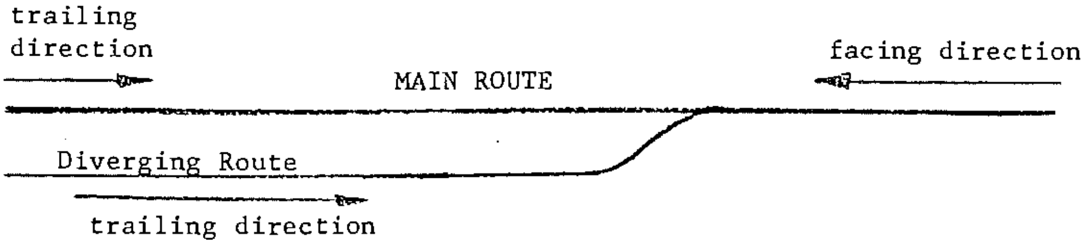

Figure 2-18 Spring Switch

. The other turnouts of Figures 2-15, 16, 17 are the ordinary powered type.

2. Operation

Consider the hump herringbone yard represented in Figure 2-15. Before sorting begins the yardmaster knows the number of cars to be included in each classification. If a single pocket is too short he merely assigns two or more consecutive pockets to the same classification and sets the inert retarders for all but the last pocket in the off position. For example, if for classification X the number of cars will exceed the capacity of a single pocket, pockets 2 and 3 may both be used, making a longer class track.

The cars enter from the left. If the first goes to pocket 5 it rolls down A through the crossover and down pocket 5 until it is stopped by the inert retarder or any cars already in the pocket. If the second cut is X it rolls down A through the crossover, down 2 and continues into 3 until stopped by the retarder. A cut for pocket 1 would go into that pocket at the first turnout. A cut for pocket 7 goes down running track A to B and into 7. The pockets at the ends of the running tracks are best for bad orders, cabooses, cleaners, re-icers, etc. If the regular blocks were to be put in these pockets they would have to be doubled when made into trains.

When all the cars have been classified the train is assembled by simply adding a caboose to the appropriate pocket and backing the locomotive in from the right far enough to couple all the blocks. Once the air hoses are connected and the standing brake test performed, the train can depart. There is no doubling necessary unless there are more blocks in the train than a single track has pockets. A single track can have more pockets than is shown in Figure 2-15 simply by making the whole yard longer.

3. Capacity

The Japanese claim a capacity of 2000 cars per day for a flat herringbone and of 3000 cars per day for a hump herringbone.[5] By way of comparison, they consider capacities of 500 cars per day for a conventional flat yard and 1000 cars per day for a conventional hump yard. As noted above, capacities for similar yards in the United States and Canada are greater for conventional hump yards.

All the preceding yards have limitations and inadequqcies that are inherent in their basic design. The next chapter will discuss these.

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[5] Haranda, p.58

CHAPTER III

INADEQUACIES AND LIMITATIONS OF EXISTING CLASSIFICATION YARDS

In broad terms the inadequacies of existing yards are: 1) costs of classification are too high; 2) the procedure is time consuming and cars are delayed too long. The reason for these problems will be analyzed in detail below.

A. Inadequacies and Limitations Common to all Types of Existing Yards

Some problems are common to all existing yards; others peculiar to only one type of yard. The first to be discussed are those common to several types of existing yards.

1. Yard construction costs

The first problem is the large initial capital investment common to all types of classification yards. For example, the initial investment for the Alton & Southern's St. Louis Gateway Yard was 5.5 millions, for the Chesapeake & Ohio's Russell Westbound Manifest Yard, 5.5 millions, for the Pittsburgh & Lake Erie's (P&LE) Gateway Yard, 7.7 millions and for Canadian National's (CN) Montreal Yard (actually 3 in 1), 30 millions.[1] These capital expenses can be broken down into purchase of land and necessary grading, the cost of the turnouts, the trackwork, signalling, communications, lighting and auxiliary facilities such as buildings. These expenses are for only the classification yard proper and do not

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[1] - All data on existing classification yards supplied by Industrial Engineering Department, Chesapeake and Ohio Railway-Baltimore and Ohio Railroad.

include items such as the facilities for engine servicing, car repair, etc.[1]

a. Amount and shape of land required

The amount of land required for any yard consists of two components; the amount occupied by trackage for the freight cars and the additional amount required to sort the cars. A car-length is defined as 45' and width as 10-1/2'. If all the cars in a yard were stored in a straight line, each would require an area of 472.5 square feet. The determinant of space required would be the maximum number of cars in a yard at any given time. This is a function of thruput time and the traffic pattern. The lower the thruput time the fewer the cars in the yard. When cars are placed side by side, as they are in yards, the necessary clearance is considered to make the car 13' wide. Thus each car occupies an area of 585 sq. ft. Additional space is required for turnouts and running tracks. It is here that yard design determines much of the yard land area.

Turnouts are numbered from 5 to 30 to indicate the degree of curvature of the diverging track, 5 being the sharpest curve. Yard turnouts are usually number 8's. When 13' is allowed from the center of one track to the center (13' track center) of an adjacent track a number 8 turnout is 100.43' long and 15-1/2' wide or 1557 sq. ft.[2] Turnouts can seldom be surrounded by other yard apparatus and so usually take more space. Therefore, the fewer classification tracks there are for a given number of cars, the less acreage required.

Another feature of yards which makes land procurement expensive is their general shape. The difficulty usually lies in obtaining the neces-

[2] - Hay, William W., Railroad Engineering, Vol. 1, John Wiley & Sons, New York, 1953, p. 442.

sary width rather than length. Railroad rights of way are frequently from 50 to 150 feet wide but a minimum of 104' is required for a 7 track yard even if using the maintrack as a running track, which is to be avoided, if possible. Beyond the railroad right of way the land is often developed or unsuitable for additional tracks without excessive grading. Therefore, railroads are sometimes forced to locate a new yard in "the wilderness" which is not an ideal location from an operating viewpoint. If there were some way to make yards narrower, and consequently longer, it would be advantageous in land availability.

b. Turnouts

Turnouts are more expensive than yard trackage. The number 8 turnout that is usually used in yards, costs $4642 installed, whereas yard trackage costs only $14.51 per foot.[3] A number 8 turnout has 95'7-1/8" of track in the diverging route and 96'4-7/8" in the through route for a total of 192'.[4] This would cost only $2786 in yard trackage in addition to being useless for holding cars. Yard trackage must still be built to accommodate cars.

In all the yards discussed in Chapter II except the classical two stage yard, at least two turnouts are required for each classification other than the first. If there are n classifications to be made in a flat or hump yard there are a minimum of 2(n-1) turnouts required.

c. Trackwork

As mentioned, a standard car is 45' long. With yard track at $14.51

[3] - Office of Deputy Chief Engineer, Baltimore & Ohio Railroad, Baltimore, "Cost of Trackwork", December 1, 1964, pp. 3, 5.

[4] - Hay, op cit, p. 438

per foot, trackage costs $553 for a single car. The number of cars that a yard must hold at one time is a function of scheduling and the thruput time of the yard. Minimum thruput is dependent upon yard design and facilities.

d. Length of classtracks

Many times a single class track is used for more than one classification during a day. Track 4 may be in use for classification Y83 until two hours before the departure of train 87 at 1:30 a.m.; then until two hours before the departure of train 93 at 12:15 p.m. Track 4 is used for classification Y17.

Each classification has an expected number of cars. If only a single classification is put on a single track at a single time each track must be built to accommodate the maximum expected number of cars. This is the expected value plus the variance. If two classifications are put on a single track it must be long enough to hold the sum of the expected value of each classification plus the variance of the sum rather than the sum of the expected values plus the sum of the variances. When the variance is large this can result in a substantial saving in feet of track required. Therefore, the more classifications that can be put on a single track the less the variance that must be added to the expected value.

e. Signalling and communications system

Nearly all yards have extensive signalling and communication systems. There are signals to control train and locomotive movement; and radio teletype, pneumatic tube, telephone, television, loudspeaker, and talkback speaker communication systems to direct, control, and inform the employees. The larger the yard the more complicated and expensive the systems. For example, as part of its communications system Canadian National's Montreal Yard has 8 separate talkback speaker systems and 5 separate radio systems.

f. Lighting

Because railroads operate continuously the yards are well lighted at night, not only for ease of operation but for reduction of vandalism. The lighting usually consists of a number of floodlight towers such as those used to light a sports stadium.

2. Operating expenses and limitations

Most of the operating limitations of yards result from being a flat yard, a hump yard or otherwise and must be discussed separately. Generally, one can note that a supervisory and a clerical force are always needed. Each switch engine costs \$87 per day and yard crew members are allotted an established wage plus 22% for fringe benefits. A wage table (without fringe benefits) is given in Table 3-1. There is always the maintenance of the yard. For track work this is approximately \$2500/mile/year and \$250/turnout/year.[5]

3. Time

The time needed to sort cars depends on the method of sorting. The time necessary to assemble a train, the Assembly Processing Time (APC) may be taken as:[6]

APC = 0.5 min.(No. of cars) + 8 min. (No. of tracks pulled) + 12 min.

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[5] - Office of Industrial Engineering, Baltimore and Ohio Railroad, Baltimore.

[6] - Nippet, David "Simulation of Terminal Operations" in Simulation of Railroad Operations, Railway Systems & Management Association, Chicago, 1966, p. 176.

TABLE 3-1

Rates of Pay* of Yard Personnel - 5 Day Week

Occupation	Rate/Day
Yard Conductor	$27.88
Yard Helper	25.87
Switchtender	23.77
Retarder Operator	28.88
Hump Conductor	28.88
Engineer**	29.21
Fireman**	25.52

* To find expense to company add 22% for company borne fringe benefits.

** Engineers and firemen are paid for weight on locomotive drivers. The figure given is typical.

Source: Baltimore and Ohio Railroad Company, Baltimore, Md. Effective August 12, 1966

The inbound inspection time depends on the number of inspectors used and the method. When the train is inspected in the receiving yard and there is one inspection for each side of the track, a time of 1.00 min/car is typical.[7] If bleeding is required, 15 seconds more per car are needed.

The outbound inspection typically takes one half minute per car plus a constant of 20 minutes.[8]

The summation of the above times plus the sorting time (dependent on the type of yard) would seem to give the total time spent in a yard. But this is not the case because there is also a congestion factor. A train must wait for the preceding train or trains being humped, there is a shortage of switch engines, there is frequent blocking on the tracks causing congestion at each step.

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[7] - From "Times Used by Battelle Memorial Institute's Terminal Model II for Computer Simulation of Walbridge Yard, Toledo, Ohio, 1966" - Working Papers of C&O-B&O Planning Department, Baltimore, Md.

[8] - Ibid.

Finally, there is accumulation time. Though only seconds are needed to classify a car it may sit for hours on the classification track awaiting arrival, classification and inspection of other cars for that same classification.

B. Inadequacies of Flat Yards

The relatively small number of cars that a flat yard can classify per day is not a limitation. When the volume becomes so high that the costs for the flat yard are higher than for a hump yard, a hump yard can be built. There are places where a yard is needed and volume does not warrant a hump yard. What are the limitations in such an instance?

1. Number of impacts

Important is the number of impacts a car can sustain while undergoing classification. Impacts can cause damage to the lading. In a hump yard the cars are pushed up the hump at a constant speed, roll down the hump and experience an impact only when coming to a stop in the class track by hitting cars already in that track. If the retarders have done a proper job speed is reduced smoothly and the impact is gentle - less than 4 mph. However in flat yards, as described in Chapter II, kicking can involve many impacts. As an illustration consider an engine with ten cars of which no two consecutive cars go into the same class track, i.e., there will be ten cuts. The engine accelerates all ten cars, the pin is pulled for the lead car (number 1 in Figure 3-1) the engine brakes are applied abruptly, the nine cars still coupled to the engine slow suddenly and the end car (number 1) coasts down the lead into the proper class track and hits the cars in that class track. Thus it has only one impact but the sudden slowing

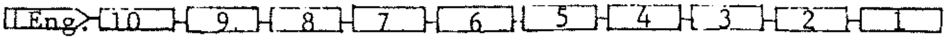

Figure 3-1 Engine with Ten Cars to be Sorted in a Flat Yard

of the other nine cars has produced a shock to each.

To a reader who is not familiar with railway operations this may not seem serious, but it should be remembered that the car brakes are not used in switching and that there is so-called "slack" between each car. That is, if two cars are pushed against a wall as in Figure 3-2 when the engine pulls away it will move several inches, say x inches, that is, there are x inches of slack, before number one car will move. The engine and number one car will then both move x more inches before car number two will move, etc.

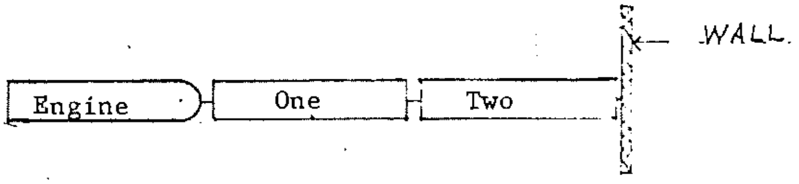

Figure 3-2 Engine with Two Cars

Slack is purposely allowed because otherwise it would be impossible to start a long train. With slack the locomotive starts only one car rolling at a time.

In a 10 car train there is about 3 feet of slack. If an engine is pushing the cars and then its brakes are applied, the cars are suddenly shifted from compression to tension and there will be considerable shock to the last car.

While it is possible to avoid severe shock in starting cars by going slowly until all cars are rolling, this is usually not done in flat switching since it would require a greater distance to accelerate the cars to sufficient speed for a cut to coast all the way to its place on a class track. Since backing down the lead takes more time and a crew is under pressure to classify as many cars as possible in a given period of time, the engineer accelerates the cars as rapidly as possible.

Returning to the 10 car train of Figure 3-1, the number 1 car received only two shocks, the initial acceleration and the shock when it stops in the class track. The other nine cars have also suffered two shocks, one from acceleration and one from deceleration. The eight remaining cars then receive two more shocks when the number 2 car is cut loose, etc. In a train of n cuts, the first cut receives two shocks, cut 2 receives four shocks and car n receives 2n shocks. A cut in a train of n cuts receives an average of:

$$\sum_{i=i}^{n} \frac{2i}{n}$$

or n+1 shocks. The shocks diminish in amplitude as the train becomes shorter.

When a car is loaded with color television tubes several hard impacts can result in a large damage claim against the railroad.

