A STUDY OF BALLAST AND BALLASTING

Thesis for the Degree of B. S.

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A Study
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Ballast and Ballasting

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by

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Table of Contents

List of Figures

Preface

It is the primary purpose of this article to acquaint those who have not been exposed to the fascination of "working on the railroad", or those with a limited knowledge thereof, with the many and varied operations connected with Ballast and Ballasting.

Included in this article is a section on the various machines which are used in the operations. Where possible the use of these machines is included in the discussion of the particular operation for which the machine was designed.

Emphasis is made on the use of machinery in all operations performed. With the increase in cut-throat competition between the main methods of long distance transportation and the increasingly inferior output in this inflationary-influenced period, there seems to be no other choice than to resort to the steady, plodding, exacting, unquestionably servile instruments of the industrial world.

INTRODUCTION

Ballast is the material placed directly under the ties which, to most observers, serves only in the obvious capacity of supporting the ties. The ballast material, however, can be said to be the heart of the roadbed--- even the heart of the railroad itself---for when ballast ceases its functions, the roadway slows, idles, stops, and becomes as a ghost of its former self.

A railroad line without ballast is like a duck without its "oil-filmed" feathers---it will flounder and struggle and force itself under the destructive elements of water and mud.

The ballast (the name derived from the use of gravel as a weight ballast in old ships) then serves several very important functions which are outlined as follows:[1] (1) to drain water away from the ties; (2) to provide a firm and even bearing for the ties and to distribute the pressure from the ties over the roadbed; (3) to provide against heaving by frost; (4) to supply filling material between the ties to hold them in place and against the ends to hold them in line; and (5) to impede the growth of grass and weeds in and near the track.

All of these functions would be complied with if solid concrete were used instead of ballast, but experience has proved that rigid concrete track structures do not

perform satisfactorily and are of little practical value. Therefore ballast may be said to perform two additional functions:[2] (6) that of providing a resilient and elastic support for the tie and the rails, and (7) that of affording a means for the elimination of capillary action. Ballast cleaning is closely related to these latter two functions and a detailed analyses of them is taken up later in the discussion on the need for ballast cleaning.

CHOICE OF BALLAST

Natural ballast materials vary greatly in quality and the choice must often be determined by availability and expediency under the particular circumstances. Financial consideration may sometimes control the choice or there may be only one suitable material readily available.[3] Most of the "big" roads will desire a superior ballast regardless of cost since they can afford to postpone the "saving" until the future period of decreased maintenance expenses has made up the difference in initial cost.

Among the types of ballast available are crushed stone, slag, and gravel for use on Class "A" railways (see Appendix for Classifications) and cinders, cementing gravel, chert, chats, burned clay, gumbo, and disintegrated granite for use on Class "B" and "C" railways.

The various types of materials are defined in the appendix at the end of the article.

Broken or crushed stone is generally considered the best material available for ballast. It should be made from a hard, tough, and durable stone such as limestone, trap rock, or granite. It should be screened in revolving screens and be free from dirt, dust, rubbish, and small particles. It is largely used because of the excellent drainage it affords and its freedom from dust. Also since it is a manufactured article and the process

is under control, it is practical to make the product conform to specifications.

In the choice of ballast where gravel is available, it should receive careful consideration as it has given excellent results, expecially when properly screened, crushed, and washed. It is usually composed of hard particles worn smooth and round by glacial pressure, being inferior to rock mainly because its rounded pebbles do not bind together so readily as the sharp edged stone. Pit run gravel is much used for ballast and the amount of dust and sand allowed is specified by the American Railway Engineering Association.

Slag in many cases furnishes a ballast nearly as satisfactory as crushed stone and finds extensive use on roads in the vicinity of furnaces and steel mills. The best product is obtained by crushing as in stone ballast. Granulated slag, which is the flux from the furnace broken down, while hot, with a water jet, is not desirable for first-class roads, but a great deal of it is used for ballast on side tracks and for the first lift on new track.

With regard to the first lift and the use of sub-ballast, it has been found that stone ballast when resting directly on the subgrade will break the surface of the road bed and prevent the water, which readily passes through the stone, from draining off, with the result that mud pockets are formed and the subgrade material

works its way up into the ballast, destroying its efficiency. The use of cinders as a sub-ballast seems advantageous, therefore, (especially in wet, spongy locations) since the particles are relatively soft and porous, readily shedding their water content.