2. Time required for classification

As explained in Chapter II, flat switching consists of the removal of the cars, kicking, and trimming. An ORI study of the Western Maryland's Knobmount flat yard revealed that the removal of cars was done in groups averaging 17 cars, required 0.40 min./car, and the average kicking distance was only about 13 car-lengths.[9]

At Knobmount the class tracks are separated by a distance of two car lengths. Thus only six class tracks could be switched simultaneously and the track nearest the engine had to be trimmed, that is, shoving of cars previously placed on the track further down the track to make room for additional cars, once for each 13 cars placed upon it. The trimming time was 5.2 min/track.

ORI further calculated that the Knobmount Yard had nearly optimum characteristics for a flat yard. In an optimum yard, the classification time for the Knobmount traffic would be reduced from 1.36 min./car to 1.28 min./car.

C. Limitations Peculiar to Hump Yards

Unlike the flat yard, classification speed is a limitation to be considered in a hump yard because there is no existing way of classifying cars more rapidly. Whenever a queue is created awaiting humping, the speed at which the cars are shoved over the hump is the limiting factor. A queue

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[9] - Rosenstock, Henry M, Donald A. Melnick, Robert R. Hare, Jr., and Emory Cook, "Classification Rates in Flat Switching Yard." Operations Research Inc. Technical Report No. 52, Silver Spring, Md., October 1957,. pp. i-iii.

usually develops when several trains arrive at the yard at about the same time.

1. Humping speed and the pin puller

Humping speed is usually only about two miles per hour. The limiting factor to increased humping speed is the only factor not yet mechanized,the pulling the coupler pin to uncouple the cuts. A man must still jerk a lever connected to the pin. Timing is very critical in this job. It is physically impossible for a man to pull the pin when the couplers are in tension or compression. When the cars are being pushed up the hump the couplers are in compression. As a cut gets halfway over the crest the couplers come into tension and it is at this moment, when the cars are between tension and compression, that the pin must be pulled. In practice the pin puller walks along with the cut as it starts to go over the hump, watching the couplers and applying some force to the lever that actuates the coupler pin. At the right moment he jerks the lever.

How does this limit humping speed? A man can only walk at about 3 mph and apply the required force. Even 3 mph would be a 50% improvement over the common 2 mph humping speed. The difficulty arises when he must pull a pin, then walk back to the next separation, walk forward with it until it separates, walk back again, etc. This may not seem difficult but consider the case where cut n consists of a single 34'car and cut n+1 consists of an 89' car. Cut n will uncouple from n+1 when n is about halfway over the crest, that is, when the front of n+1 is about 17 feet from the crest. Cut n+1 will uncouple from n+2 about 40 feet before the front of n+2 reaches the crest. At 2 mph the cars are moving at 2.93 ft/sec. If it takes the man 1 second to reverse direction at each end of his walk and he should get hold of the lever 2 seconds before it will uncouple he must get to the coupler between n+1 and n+2 and get hold of it when it is 50.86 ft. from the crest. When n uncouples from n+1 he will be about 15 ft. from the crest when he turns around ready to walk back. At this time the coupler of the second cut will be 103.07 ft. from the crest. It will take the coupler 17.8 seconds to reach a point 60.86 ft. from the crest. Thus the man must walk 35.80 ft. in 16.8 seconds or 2.13 ft/sec. or 1.45 mph. Even at the slow speed of 3 mph he has to return at 2.74 mph. At 4 mph he must run back at 4.76 mph.

What happens when the pin puller misses the pin? The hump engine must stop, pull the cars back from the crest, reverse direction and try again. This commonly will take from 2 to 5 min. and is totally unproductive time.

In Europe higher humping speeds are common. However, cars are held together, not by automatic couples but by a chain arrangement. Thus the cuts are unhooked from one another before being shoved up the hump. They can still be shoved along because of the bumpers or shock absorbers that are characteristic of European cars. In North America, when the cars are shoved together the couplers close automatically.

In North America the solution to humping more cars in a given time is to use more than one hump. Often there are two separate humps with two separate classification yards, one for eastbound and one for westbound traffic. Another variation is the dual hump where there are two tracks over the same hump and the classification yard has twice as many tracks.

Neither of these approaches however, solves the basic problem that occurs when a queue develops because the train contains cars for any combination of class tracks. That is, the train cannot be cut in two and shoved over two separate humps at the same time because each half of the train contains cars for the same classifications. This also holds true for two trains containing cars for the same classification. Thus the true limit of classification speed at present hump facilities is the rate at which the pin puller can work. There is no known case where two pin pullers are used, one for every other cut.

2. Catchup

Another problem inherent in hump yards is catchup which results when cut n+1 rolls enough faster than cut n to catch-up with it or to come so close to doing so that there is not enough time between the cuts to reposition the switch. This means that the second cut will be on the wrong class track, i.e., it will have been misclassified. Depending upon whether the misclassified car is close to the hump end of the class track or the assembly end, either of two correcting actions can be taken. Both are expensive.

If the car is closer to the hump the usual procedure is to finish humping the cars the hump is pushing, then to have the hump engine continue down over the hump and dig out any misclassified cars and place them in the correct tracks, instead of going back to begin pushing more cars over the hump. Depending upon how far the misclassified cars are from the hump end of the class tracks this can take anywhere from 5 to 20 minutes per car. During this operation the hump is totally unproductive.

If the misclassified car is at the far end of the class yard a switch engine will usually pull it out from the far end and put it in the correct track. Humping can proceed as usual but the train assembly operation is fouled.

The rollability of a car is impossible to predict with any degree of accuracy, especially if the car goes through <u>curved</u> track. The same car permitted to roll down the same track under conditions as nearly equal as possible will not roll at the same speed.

However, conditions that generally affect rollability are weight, type of bearing, ambient temperature and wind. The heavier a car the better it rolls; roller bearings roll better than solid journals; and all cars roll better in hot weather. Catchup is likely to occur on a cold day with the wind blowing directly toward the hump from the bowl and where cut n is an empty 50-ton hopper car with solid journals destined for the near end of class track x, and cut n+1 is a loaded 125-ton tank car with roller bearings destined for the far end of the class track next to x.

The cars will not be separated until the last turnout. The distance between the group retarder and the last turnout is called the switching distance and frequently is anywhere from 300 to 600 feet. Furthermore, the tank car will have reduced the distance between it and the hopper while the cars were rolling from the crest to the master retarder. There the master retarder slowed the faster car. Then from the master retarder to the group retarder the tank car will have further reduced the distance.

The distance from hump to clearance is frequently from 900 to 1500 feet. Why is the crest to clearance distance so long? This is a very complex subject with volumes written on the proper design. Briefly the reasons are as follows: Usually there are 30 to 60 class tracks making the yard 390 to 780 feet wide and the curves to obtain this width cannot be sharp. The less curvature, the better the rollability can be predicted and thus the more accurately the retarders can work, but the greater the distance to clearance. The retarders have to be on straight track and are commonly 39 feet to 180 feet long. There are only four ways to shorten the crest to clearance distance. 1. Have fewer class tracks. 2. Develop economical curved retarders. 3. Use turnouts that require shorter average distances to complete the diverging movement. 4. Have a retarder on every class track.

The ordinary turnout (technically known as the split switch turnout) is most commonly used in yards. For a diagram of the parts of a turnout refer to Figure 3-3.

To form three tracks, two turnouts are required. They could be placed as in Figure 3-4. To shorten the distance to clearance a 3-way turnout can be used. Two types of 3-way turnouts are shown in Figure 3-5.

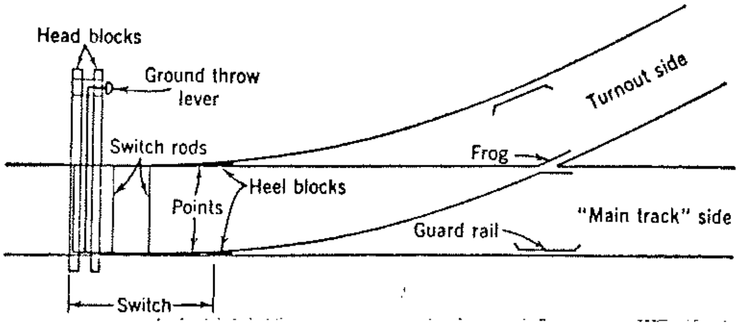


Figure 3-3 Schematic of a Split Switch Turnout

Source: Hay p. 427

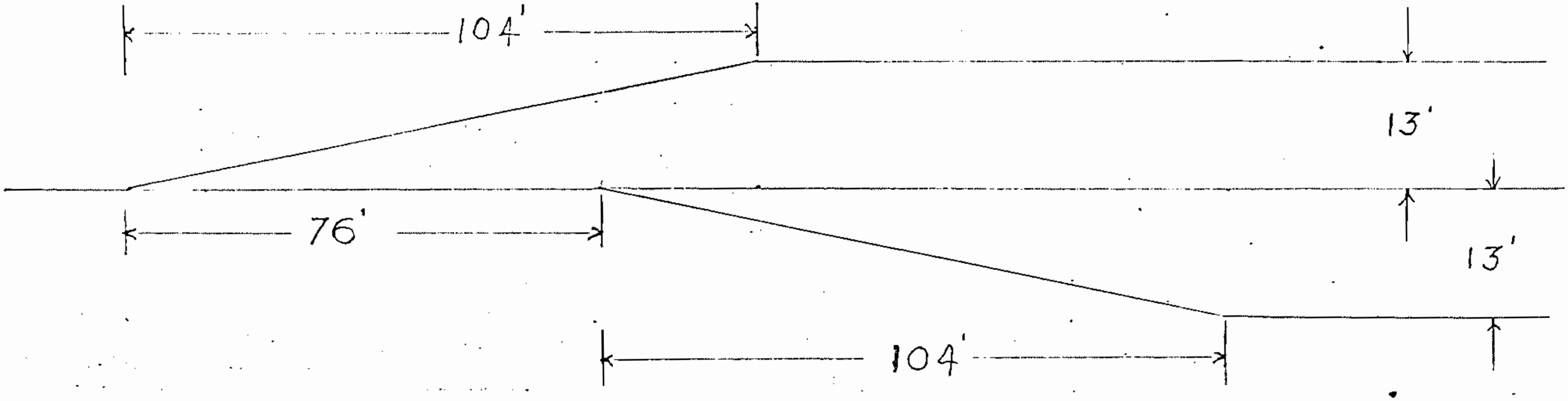


Figure 3-4 Distances Required to Form Tracks with #8 Turnouts

Source: Adapted from Webb, W. L., Webb's Engineering Tables, New York, John Wiley and Sons, 1932, p. 216

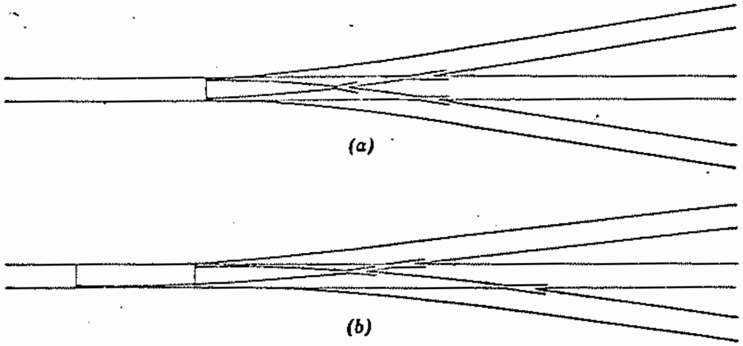


Figure 3-5 Three Way Turnouts

Source: Hay, p. 444

Hay has the following comments.

"The example illustrated in Figure (3-5a) has some limited use in the yards of Europe, where the type of the yard layout is definitely related to this design of switch. As can be seen, three frogs and two sets of points are required, with one set of points acting as stock rails for the other set. Two throw rods and stands are also required. This layout is structurally weak, complicated to install and difficult to maintain. A much simpler and structurally sound three-way or lap turnout is being used by United States railroads as seen in Figure (3-5b). Here the switches are separated with the points bearing against conventional stock rails instead of other switch points."[10]

Note that the lap turnout is considerably longer from first point to last frog than the European 3-way turnout. The yard lap turnout shown in Figure 3-6 has a length from point of switch to heel of frog of 98.3 feet.

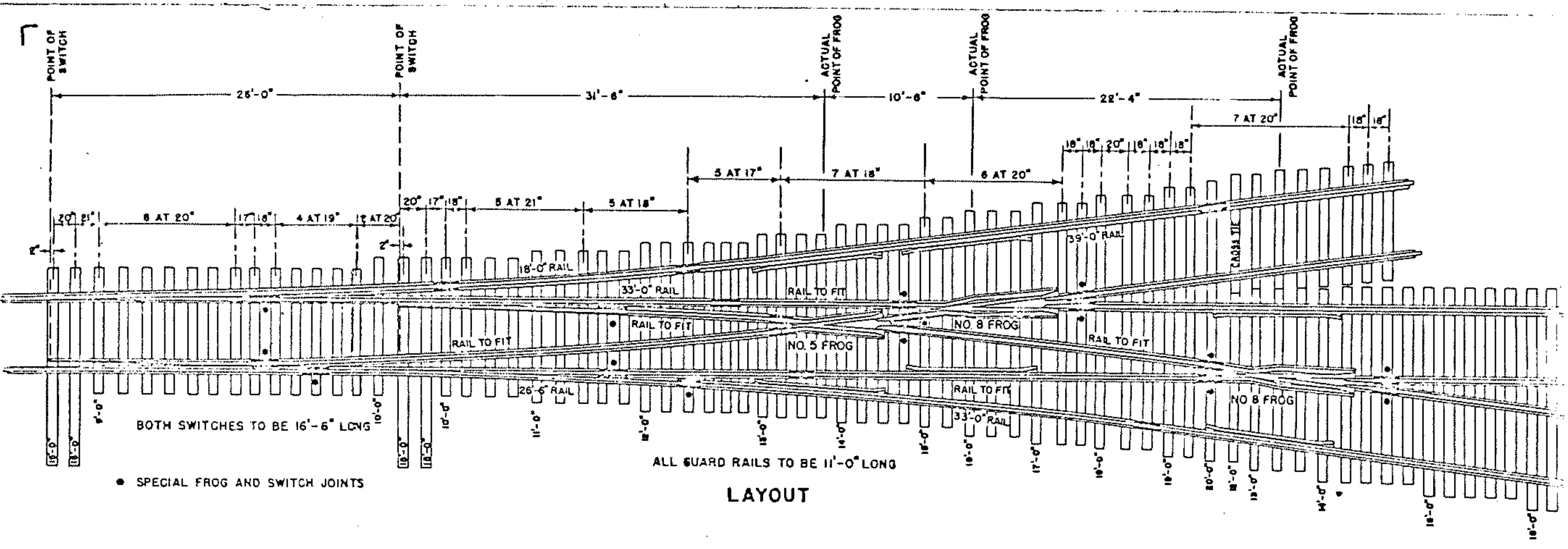
It is surprising that more lap turnouts have not been used in yard design. The main reasons seem to be that they require the extra frog and that only relatively recently have railway engineers become concerned with shortening the switching distance.

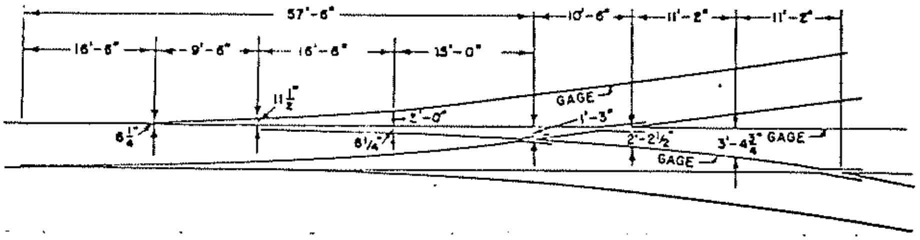
The final type of turnout is the stub switch. Hays comments that, "Stub switches, commonly used in earlier day, are now obsolete. A portion of the main-line tracks was made flexible and free to shift in response to lever movement to either route desired. The stub switch is structurally weak. Many derailments occurred from failure of the switch and lead runs to align properly. In summer, rail expansion was likely to cause binding between the switch and lead rails. In the winter, the gap became too wide."[11]

It should be noted, however, that now rails can be anchored in such a way as to eliminate expansion problems as evidenced by the use of welded rail with only one expansion joint every quarter mile. Also, modern positioning machinery can insure perfect alignment. On the Irish Railways

[10] - Hay, p. 444

[11] - <u>Ibid</u>. p. 427-8





TURNOUT-TIES			
73 PCS.			5055.75 B.M.
13 PCS.	7"X5"-9'-0"	11 PCS	7"X9"-15'-0"
5 PCS	7"X9"-10'-0"	7 PCS	7"X9"-16'-0"
5 PCS.	7"X9"-11'-0"	3 PCS	7"X9"-17'-0"
7 PCS.	7"X9"-12'-0"	3 PCS.	7"X9"-18'-0"
7 PCS.	7"X9"-13'-0	2 PCS.	7"X9"-19'-0"
9 PCS.	7"X9"-14'-0"	1 PCS.	7"X9"-20'-0"

Figure 3-6 Number 8 Lap Turnout

Source: Cheseapeake and Ohio Railway, Baltimore and Ohio Railroad stub switches are used at the present time.

For a three-way turnout, stub switches are as short as the European three-way turnout of Figure 3-5a, but without the structural weaknesses mentioned.

3. Train makeup

Once the cars have been successively classified, another bottleneck remains in the pulling of the blocks from the class tracks and putting them together into trains. Surprisingly, this is frequently the true bottleneck in the operation. To get an idea of the time involved in the assembly process assume that the Chicagoan of Chapter I is leaving Cumberland with 7 blocks. Each block is on a separate class track and the total number of cars is 86. Using the formula given earlier in this chapter the assembly processing time is 86(0.5) + 7(8.0) + 12 = 114 minutes or almost 2 hours! To classify the 86 cars with a humping speed of only 1.65 mph used in the model the Classification Processing time = A times number of cars + B, where A = 0.3 min. B = 15.0 min.[12] In the example CPT = (86)(0.3) + 15 = 40.8 min. Thus in this instance it takes almost three times as long to assemble the train as to classify it.

Note that the time consuming part of making up the train is pulling the tracks, i.e., the doubling noted in Chapter II. In the Herringbone and two-stage yards there may be little or no doubling because several classifications end up on the same track.

[12] - Nippert, p. 176

The final operating limitation to be discussed that is inherent in hump yards is the number of different classifications that can be made simultaneously. If there are 40 class tracks 40 classifications can be made at one time. In practice, fewer are made because one track will be for bad order cars, another for no bills, etc. It is often desirable to make more classifications. For this, several classifications are put into one track, when all the other cars have been classified, this track is brought back to the hump and sorted into those tracks which have enough room left at the hump end. These cars must next be assembled from the hump end and no humping can be done while this assembly is taking place.

Note that rehumping is not as efficient as the two stage yard because two trains cannot be assembled at one time, and only two classifications result for each class track.

The European railroads, because number of cars humped in a given time is higher, use geometric progressions and triangular series, humping the cars over and over. Furthermore, it is not necessary to clear the whole yard. Instead, for the first rehumping, they rehump only the first class track, for the second rehumping only the second track, etc.

For a geometric progression the number of tracks is given by n and the maximum number of classifications by x in the expression:

$$x \leqslant 2^n - 1$$

One can choose either x or n and solve for the other unknown. Thus if x = 14, then n = 4. And if n = 4, x can have a maximum value of 15.

For a triangular series $x_n \leqslant n + x_n - 1$ where n = 1,2,. . and $x_o = 0$.

While this formula will generate the series it is not particularly useful. A better method is represented in Figure 3-7.

Track	A	B	C	D	E	F. . .
	1					
	-	2				
	3	-	4			
Classification	5	6	-	7		
	8	9	10	-	11	
Identifications	12	13	14	15	-	16
	17	18	19	20	21	- ...
	.	.	.	.	.	
	.	.	.	.	.	
	.	.	.	.	.	

Figure 3-7 Triangular Series

In a triangular series four tracks will handle a maximum of 10 classifications, 5 tracks, 15 classifications, 6 tracks, 21 classifications, etc.

Incidentally, the classifications given on the tracks of Figure 3-7 are the way cars would be sorted for the first stage. Track A alone would next be rehumped in tracks A B C D E F ...[13]

4. Other inadequacies of hump yards

The other undesirable aspect of hump yards is the additional investment. While this is more than balanced by the lower operating costs, it would be desirable to have both low initial cost and a low operating cost.

Initial costs inherent in hump yards and not present in other yards are the hump, signals to control humping speed, the retarder system and the greater amount of land required for the track layout because of the retarders

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[13] - For a full discussion of these methods of sorting the reader is referred to the Netherland Railway's J. A. Pentinga's article "Teaching Simultaneous Marshalling" in the May 22, 1959 issue of The Railway Gazette or pp. 762-72 of the September 1960 Bulletin of the International Railway Congress Association.

and the gentle curves required. As noted earlier it is common for a 50-track yard to have up to 1400' clearance distance. Fifty tracks require a minimum of 650' and thus the land required to get from the hump to the yard is approximately 470,000 square feet or nearly eleven acres!

D. Limitations of the Herringbone Yard

No herringbone yard is known to exist in North America. The disadvantages from a theoretical viewpoint appear to be catchup and the great amount of track used as running track. The catchup problem seems to be even more severe than that of the conventional hump yard

E. Limitations of the Classical Two Stage Hump Yard

About the only significant inherent limitation of a classical two stage yard is the initial investment in two humps, two complete sets of retarders and related equipment. Catchup would be a lesser problem because there are fewer class tracks and thus less distance to clearance. However, the two stage yard introduced in this paper will show advantages over existing 2-stage yards with respect to aspects not even considered as problems to a classical two-stage yard at this time.

F. Summary

This chapter has emphasized the many inadequacies and limitations in existing yard designs. The folded two stage yard to be discussed for the rest of this report has been specifically designed to overcome many of these limitations.

PART TWO

THE FOLDED TWO-STAGE CLASSIFICATION YARD

CHAPTER IV

INTRODUCTION TO THE FOLDED TWO-STAGE YARD

> He who rejects change is the architect of
> decay. The only human institution which
> rejects progress is the cemetery.
>
> Wilson

The folded two-stage classification yard is a new concept in yard design. It may never have been proposed before because it would be inoperative using the sorting techniques presently employed by railroads. The yard uses neither an engine nor gravity to separate the cars. It is virtually fully automatic because it is impossible to use people to perform the work. The conventional machines and their associated operators and attendants, e.g. a switch engine with its crew of 3 to 5 men, have been eliminated and replaced by new machines. The complete sorting operation can be performed by two men; more would be superfluous.

The folded two stage yard is so named because it functions as a two stage yard but unlike the conventional two stage yard the second stage looks as if it could be folded back onto the first stage. Because "folded two stage yard" is an unwieldy name it will henceforth be called the twofold yard.

A. Track Layout

A simplified track layout of the essentials of the two fold yard is shown in Figure 4-1. For purposes of preliminary explanation, a yard with only three tracks in each stage is shown. The classification

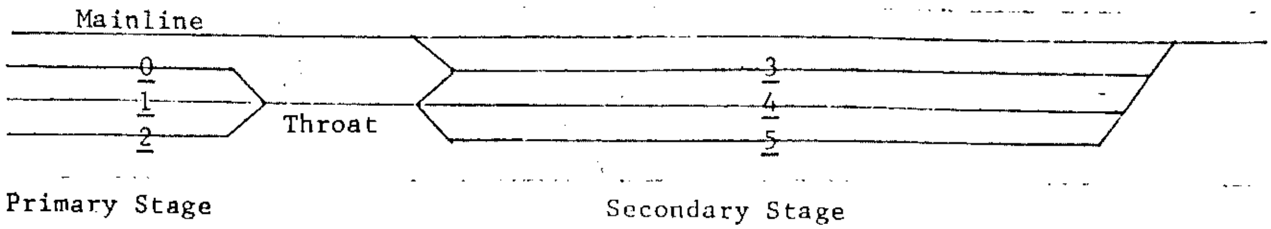

Figure 4-1 Two Fold Yard

tracks are numbered from 0 to 5. As with any two stage yard it is possible to form as many classifications as the product of the number of tracks in both stages. In this case 3 x 3 = 9.

B. Operation

To classify a train the initial step would be to place the train on track 3. From 3 the cars are sorted into tracks 0, 1 and 2 and then resorted back into 3, 4 and 5.

Suppose the train shown in Figure 4-2 is initially on 3, the cars being represented by numbers that identify their required classification. The cars on 3 are initially in random order. The particular sequence of Figure 4-2 was taken from a random number table.

The required ordering is to have all the 1's in the first block of an eastbound train, the 2's in the second block ... and the 9's in the last block.

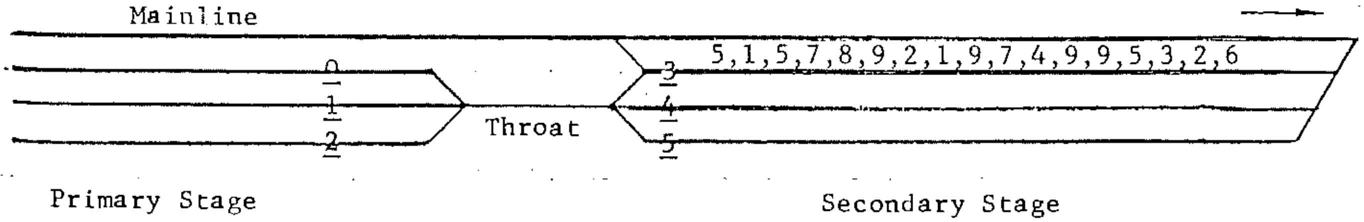

Figure 4-2 Initial Condition of Two Fold Yard

The two fold yard, like all two stage yards, simply uses an arithmetic progression for sorting. In the case where each stage has 3 tracks the first sort will place on one track all cars whose final classification is 3y where y = 1, 2, 3,; all cars whose classification is 3y - 1 will be placed on another track and those of 3y - 2 on the remaining track.

In general if:

x = number of tracks in first stage
y = 1,2,3,. . ., number of tracks in second stage
n = the track number -- assigned sequentially from 0 to x
c_n = the classifications to be sorted into track n of the first stage

then:

$$c_n = xy - n$$

Returning to the sorting example, the cars are pushed from track 3 at a constant speed into the throat where they are uncoupled, accelerated, and allowed to coast into tracks 0, 1 and 2. The details of how this is done are presented in the next chapter.

The yard appears as in Figure 4-3 after the first sorting.

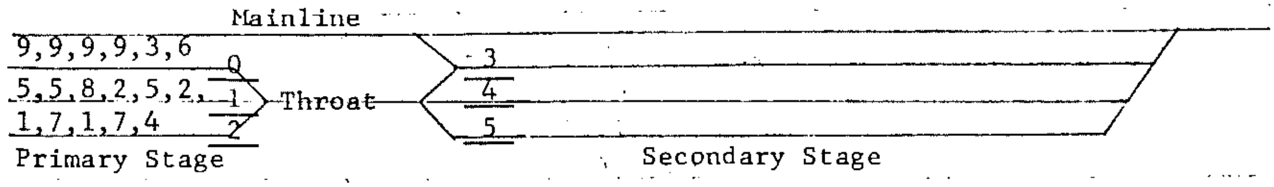

Figure 4-3 Two-Fold Yard After the Primary Stage of Sorting

To perform the second stage of sorting, tracks 0, 1 and 2 in that order are pushed back through the throat into tracks 3, 4 and 5. Figure 4-4 shows the yard after only track 0 has been sorted.

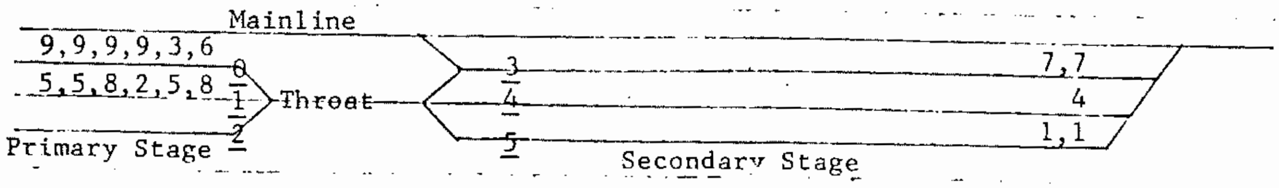

Figure 4-4 Two-fold Yard After First Track of First Stage has been Sorted into the Second Stage

Figure 4-5 illustrates how the yard would appear at the completion of sorting.

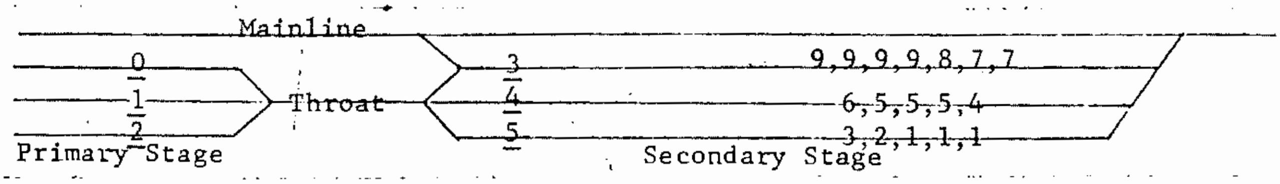

Figure 4-5 Two-fold Yard Upon Completion of Sorting

To make up the train only two doubles are made. The road locomotive backs into track 5, couples to the first car of the block 1, pulls all the cars out, backs them onto track 4 and couples to those cars. At this time, i.e. after the first double the yard would appear as in Figure 4-6.