Cinders are obtained from the coal burned in locomotives and, when used for sub-ballast, a blanket of not less than twelve inches is usually effective in preventing mud and similar material from working up into the top-ballast.

The use of cinder as ballast is further recommended for such lines as follows: on branch lines with light traffic; on sidings and yard tracks near the point of production; as sub-ballast on new work where embankments are settling; and in locations where there is particular danger of the track heaving from frost.

Chats ballast, obtained from the tailings or waste from the concentration of zinc, lead, and other ores, is occasionally used for ballast with satisfactory results. The material is also known as stamp sand and consists of heavy particles of fairly uniform size, those from zinc being somewhat coarser than those from lead ore. Chats are regarded as in the same classification for ballast section as gravel and cinder.

Burnt clay ballast, while ranking low as ballast, has been used with success in the main tracks of a

number of railways throughout the Missippi Valley and the West.

Clean sand has been used in South America and the West, but it is so light that it drifts readily and has to be covered with a layer of broken stone or some type of bituminous binder.

An example of the availability of the material being the governing factor in the choice of ballast is found in the decision made during the rebuilding of the Moffat Railroad in the Rocky Mountains of northwest Colorado.*

Here in a 20-acre tract near the middle of the line is a formation of solid volcanic cinders, a ballast pit of almost unlimited supply, which has been opened up to supply the road. The ballast material was brought down by a charge of explosive and the blasted cinder rock loaded by a 1¼ yard shovel onto a portable belt conveyor discharging into a jaw crusher. Another belt conveyor loads the crusher run directly into the ballast dump cars. It is claimed by the Moffat engineers that this ballast material is the equal of any in the world.

All things considered, the selection of a good ballast for a Class "A" road is usually narrowed down to a choice between crushed stone and gravel. Due to the constant demand for increased speeds for rolling stock with the consequent greater abuse to the track (said to vary as the square of the speed[5]), most roads are

selecting crushed stone for ballast because it possesses superior qualities which better combat these abuses.

SELECTION OF CROSS-SECTION

The ballast sections illustrated in the drawing included in the pocket in the back cover are those officially adopted by the American Railway Engineering Association, and because of the care used to obtain the consensus of opinion of the best officials of the country, they may be considered as the most authoritative designs obtainable.

As in the case of rail, however, road after road is giving increased attention to its cross ties and ballast section. In the latter regard, they have found that they require not only a better grade of ballast but a deeper section of ballast as well. And in at least a few cases, under the excessive thrusts of high speed passenger and freight traffic, roads have found it necessary to increase the width of their ballast section, as well, in order to hold the track in proper alignment.

The depth of cross-section is based on tests made showing the distribution of pressure throughout the ballast. The A. R. E. A. has noted particularly the experiments made in Germany by Schubert to determine the distribution of force upon the subgrade. His experiments showed that the most favorable distribution of forces is accomplished by the use of broken stone ballast. Later experiments by the Pennsylvania Railroad, in tests more

nearly approaching track conditions, substanstiated Schubert's conclusions.

NEED FOR CLEAN BALLAST

In the introduction, we stated a number of functions of the ballast material. It will now be shown that every one of these functions depend for their efficacy on the property of cleanness of ballast.

The discussion will concern crushed stone principally, because there is very little data available on the cleaning operations on gravel and the other materials. Until the present, cleaning has been confined to crushed stone and slag ballast, but as the benefits of cleaning become more widely know, and as it becomes less feasible to raise the track by introducing a layer of new, clean ballast over the old, the necessity and practibility of cleaning the other types will increase.

The latter two functions, those of resiliency and capillarity will be considered first.

[2]The question arises, "What is resiliency or elasticity as applied to ballast?" In general, a definite ratio exists between the unit stress or load on the material and the amount of deformation or movement of the material, this being termed the modulus of elasticity. The stone suitable for ballast has a minimum value of 5,000,000 in tension and 2,700,000 in shear. When a large stone is broken up, each retains the modulus of elasticity of the large one, but when the mass of small

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pieces is compacted together to form a load-carrying element, the modulus is quite different.