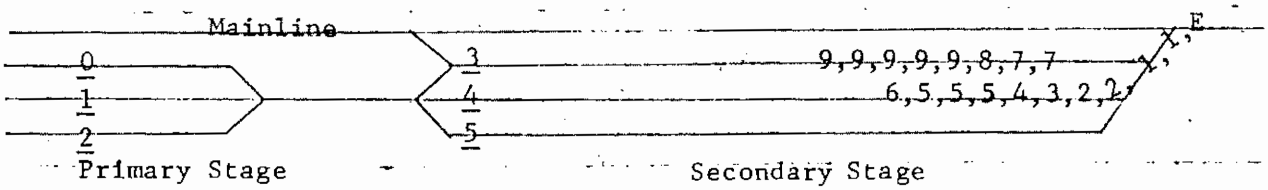

Figure 4-6 Two-fold Yard After First Double

Finally the engine pulls track 4 and backs it to track 3 and the train is ready to depart. This is only a brief description of the operation and the details will be discussed in the next chapter.

C. Problems the Yard Eliminates or Reduces

Remembering that only the roughest overall description has been given thus far, it is still evident that the yard can solve many problems inherent in conventional hump and flat yards.

1. Assembly time

The foremost problem to be eliminated is the bottleneck of train assembly.

Using the time values used in Chapter III the total time to make up the train in the above example would be:

$$\begin{aligned} APT &= 0.5 \text{ min. (number of cars)} + 8.0 \text{ (number of tracks)} + 15 \text{ min.} \\ &= 0.5 \text{ min. } (17) + 8.0 \text{ min. } (3) + 15 \text{ min.} \\ &= 47.5 \text{ min.} \end{aligned}$$

If the same train were made up in the conventional yard where each of the nine blocks would be on a separate track the time would be:

$$\begin{aligned} APT &= 9.5 \text{ min. } (17) + (8.0)(9) + 15 \text{ min.} \\ &= 92.5 \text{ min.} \end{aligned}$$

or almost twice as long.

As trains are now commonly operated with 2 to 10 blocks it is conceivable that a whole train would end up on only one track of the second stage. If each stage had 10 tracks, 10 blocks could be on each track of the second stage at the completion of sorting. Thus there would be no assembly time at all.

2. Land acquisition

Another problem partly solved would be land acquisition. A space only six tracks wide, or only 78 feet, could make up 25 classifications leaving one track width for a running track. As noted in Chapter III, railroad owned property is frequently this wide and as long as desired, even in the middle of populated areas.

3. Turnouts

Fewer turnouts are needed to form the blocks. In the yard illustrated there are 9 turnouts whereas a conventional yard for the same job would require 18 turnouts. Turnouts alone are expensive but in a classification yard they must be capable of being thrown remotely and are sometimes wired to tell when the car has cleared the switch.

4. Catchup

Because the distance from the point of uncoupling to clearance is considerably shortened, even if conventional split turnouts are used, catchup is less likely to occur and fewer cars are misclassified. However, in the two fold yard it is proposed that 3-way stub switches be used to reduce the clearance distance even more.

D. Auxiliary Functions of Yards

While the main function of a classification yard is to classify cars, other functions are also performed as explained in Chapter II. The more common of these auxiliary functions include locomotive servicing and maintenance, caboose servicing, inspecting, repair of defective cars, re-icing, cleaning and weighing. Since locomotives travel under their own power, where the service facilities are located is quite irrelevant as long as the locomotives do not cause interference in moving to and from the servicing facility. All other auxiliary services are performed on cars and if moved, they must be moved by some force. Therefore the servicing facilities should be located to minimize both extra handling and interference. Depending on the yard, the location may vary.

Some functions such as icing, cleaning, and minor repair could be done by mobile self contained units while the cars are in the first stage. This would require track centers wider than the 13 feet used in calculations thus far. The auxiliary functions will be discussed more fully in Chapter V. For the present it may be assumed that they can be done in numerous ways at various places depending on the size and input-output traffic patterns of any particular yard. All that is truly basic to the two fold yard is the general arrangement of the class tracks.

E. Disadvantages

Disadvantages that immediately come to mind are that each car must be sorted twice through the single throat, and the yard may be longer. Once the second stage of sorting has begun it is more difficult to add "late arrivals", and finally the yard is a dynamic yard, i.e. one can't just store cars on a track. However, each of these problems can be overcome or mitigated and the overall result is a yard with lower thruput time, lower operating costs and lower total initial investment.

CHAPTER V

DETAILS OF THE TWO FOLD YARD

This chapter will discuss the features that permit the two fold yard to function. It is well to remember that some of the devices have never been built, since there has been no demand for them. All have been designed to be as simple as possible. Naturally some have not been fully designed in the sense that blueprints are included in this paper. However, all engineers consulted on the various points agree that these devices could be constructed.

Because every yard is unique, the final design of any two fold yard depends on such factors as land availability, proposed capacity, traffic pattern, blocking policy, scheduling, etc. To design a two fold yard, or any yard for that matter, the complete rail network and its associated traffic flow, blocking policy and schedules must be analyzed.

A. Turnouts

The object is to keep the switching distance to a minimum without introducing excessive curvature or restricting speed.

1. Track length

The maximum speed needed must insure that a bad roller will travel to the far end of the longest class track and couple. The class tracks are graded so that a good roller will maintain a constant speed. By statistical sampling techniques it has been established that the maximum difference in the coefficient of rolling friction between a good roller and a bad roller is 6 lbs./ton.

Only one car in 5000 exceeds these tolerances.[1] The track resistance of the switching section can be approximated as equivalent to a one foot hill for all cars. The speed at which a high friction car must enter the switching section is given by:

$$1/2\ S^2 = (32.2\ \text{ft/sec}^2)(1\ \text{ft}) + 0.003L + 9.7\ \text{ft}^2/\text{sec}^2 \qquad (5.1)$$

where: S = speed upon entering switching section
L = class track length

The first term of (5.1) is the resistance of the switching section, the second that of the class track (6 lb./ton is equivalent to a grade of 0.003) and the last term is the kinetic energy corresponding to coupling at 3 mph.[2]

Using equation (5.1) the track-lengths and corresponding required speeds presented in Table 5-1 were computed.

The first constraint is the required class track length. Assume for the rest of this analysis that the maximum length class track is 80 car lengths, or for yards that require longer tracks, there is a way to circumvent the coasting distance of a bad roller with accelerating a good roller. This will be discussed later in this chapter.

2. The three way stub turnout

With the above assumption a number 8 turnout can be used. Now the object is to shorten a number 8 turnout as much as possible. It is suggested that a three way stub turnout be used. This turnout is illustrated in Figure 5-1. Whereas conventional split turnouts

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[1] - Measured friction constants for a sample of 163 cars was supplied in a letter from the Union Switch & Signal Co., Swissvale, Pa.

[2] - Rosenstock, Henry M., Ransom V. Parlin & Emory Cook, "Classification Rates Attainable in Automatic Retarder Yards" Operations Research Inc., Technical Report No. 53, Silver Spring, Md., October 1957, pp. 9-10.

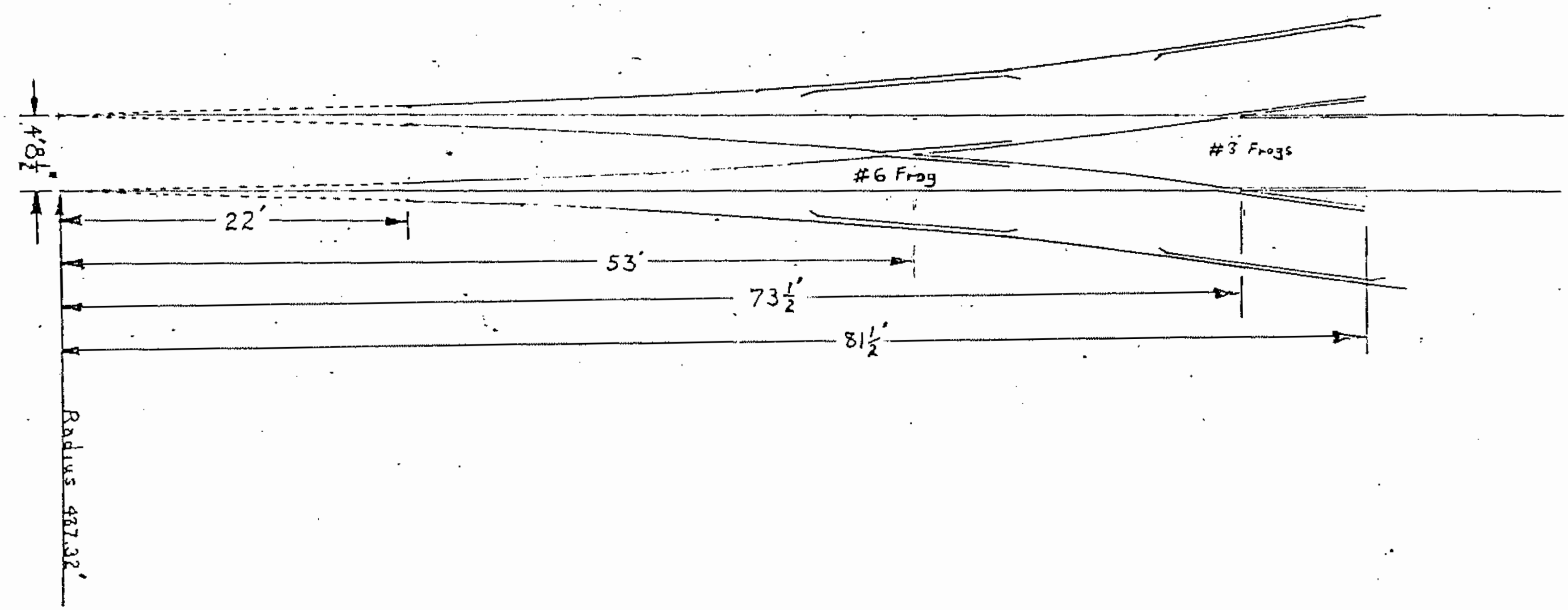

FIGURE 5-1 Number Eight Three-Way Stub Turnout

TABLE 5-1

Track Length	Speed	
Car Lengths	ft/sec	mph
10	11.5	7.9
20	16.1	11.0
30	18.6	12.7
40	20.8	14.2
50	22.8	15.5
60	24.6	16.4
70	26.3	17.9
80	27.9	19.0
90	29.4	20.0
100	30.9	21.1

The maximum speeds through turnouts are given in Table 5-2.[3]

TABLE 5-2

Turnout Number	Maximum speed in mph	
	Lateral turnout	Equilateral turnout
5	12	-
6	14	-
7	16	29
8	19	29
9	21	29
10	21	29
11	27	38
12	28	39
14	28	39
15	37	52
16	38	53
18	38	53
20	38	-

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[3] - Hay, p 443

requires 76' from point to point (Figure 3-4) the stub switch requires only 81.5 feet for two turnouts or an average of only 40.75 feet per turnout.

As noted in Chapter III, stub turnouts were used when railroads were first built in North America, but have fallen into disuse. However now that rails can be securely anchored, binding would not be a problem. Since modern machines can position an object such as a switch point within a few thousandths of an inch in 1 second or less, alignment would no longer be a problem.

The time required to position a turnout must be less than the time between successive cuts minus the time the first cut is on the moveable part of the switch. This is one of the constraints upon the accelerator since the greater the difference between entrance and exit speeds of the accelerator, the greater the time between cuts.

B. The Accelerator

The two fold yard uses a device which in this analysis has been given the name "accelerator" to separate the cars. The cars are pushed through the throat at a constant speed, the pin is pulled and the accelerator simply speeds up the first cut by pushing on the last axle of the last car of the first cut.

1. Variables

The variables affecting the accelerator are: the length of the cuts (l); the distance over which the accelerator works (l_a); the speed which the cars are moving before acceleration (the feed speed, v_o); and the exit speed from the accelerator (v_e).

2. Constraints

The constraints applicable to the accelerator are: the rate at which the cars can be accelerated; and the minimum exit velocity required to prevent catchup.

a. Catchup

The equation expressing the required separation between cars in the switching section, in units of time, is:

$$t_b - \frac{\bar{v}_f - \bar{v}_s \frac{L}{\bar{v}_f}}{\bar{v}_f} - \frac{l_f}{\bar{v}_f} - \text{whichever is greater} \begin{Bmatrix} \dfrac{l_m}{v_{sm}} \\ \\ t_t \end{Bmatrix} \geqslant 0 \qquad (5.2)$$

where: l_f = length of cut n+1,
l_m = length of movable part of last turnout,
L = length of switching section.
t_b = time between rear axle of cut n and rear axle of cut n+1,
t_t = time to position turnout,
v_{sm} = velocity of cut n at end of switching section,
$\bar{v}_f$ = average velocity of cut n + 1,
$\bar{v}_s$ = average velocity of cut n.

The second term of equation (5.2) expresses the amount of closure between cuts n and n+1 in units of time. The third term is the length of cut n+1, also expressed in units of time. the fourth term gives the time for the rear axle of cut n to traverse the movable part of the turnout or the time required for the turnout to position; whichever is greater.

The average velocity of cut n+1 can be expressed as:

$$\bar{v}_f = \frac{v_e + (v_e - S_f)}{2} \quad ; \qquad (5.3)$$

the average velocity of cut n can be represented by:

$$\bar{v}_s = \frac{v_e + (v_e - S_s)}{2} \; ; \qquad (5.4)$$

and the velocity of cut n at the end of the switching section, v_{sm}, is:

$$v_{sm} = v_e - S_s ; \qquad (5.5)$$

where S_f = speed cut n+1 will lose in the switching section,
S_s = speed cut n will lose in the switching section,
v_e = velocity of cuts when leaving the accelerator

The time between cuts before acceleration, t_b, is given by:

$$t_b = \frac{l_f}{v_o} \; , \qquad (5.6)$$

where: v_o = the accelerator feed speed.

Finally S_f and S_s are given by:

$$1/2S_f^2 = g_f \; L \; (32.2 \text{ ft./sec}^2); \qquad (5.7)$$

$$1/2S_s^2 = g_s \; L \; (32.2 \text{ ft./sec}^2); \qquad (5.8)$$

where: g_f = grade equal to amount of rolling resistance by which cut n+1 exceeds the grade of the switching section,

g_s = grade equal to amount of rolling resistance by which cut n exceeds the grade of the switching section.

The conditions of interest are those under which catchup would be most likely to occur. The switching section is graded in such a way that a good roller has zero acceleration. As noted earlier, the maximum rolling resistance of a bad roller exceeds a good roller by 6 lb./ton. This is equal to a grade of 0.003 or 0.3%. Therefore the conditions most favorable for catchup are:

$$g_f = 0.000$$
$$g_s = 0.003$$
$$l_f = 35 \text{ feet}$$

If t_t is assumed to be 1 second and l_m is 22 feet, t_t is greater than l_m/v_{sm} only when v_{sm} is greater than or equal to 15 mph. Therefore in the worst possible situation equation (5.2) reduces to:

$$\frac{35'}{v_o} - \frac{L\sqrt{0.1932L}}{2\,v_e^2} - \frac{35'}{v_e} - \frac{22'}{v_e - \sqrt{0.1932L}} \geqslant 0 \qquad (5.9)$$

Because each car must be sorted twice in a two fold yard, it has been arbitrarily decided that $v_o = 6$ mph. This is twice the humping speed of the fastest yards in existence.

If the two fold yard is to have seven tracks in each stage and the turnouts of Figure 5-1 are used, L = 185 feet and l_m = 22 feet.

Solving equation (5.9) for v_e it is found that v_e must exceed 22.6 ft./sec., or about 15.4 miles per hour.

Since the maximum v_e for a number 8 turnout is 19 miles per hour, it is possible to solve for L. In this case t_t is greater than l_m/v_{sm}. The result is that the maximum switching distance can be only 298 feet. This illustrates how important it is to keep the switching distance to a minimum.

The above calculations for the worst possible case, that is, where the shortest cars, with the first being the worst possible roller, and the second the best possible roller, are not separated until the last possible turnout, show that *if* the accelerator can accelerate every car from 6 miles per hour to 19 miles per hour there will not be any catchup. In the unusual case where a long string of very short cars must be classified, the speed the cars are fed to the accelerator, v_o, can be reduced. Reducing v_o increases the time interval between successive cuts undergoing acceleration, t_b. If the accelerator pushes every car to the same exit velocity the time between the rear axle of the cuts coming out of the accelerator is equal to the time going in.

b. Rate of acceleration

The constraints on the rate of acceleration for the accelerator are that it must accelerate any car from 6 to 19 mph in the time interval between successive cars. Again the worst possible case is accelerating 35' cars and the heaviest cars are about 314,000 pounds.

The design problem is simply a balancing of acceleration against the time to engage the accelerator and the distance over which the cars are to be accelerated, that is:

$$a = \frac{v_e - v_o}{\frac{l_a}{\bar{v}}} \qquad (5.10)$$

with the constraint that:

$$\frac{l_a}{\bar{v}} \leqslant \frac{l_c}{v_o} + t_e \qquad (5.11)$$

where: a = acceleration
l_a = length of accelerator
l_c = length of next cut to be accelerated
t_e = time required for accelerator to engage
$\bar{v}$ = average velocity of car while undergoing acceleration

The relation is graphed in Figure 5-2 for v_o of 4, 6 and 8 mph and v_e = 19 mph.

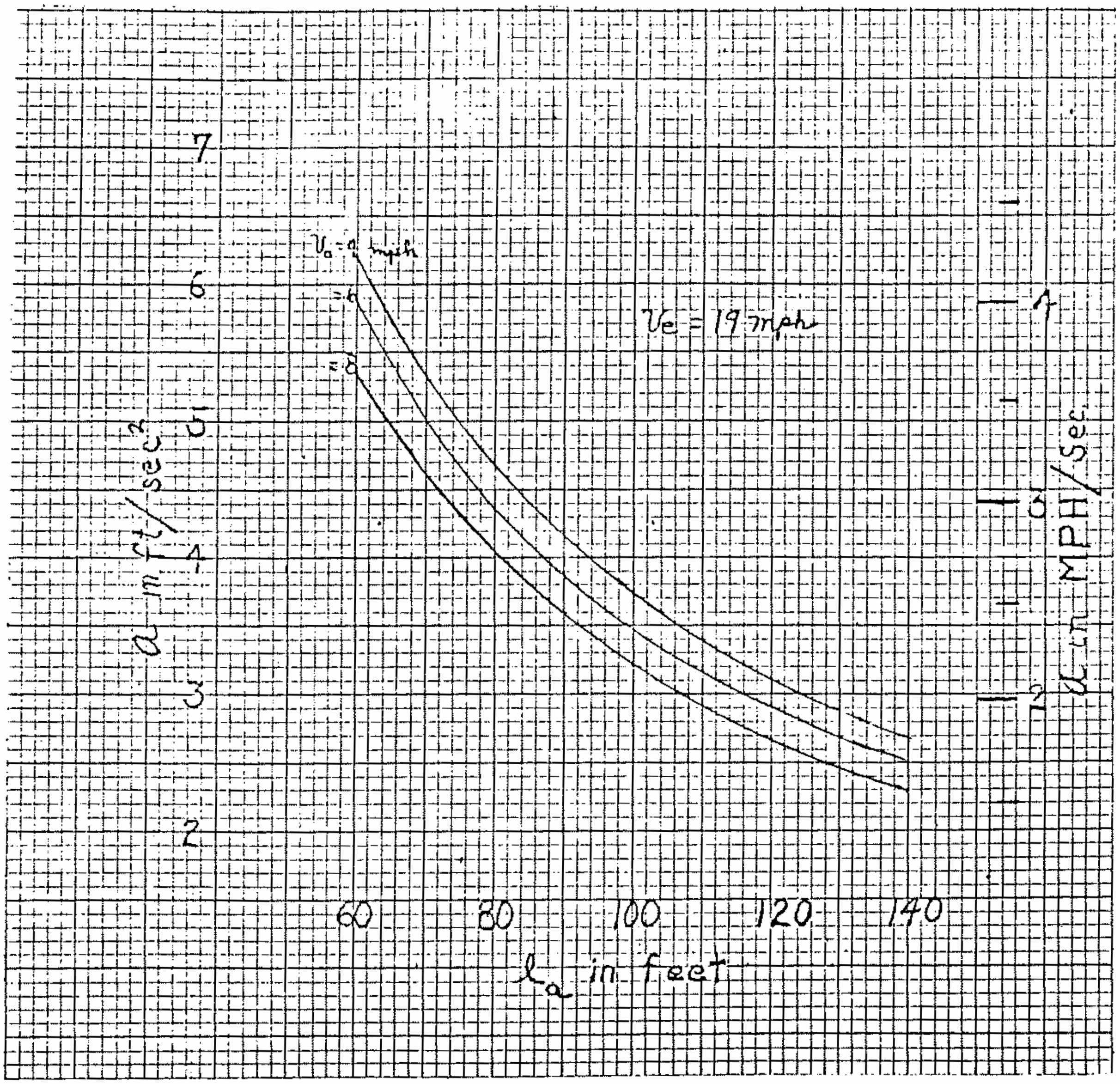

Figure 5-2 Acceleration vs. Length of Accelerator

It is suggested that the accelerator be slightly longer than the longest cars. Since these are about 90 feet, the proposed accelerator is 100 feet long. This will require a rate of 3.5 feet/sec.^{2} or about 2.4 mph/sec.

3. How the accelerator works

Each proposed accelerator is simply a continuous cable driven by an electric motor. Attached to each cable are two devices which can push against the rear axle of a car. These devices, referred to as the axle-pushers, are equally spaced along the cable. While one accelerator is pushing a car with one axle-pusher the other is returning. See the schematic drawing of Figure 5-3.

The accelerators are placed between the rails where the axle-pushers run in a guide to eliminate vertical and lateral motion while pushing. Each face of the axle-pusher, where it contacts the axle, has several rollers to minimize friction, and is slightly concave to circumvent any tendency to lift the cars. The manner in which it pushes against the axle is represented in Figure 5-4. In Figure 5-5 a simplified end view shows how it runs in the guide.

Note that there are two completely independent accelerators between the rails in Figure 5-5. (Only the left is illustrated, the other being identical). Hence two cars may undergo acceleration at the same time. As indicated by constraint equation (5.11), this is required when the cars are very short. For example, if $l_c = 35'$, $v_o = 6$ mph, $l_a = 100$ and $t_e = 0.5$ sec. the accelerator must travel at an average speed of 22.4 ft/sec. or 15.2 mph. This requires an exit speed of 24.4 mph. However, the maximum permissible exit speed is 19 mph. To stay within