The modulus of the individual pieces is dependent upon the movement of the molecules within it. By the same reasoning the modulus of the mass is dependent upon the movement of each of the small pieces against each other. The amount of the movement depends on the friction. In crushed stone ballast the amount of friction determines the load-carrying capacity of the ballast section and governs the amount of movement of the individual pieces. To prove this, place a weight on a pile of clean dry stone. There is a relatively small movement of the pieces and the pile will return to its original shape when the weight is removed. If the pile is saturated with a lubricant and the weight again placed upon it the movement will be much greater and the chances are, it will not return to its original shape. Therefore, we can state that the modulus of elasticity is dependent on the cleanness and dryness of the individual pieces or on the amount of lubricant on their surfaces. The presence of water and mud is one of the greatest enemies of good ballast and acts very much like the lubricant for drushed stone. Much of this material comes from the lower roadbed section by capillary action and under the proper conditions clean ballast can eliminate or materially reduce this action.[2]

The topic of capillarity is equally important.

Capillary action occurs as the result of adhesion and water tension. If two tubes of the same material, but of different small diameters, are place in water, the water will rise higher in the tube with the smaller diameter. Capillarity can be transmitted in all directions regardless of the force of gravity. Ordinarilly the voids in stone ballast are too large to facillitate capillary action. The soil in the subgrade, however, is usually of such composition that this action will occur.

Again if we were to take a moist lump of clay and continuw patting the top of it the moisture in the clay would tend to be "pumped" to the top of it. This same action takes place in the soil directly below the railroad ballast due to the pumping action of the wave motion in the track structure when successive wheel loads of the moving trains pass over. With the rise of the water is accompanied a rise in the soil so that over a period of time the soil works its way up into the ballast.

The presence of dirt compacts the ballast into a solid "dead" mass which abhors resiliency and the following effects become evident. (a) The track line, surface, and gage become very bad. These conditions are so related that they never occur singly, as one produces the others. This dead mass sometimes produces a condition known as a "centerbound" track, which refers to one where the ballast in the center of the track becomes more solidly

compacted than that under the rails. Consequently, there is more bearing on the middle of the tie than under the ends and the surface reverses from side to side as though the track were supported by a ridge in the center.

With the presence of bad surface, line, and gage the rail will be observed to be deteriorating, the ties will wear (under the tie plated) due to mechanical (impact) action, the tractive effort required to move the tonnage is increased with a consequent increase in the cost of operation, paychological factors of undesirable impressions will be left with the patron due to the rough ride thereby resulting in a consequent loss of revenue.

Furthermore, weeds will thrive luxuriantly for a portion of the year, which will result either in a costly program for ridding the ballast of the weeds, or a loss in revenue due to the further unfavorable impression left with the patrons.[6]

Need we stress further the vast importance of maintenance of clean ballast and a good maintenance program!!!

MACHINERY AND BALLAST WORK

General

The past World War period has probably influenced the increase in the development of all kinds of machinery more than any other period in our history. Speed and efficiency was the constant goal. In the railroad field, also, these aims were sighted. Our industrial machine has weakened and bent the climbing "cost curve" by producing a steady flow of the new labor-saving, speed inducing machanisms.

Among the number of machines connected with ballast work the more noteworthy ones include machine adzers for preparing the incline on the tie to receive the tie plate, pneumatic and electric hammers for tamping or spike driving, rail layers, spike driving motor cars, spike pullers, power jacks for lifting the track, power tampers, and ballast cleaning machinery.[7]

The Meco Power Rail Layer (Figure 1) is an example of a great labor saving device for a simple, yet expensive, operation. Formerly it required about 20 to 30 men to remove and replace a worn rail at the rate of one every half hour. The crew of the Power Rail Layer consists of only four or five men and yet the rails can be replaced at the rate of at least one per minute.