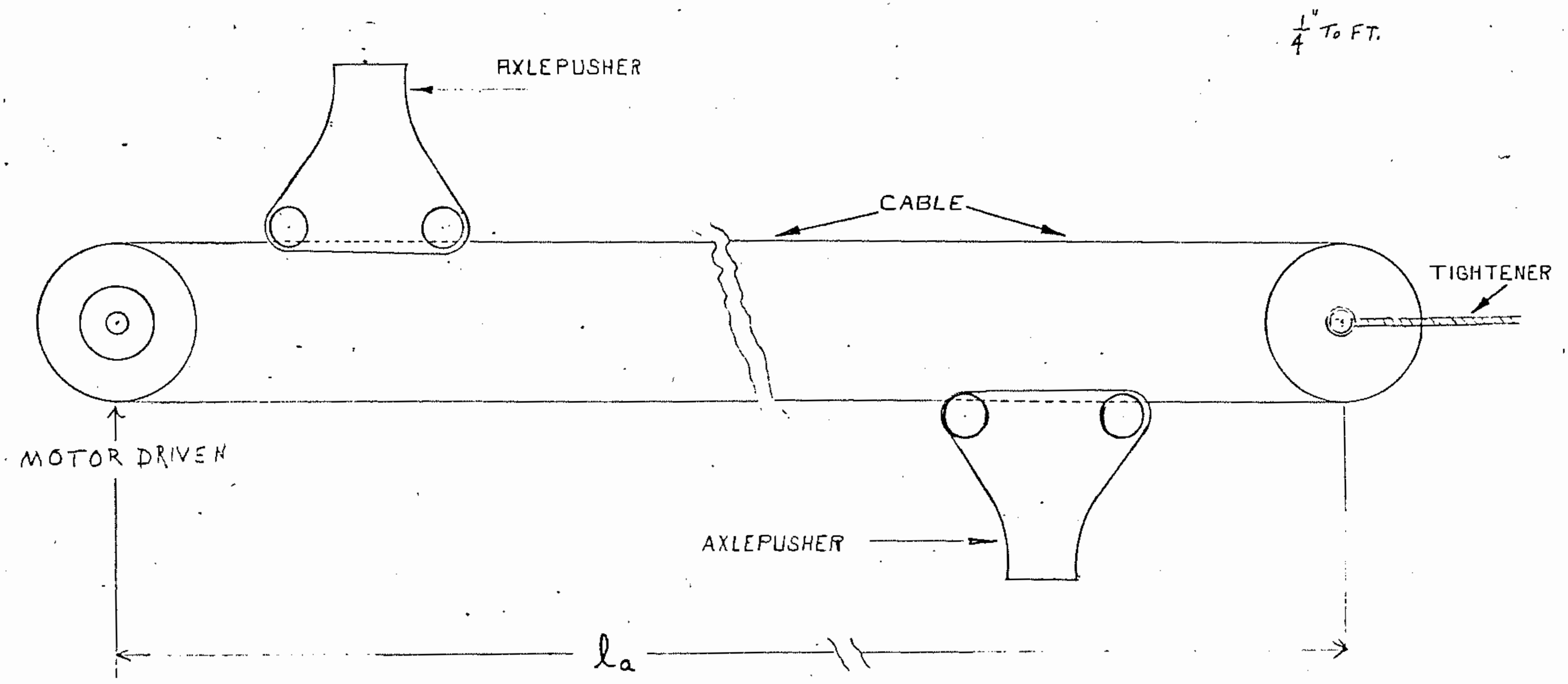

Figure 5-3 Side Schematic of a Single Accelerator

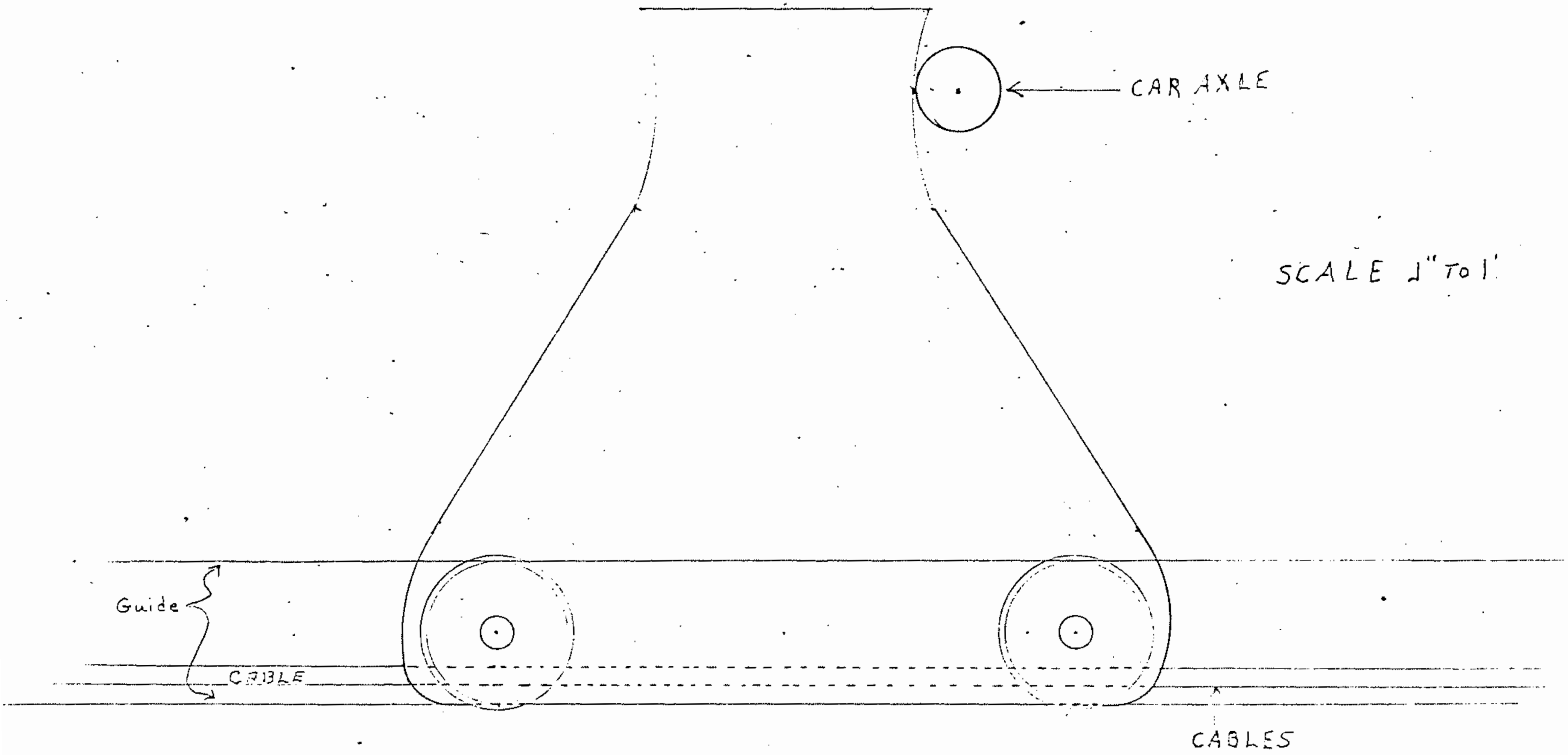

FIGURE 5-4 Side View of Axlepusher Showing Position of Car Axle

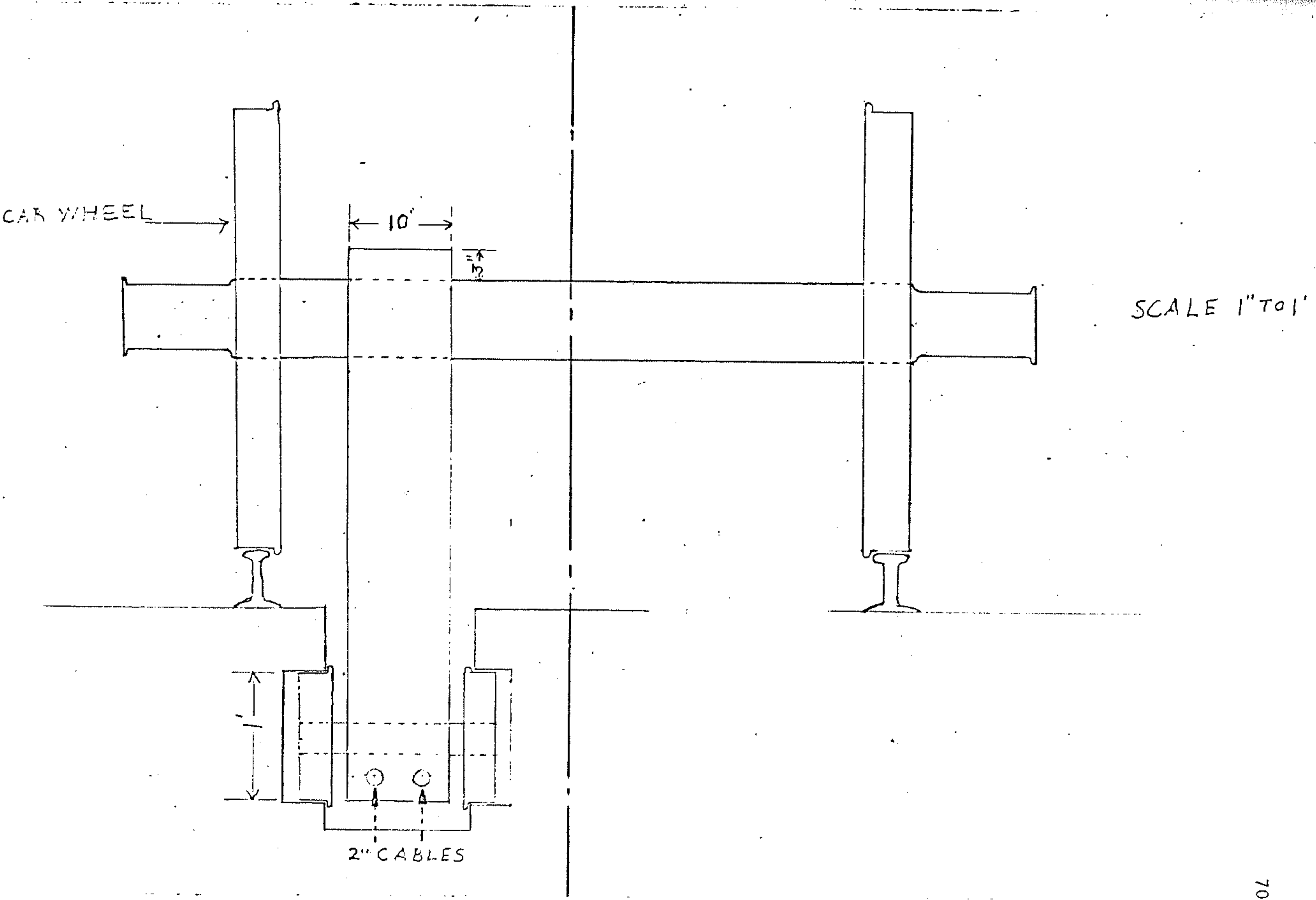

Figure 5-5 End View of Axlepusher Showing Guide

the constraints either the accelerator must be shortened or more accelerators used. As indicated in Figure 5-2 if the accelerator is shortened, then it must perform the same total velocity change in a shorter time i.e. the acceleration is greater. This requires much more force and can result in cargo damage and/or derailment. Thus two accelerators are used in this analysis.

By using two, a spare is available. Since most cars are over 35' and a reduction in v_o can be made for very short cars, one accelerator could be used. This would limit capacity but some sorting is better than no sorting in the event of a failure. In small yards only one accelerator may ever be needed, but this analysis is considering the worst possible conditions such as high volume, short cars, and many classifications.

The accelerator is simple and completely automatic. All components of the yard are tied to the central controls. As a car approaches the end of the accelerator it passes over a flange counter. This counter is one quarter of the circumference of the accelerator end pulley away from the end of the accelerator. As the last flange of the car passes the counter the accelerator moves forward at the same speed as the car. This causes the axle-pusher to come from a horizontal position to a vertical position against the axle. The coupler pin is pulled and the car is accelerated. In the meantime the next car is still moving forward to be pushed by the other accelerator. The accelerators work in either direction. This is necessary since the cars are sorted through the throat in first one and then the other direction.

C. The Feeder

The device that pushes the cars to the throat for acceleration must be capable of precise control. This, as well as the track layout, rules out the use of a conventional locomotive.

Electric motors are easy to control, hence the feeder should be electrically propelled. There are many possible ways to push the cars, the only requirement being that there be a direct connection between the propulsion and movement. This rules out the use of conventional drivers on the rail since they can slip.

One arrangement would be to use conventional rabbits, such as are used to push cars through repair shops, to feed car dumpers, etc. But a rabbit will not go through a turnout. Furthermore, the feeder must be capable of handling a long string of cars. Rabbits only handle up to about 25 cars. Finally, when a rabbit slows, the cars may coast away from it since it merely pushes.

The device proposed to overcome these difficulties is simply an electric cog engine. The electricity for the motor can be provided either externally or internally. Control can be either radio, through the rails, or through an external electric supply.

The feeder needs two cog wheels; when one cog wheel is crossing a rail in a turnout the other is pulling. The cog wheels must be at least fifteen feet apart.

With the cogway in the center of the track the cogwheels should be kept as close to the center of the track as possible when the feeder rounds a curve; therefore, the best place is in the center of the axle.

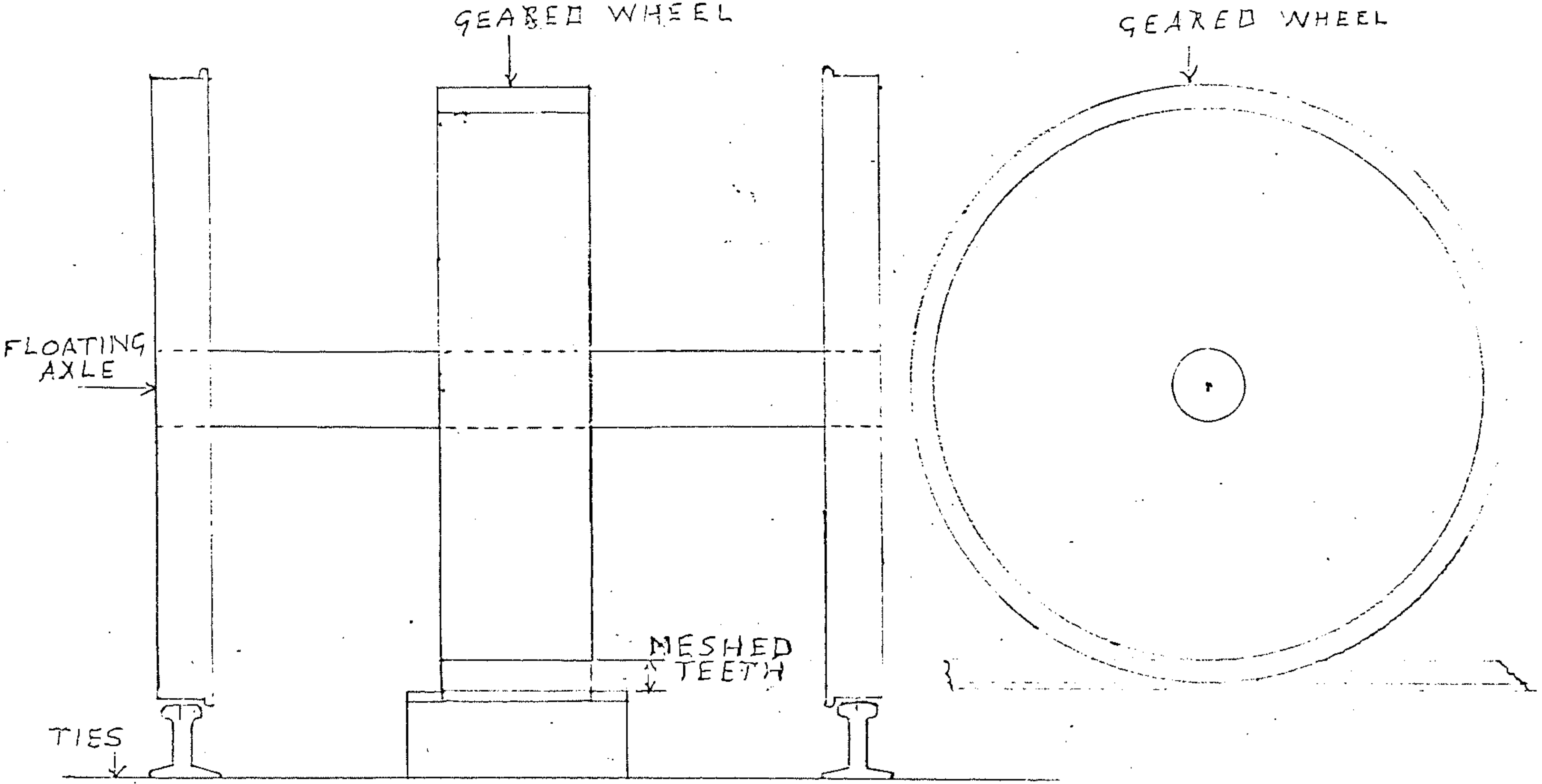

Figure 5-6 Schematic of a Cog Wheel and Cogway of the Fedder

The cogwheels are of smaller diameter than the regular axle wheels because the cogway must be above the railhead to permit the cogwheels to cross the rail. Either the cogwheel or the regular wheels must be free to rotate independently of the axle or a conventional two axle truck must be used. A simple schematic drawing is shown in Figure 5-6.

The feeder is also equipped with a coupler to provide positive control during deceleration.

Since the cog provides positive traction the locomotive need not be extremely heavy. Ordinary hump engines frequently consist of 3 to 5 switcher units that sometimes have extra weights to obtain greater traction.

As the maximum speed need be only 6 to 10 mph the electric motor may be geared very low and a very small motor would be able to shove 100 cars.

One feeder is required for each class track of the first stage if the class tracks are stub ended and one to feed the accelerator from the second stage. The advantage of using more than one feeder in the first stage is to prevent any pause in sorting while the feeder returns to the far end of the stage, negotiates turnouts (which are not necessary if there is a pusher in every track) and pushes the cars of the next track into position. The disadvantage is in having equipment that, though simple and relatively inexpensive, is idle much of the time.

Because the costs cannot be known until the feeders are designed and built it may be more economical to tie the far ends of the first stage together with turnouts and use only one or two feeders. In very small yards it may be best to have only one to work both stages. Like most aspects of yard design this is dependent upon the capacity and demands of the yard.

D. The Pin Puller

One job which cannot be automated is the uncoupling. The location of the lever which pulls the coupler pin is not uniform on all cars and the proposed feed speed is 6 mph. This is too fast for conventional manual uncoupling so the pin puller must be given some mechanical aids.

The first is a cart in which he can ride. It would shelter him from the elements, run on rails and enable him to return quickly after making a cut to be in position for the next cut and then ride rather than walk along with the couplers. The cart controls would be foot operated and the pin puller would sit facing the sides of the cars.

The second aid is a device similar to an impact wrench. It will be called the tripper in this analysis and serves two functions. It applies a torque to the uncoupling lever and is the connection by which the cart is pulled forward by the cars. The tripper is free to move vertically, and toward and away from the car but not horizontally. It has pistol grip hand controls which move it up and down or in and out, grips the coupler lever at the pivot point and applies the impact torque.

The coupler lever that must be actuated is on the front of car n+1 if n is being uncoupled from n+1. If the rear coupler of a cut were opened it might be jarred shut by the impact of coupling to the cars in the class track, then the next car into the class track would not couple.

In this analysis the tripper also grips the lever of car n+1 which does not undergo acceleration and may thus be used to drag along the cart containing man and tripper.

The man will still be very busy. As soon as car n is uncoupled, he releases the grip from n+1 and retracts the tripper with the hand controls, accelerates the cart for return to the next coupler and positions it using the foot controls (one pedal for each direction giving positive speed control so no brakes are needed) then, with the hand controls grips the lever and starts the torque impacts. The car is now being pulled along with the couplers by the tripper. Just as the accelerator starts to push on the axle the couplers slacken and the pin will pull, completing the cycle.

For 35' cars the cycle is only four seconds. However, unlike the hump yard, the uncoupling occurs at almost the same place each time. The variance is due entirely to the different distances from the rear axle to the coupler. This is greatest on long cars but with long cars the cycle is longer, leaving more time for positioning. For a 90' car the cycle time is over 10 seconds.

If a short car follows a long car, the point where the long car uncouples would be about the spot where the pin puller would want to grip the pin to uncouple the short car from the following cut. Hence, he has the time the short car takes to pass a point (4 sec.) plus the time the long car from rear axle to coupler takes to pass the point, plus the fact that he does not have to move. The most difficult case is uncoupling one short car from another short car. In a long series of short cars v_o could be reduced. When v_o = 5 mph, the cycle time is 4-3/4 seconds and when v_o = 4 mph the cycle is 6 seconds.

Remembering that everything is computer controlled, the feeder can be fully co-ordinated to suit the conditions. This is not possible in an ordinary hump yard.

A cart for the pin puller must be located on each side of the throat. When he faces the cars they must be moving to his right since he must pull the pin on the rear car.

E. Grading

The class tracks slope down from the ends of the accelerator with a grade of 0.001. In 100 car lengths this is elevation change of only four and one half feet and is non accelerating for a good roller. The accelerator is level. An exaggerated representation of the grading is shown in Figure 5-7.

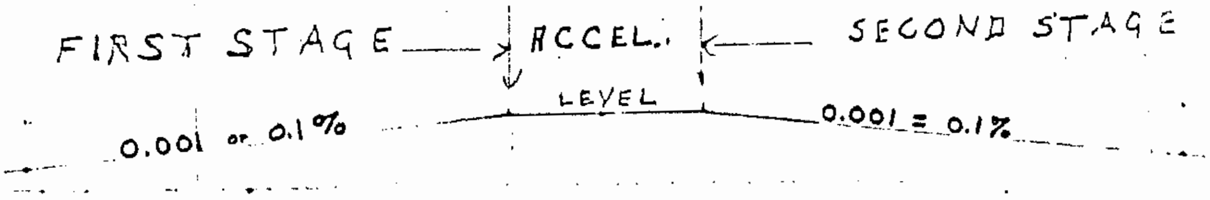

Figure 5-7 Grading of Two-Fold Yard

F. Inert Retarders

In the first stage (stub ended class tracks) no inert retarders are required since the feeders at the ends of the tracks can stop the cars; unless the option of tying the stub ends together to use less feeders has been used; ordinary inert retarders would be used. In the second stage inert retarders are required at the assembly ends of the class tracks.

G. Safe Coupling Speed

The speed a car must enter a class track to insure gentle coupling depends on how far it has to travel down the class track and upon its rollability. Either of two undesirable things may happen. In one case the entrance speed of 19 mph may cause overspeed coupling, and in the other the cars will not go far enough.

1. Excessive speed

The various speeds to prevent overspeed coupling can be obtained in either of two ways. First the exit speed of the accelerator may be varied; second each class track may be equipped with a retarder.

In the first alternative if car n were to go into a class track that is nearly full it would be released from the accelerator at a low speed and if car n+1 were destined for an empty track it would be released at a high velocity. To prevent n+1 from catching up with n the feeder would automatically reduce speed which would increase the time before n+1 began acceleration. The feeder would likewise be slowed if more time were required for the accelerator to position. The result would be a lower average sorting rate. This may be of no consequence in a low capacity yard.

In the case of a high capacity yard the retarder alternative would be more efficient. Since rollability on <u>straight</u> track is primarily a function of the cut weight and a coupling speed of anywhere from two to four miles per hour can be tolerated, the retarder can be of the unsophisticated weight responsive variety. One retarder would be required for each class track.

2. Too slow - class tracks too long

As previously mentioned, the worst rollers will not go further than 80 car lengths along a class track and still have enough momentum to insure coupling unless v_e is greater than 19 miles per hour. To overcome this difficulty should class tracks of over 80 car lengths be required, it is proposed that a system similar to the cable driven mules used by the Swedish State Railways (A.S.E.A.) at

Gavle be employed from a distance of about 70 car lengths from the beginning of the class track to the end.[4]

H. Controls

It is obvious that the two feed yard requires a sophisticated control system. The heart of such a system would be a small computer. For a totally integrated system the only manual input required would be the order of the cars first entering the yard, classification of each, and the final arrangement of the blocks in the second stage. An exception notice would be required noting any car with other than four axles. The computer would run the feeders, the turnouts and the accelerator. One man could feed in the input and watch over and override any part of the operation should an emergency arise. The pin puller can also override the accelerator and feeder controls should he miss a pin.

These two men would be the only employees needed to perform the sorting operation. A hump yard requires a minimum crew of 3 and 7 men crews per hump are sometimes used. The most frequently found crews are of four and five men. The number of clerical and supervisory workers required will remain the same or decrease.

Soon even feeding car input order into the computer by hand will be unnecessary. Automatic car identification is almost operative. A scanner will identify every car as it is fed to the accelerator. The car destination will already be stored in the computer based upon receipt of the advance consist of every train en route to the yard before arrival.

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[4] - Danieli, H., "Controlling Wagon Speed in Marshalling Yards," The Railway Gazette, January 6, 1967, pp. 21-24.

Since the consist discloses the destination, commodity, type of car, etc., that determine a car's classification, the computer can be programmed to classify the car automatically.

The information fed to the computer during the operation is collected from flange counters which can measure velocity and sense presence, from feedback of the various motors, (revolution counters, slip detectors, etc.) and from switch machines. All movement is electrically operated and is thus easy to control precisely.

The computer would keep a complete inventory of the yard, determine every move and check to see that what has happened is what was supposed to happen. It notifies the operator of any discrepancies.

I. Cars Requiring Separate Handling in Present Yards

Government regulations forbid the humping of cars containing explosives. These and any other cars that require special handling in present yards will in all likelihood also require special handling in the two fold yard. That is, they will have to be flat switched by switch engine into a train for departure or out of an incoming train before being automatically sorted.

J. Misclassified Cars

It is inevitable that a car will be misclassified sometime and provision must be made to reclassify it.

The sorting portion of the two fold yard is inaccessible to a conventional switching engine during the sorting process. It is proposed that a trackmobile be used. This is nothing more than a small locomotive that can run either on the ground on rubber tires, or on the rails on flanged steel wheels. It requires only one man to operate and can haul up to five cars. Because it can run on either rails or the ground it would be ideal for reclassifying misclassified cars. It could also be used to move cars in the shop, cleaning and caboose areas, etc. The steel wheel on the steel rail is not the most efficient way to move cars in a yard.

K. Other Yard Functions

Tasks such as inspection, storage, cleaning, re-icing, repairing and weighing of cars, servicing cabooses and locomotives, etc., can be handled in a number of ways depending on the size and traffic pattern of the yard. A yard in location A may need extensive re-icing facilities whereas a yard in location B has only occasional need for those services.

Cars should be inspected before sorting. In a low capacity yard this can be done while the cars are awaiting sorting, since the receiving, second stage and departure tracks are all the same tracks, i.e., the same tracks serve three different functions. In a high capacity yard the cars can be inspected in the same manner as is presently done in large hump yards. That is, the inspectors are stationary and the train moves by the inspectors. They are seated below the tracks so they can look up under the cars, on each side of the car, and in a tower looking down onto the cars. In a hump yard the inspectors are positioned along the hump lead. If any defect is found an override must be actuated on the control system so that the car will be sorted into the classification reserved for bad orders.

Only two conditions are necessary for weighing cars. The track on each side of the scale must be tangent and the cars must move over the scale at six miles per hour or less. If the scale is located on the accelerator lead these conditions will be met.

All bad orders, cars to be cleaned, cars with missing waybills (no bills) etc., will be classified as if they were only one classification. This block should be assigned to the place in the yard from which the cars may most easily be taken to the repair area, the cleaning area, etc.

The two fold yard is a dynamic yard and it cannot be used simply to store cars. A stage is completely cleared after each sort. This should reduce the all too frequent practice of allowing cars to sit in yards for days.

Since some cars must be held for a time for various reasons, a small area which the management can easily police, should be provided.

L. Summary

The two fold yard is dependent on some unique and some well proven devices for successful operation. It has not been the purpose of this chapter to present engineering blueprints of the unique devices, but to enumerate the functions, and the constraints to which they are subject, and to offer suggestions as to the general design. As engineers and designers work out the final details refinements will surely be made; upon knowing the requirements and constraints these people may come forth with better and totally different solutions to the problems. While the suggestions made here may not be optimal, they are workable.

CHAPTER VI

A COMPARISON AND THE FUTURE

A. Comparison of the Two Fold Yard and Existing Yards

The two fold yard has all the advantages of the classical two stage yard without the disadvantages inherent in flat or gravity methods of sorting.

1. Advantages of a two stage yard

The advantages of any two stage yard are: 1) the land occupied need not be so wide - see Figure 6-1; 2) few turnouts are required - see Figure 6-2; 3) as many classifications can be formed simultaneously as the product of the number of class tracks - see Figure 6-3; and most important 4) train assembly time is drastically reduced - Figure 6-4.

2. Disadvantages of the two stage yard

The inherent disadvantage of any two stage yard is that each car must be sorted twice. If the overall capacity of the classical two stage yard is to remain the same as a single stage yard all facilities directly connected with the sorting must be duplicated, i.e. two humps, two retarder systems, two control systems, two hump engines etc., along with their various attendants and operators.

The two fold yard sorts cars over twice as fast as the classical two stage yard. Hence there is no need to sort two cars simultaneously and hence no use for two sets of sorting facilities. If the two fold yard could sort cars continuously at a feed speed of

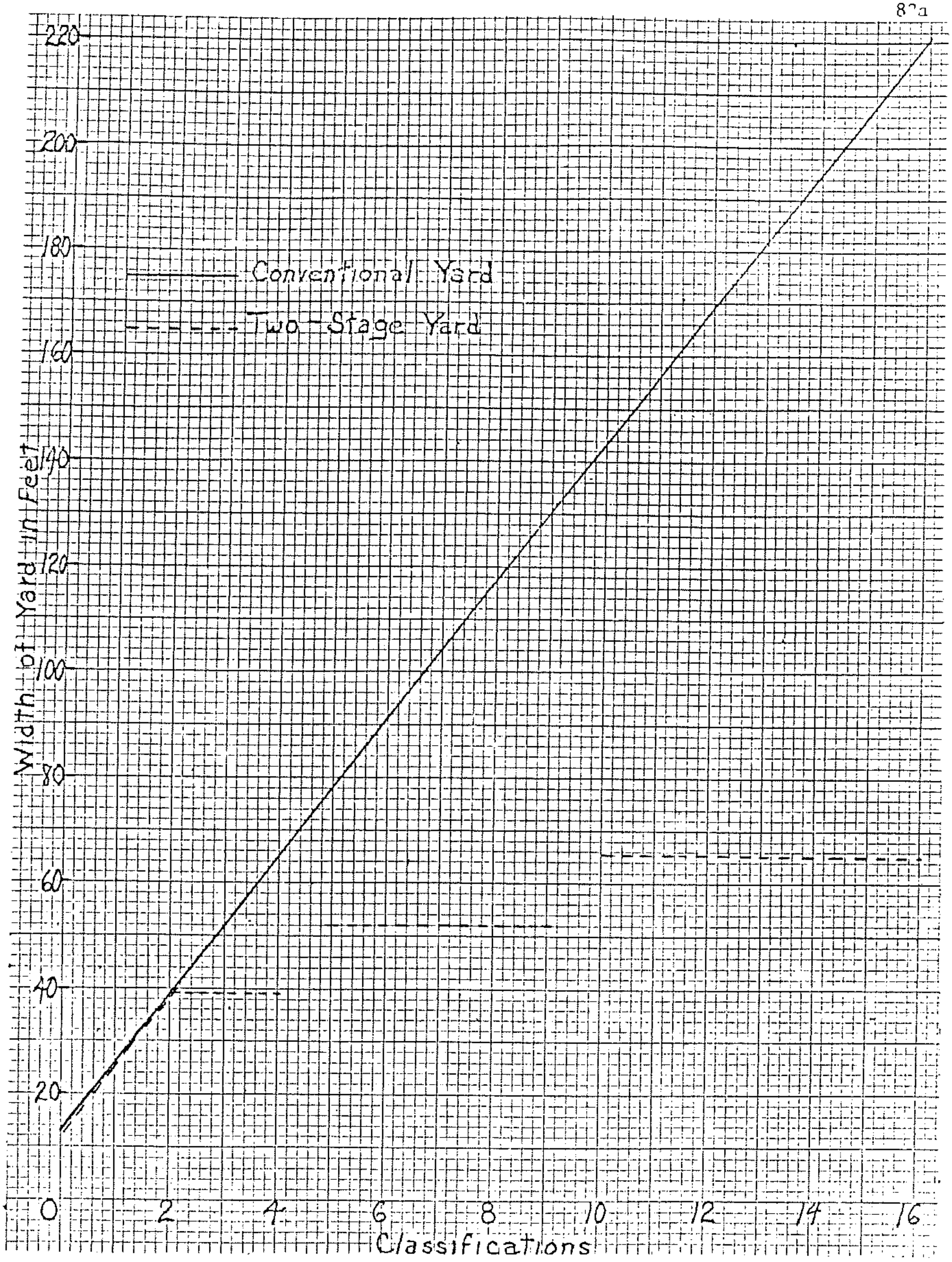

Figure 6-1 Classifications vs. Yard Width

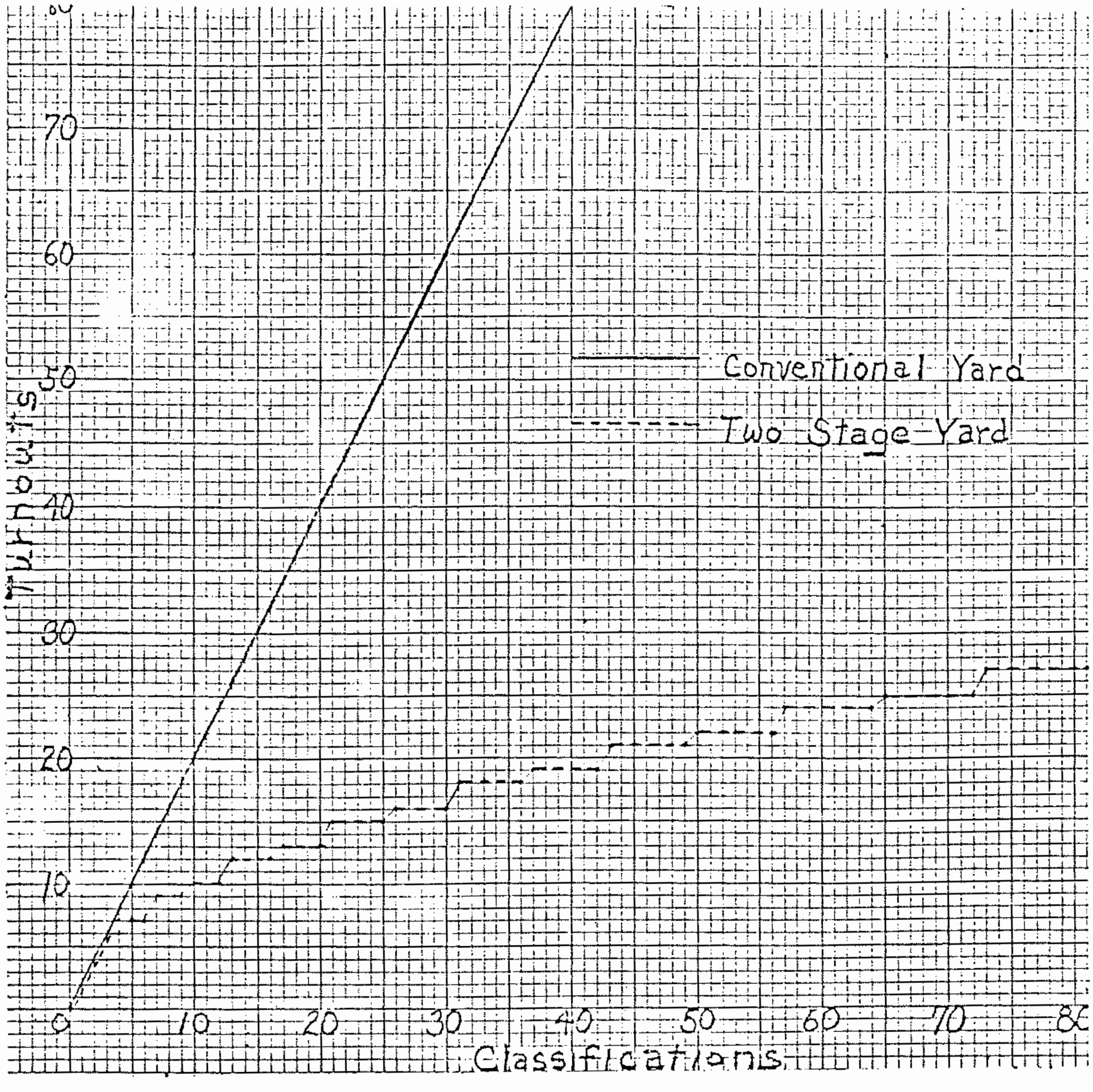

Figure 6-2 Classifications vs. Turnouts

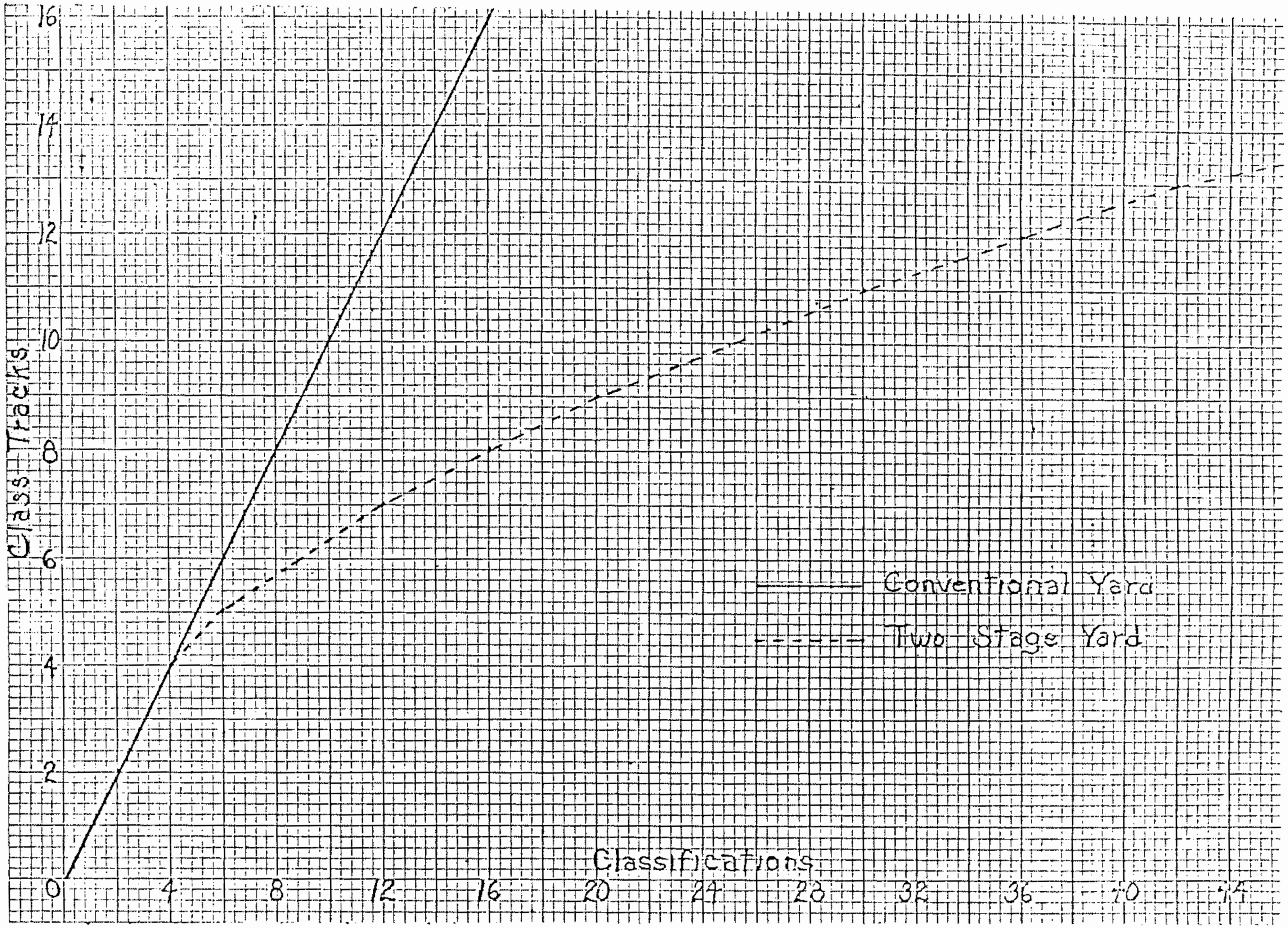

Figure 6-3 Classifications vs. Class Tracks

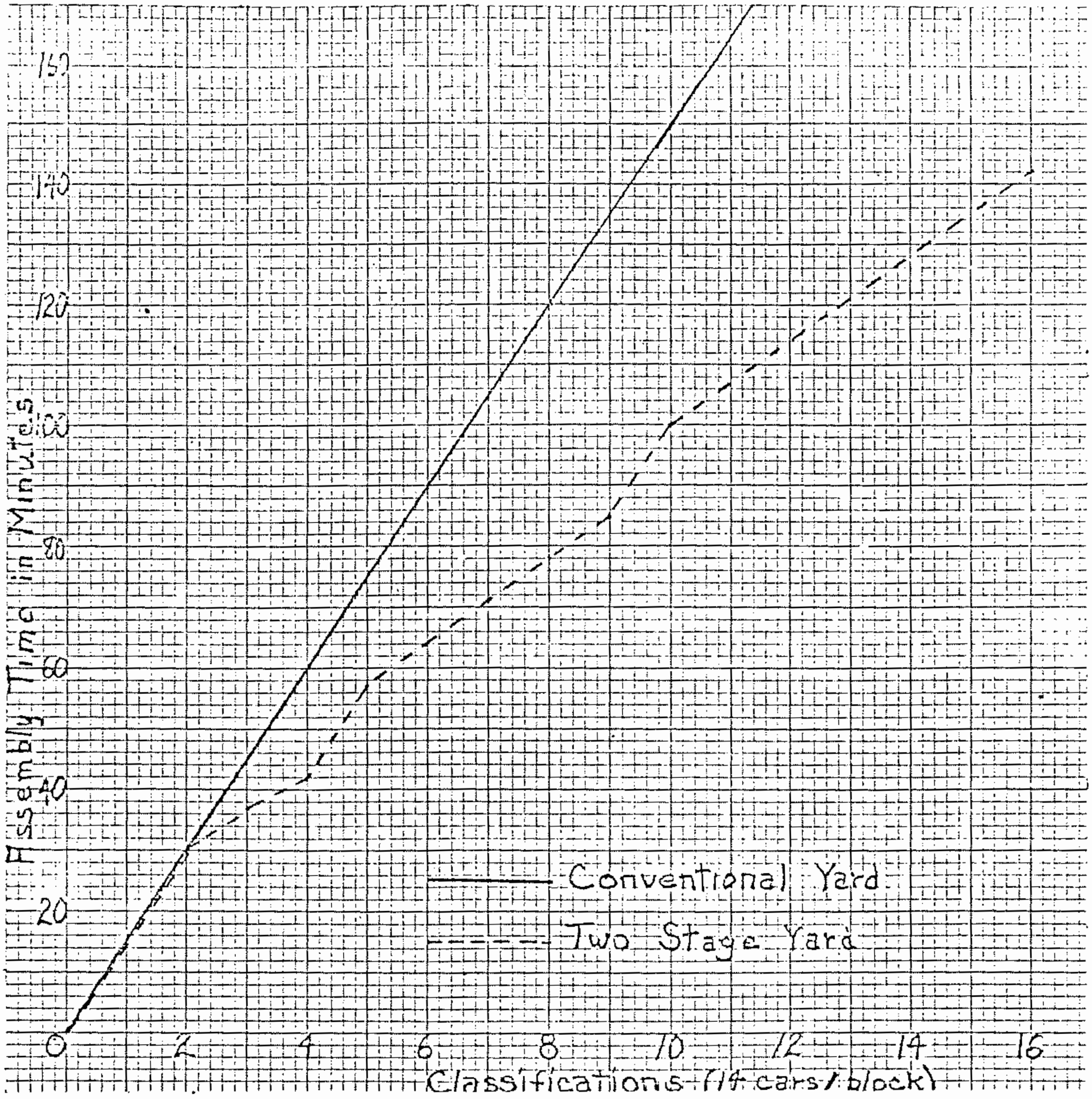

Figure 6-4 Classifications vs. Assembly Time

six miles per hour it could sort over 8000 cars per day, each car sorted twice. No sorting operation can fully utilize all available time but a capacity of 5000 to 6000 cars per day should be attained easily. In contrast, the best single hump facilities approach only 3000 cars per day.

Two stage yards are invariably hump facilities and thus have the inherent disadvantages of humps; the worst of which is catchup. Catchup results from long switching distances and poor speed control. The two fold yard eliminates the hump. The accelerator provides precise exit velocity and the switching distance is shorter because there are fewer turnouts, and they are stub turnouts.

Because there are too many class tracks, a conventional one stage yard using an accelerator, stub turnouts, and a mechanically aided pin-puller still could not obtain the capacity of the two fold yard, nor can a two stage yard using the hardware of one stage sorting be as efficient as a one stage yard. The two, hardware and technique, must be used together. This is the secret of success for the two fold yard.

Since it is impossible to use a conventional locomotive to feed cars to the accelerator, (it could not be controlled precisely enough), the feeders have to be automatic. Therefore the hump engine crews have been eliminated.

In the two fold yard as in a one stage or classical two stage yards, it is possible to assemble and sort trains simultaneously if required.

3. Disadvantages of the two fold yard

Naturally the two fold yard is not "all good". There are some disadvantages, but as will be pointed out they are negated many times over by the advantages.

a. Accelerator

Though the accelerator is simple and rugged its initial cost may be higher than a hump, or even two humps. However, because there is no hump there are no master or group retarders. Furthermore it is possible to classify more cars per unit time with the accelerator than with a hump. As noted in Chapter III, building more humps does not solve the basic problem of not being able to classify cars fast enough.

b. Pinpuller aids

The initial investment for the pinpuller aids will be higher than for the simple board walk used in hump yards. However, only one pinpuller is needed, whereas the two stage yard requires two.

c. Controls

The automatic process control system is more extensive and will have a higher initial cost than for the classical two stage yard. However it permits high operating speeds and eliminates at least one employee (the engineer) and usually two or more that are used in existing computer controlled yards. Since only one control system is used to do the work done by two systems in the classical two stage yard a minimum of four men are eliminated, three in one stage plus the one already noted. A more typical number would be six to ten.

4. Other benefits derived from the two fold yard

A reduced put-thru time for a yard allows not only better utilization of expensive rolling stock (the average freight car cost was $15,000 in 1966) but better service. Because the two fold yard can make more classifications quickly and cheaply, over the road trains may carry more blocks. There can be more set offs and pick ups at low volume mainline points.

Present practice is to serve such points only once a day with a slow train, even though dozens of trains may pass by. More frequent service means shorter average waiting time. Pick up by a multiblocked train can mean that the car goes through to its destination yard without first being taken to a large yard to be sorted.

At many terminals a great number of classifications are needed with few cars in each classification. Typical examples are interchange, transfer runs, and locals. The standard practice is to rehump the cars or resort them in a flat yard or do a lot of car shuffling outside of the yard. The two fold yard can quickly and cheaply reclassify a train of many, many blocks.

As a final example, consider a two fold yard with only seven tracks in each stage. It can arrange a 49 car train in any order in about 105 minutes, using the time values used in chapters III and IV. The 105 minutes consists of 15 minutes of sorting time ((2 x 49 cars/11 cars per min.) + constant) and 90 minutes of assembly time (7 tracks x 8 min. per track + constant).

A conventional hump yard rarely attempts such a feat because it requires about 435 minutes or over seven hours - 20 minutes of sorting time but 415 minutes, almost seven hours, of assembly time! Note that the assembly time is over 4-1/2 times as long as for a two fold yard and takes over 20 times the sorting time in the hump yard!

At present such a task would probably be done in a flat yard, if done at all, where it could be done in 300 minutes or five hours, providing the crew used an arithmetic progression. This is still almost three times that of the two fold yard.

B. Where to go from here

To completely design a yard is a long tedious process involving the skills of a myriad of people. This analysis makes no attempt to design a complete yard but has attempted to point out the advantages of this new approach to an old problem.

The logical next step would be to design a two fold yard for a particular classification task at a specific location. Deciding on the specific job to be done by a yard is extremely difficult in itself. Because the two fold yard is so flexible and can do so much more than a conventional yard design is even more difficult. A complete network analysis would be needed in almost all cases to do a proper job. Railroads are just now undertaking this project.

In the meantime it will be necessary to fully design the accelerator, feeder, and pinpuller aids. It is entirely conceivable that different and better ways to perform these functions can be developed by those proficient at such tasks. The purpose of this analysis has been to state the mathematical relationships describing the operation and the constraints to which the system is subject. Rough designs have been included to show that workable devices meeting the conditions are not difficult to conceive.

Unless, or until, the automatic railroad with the self propelled freight cars envisioned in the beginning of this analysis becomes a reality it will be necessary to have classification yards. One of the reasons the self propelled cars could become economically justified is found in the enormous cost of present terminal operations. The magnitude and reasons for these high costs have been analyzed. The two fold yard while not eliminating these costs can reduce them drastically. Lower terminal costs coupled with the inherent economies of moving cars in trains between terminals will be a very difficult economic combination to beat.

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