The Jordan Spreader-Ditcher is a good machine for

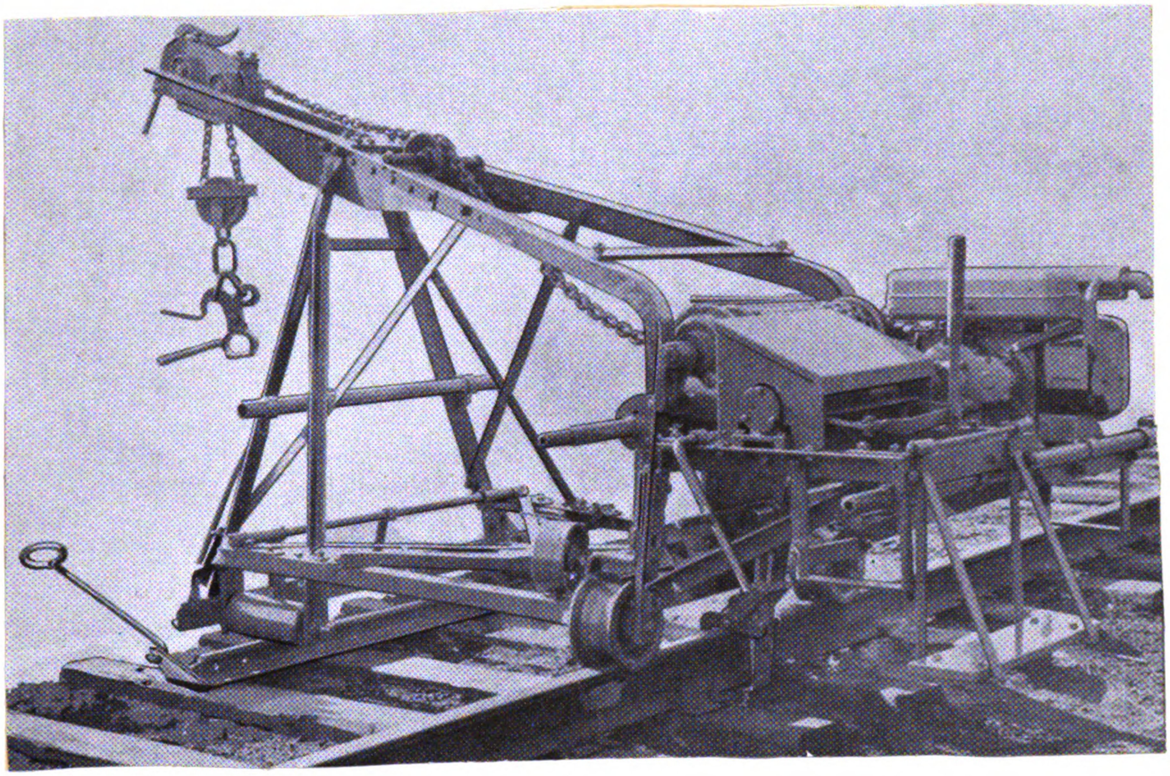

Figure 1.
Meco Power Rail Layer

final dressing of the shoulders of the roadbed and ballast. It is a huge machine which is fitted with huge metal aprons at the side which can be adjusted to conform to predetermined slopes to cut and push the shoulders into place.

The spike driving equipment is high-lighted by a "pile-driver" type machine fitted to a motor car. The driver can be operated pneumatically or electrically. Where there is only one rail in place or where the need for driving spikes is limited, the pneumatic hammers are fitted with tools for the purpose.

A Power Jack is shown in Figure 2. It is used primarily in the surfacing of track and ballast cleaning operations. The latest machines are operated on the hydraulic or screw principle with the weight of the track structure being transmitted to the ballast in the cribs between the ties. The clamps with which the rails are grasped are shown at the side of the machine.

A large number of machines have been used in the past for the purpose of cleaning or rehabilitating ballast. Originally the "machine" consisted merely of a screen placed at the side of the track on which was shovelled the fouled or dirty ballast. Earlier still the ballast was shovelled out and sifted with hand forks and forked back into place. These methods were gradually replaced by a means for the mechanical removal of the ballast and

Figure 2.
A Power Jack

a conveyance to the screen. Revolving and shaking screens were used. About 1925 a very large vacuum type machine was tried unsatisfactorily. Cranes with clamshell buckets were able to remove the sides and inter-track ballast to nearby screens and also replace it.

A revolutionary machine, on which principle all subsequent machines have more or less been based, called the mechanical "Mole" was introduced in 1926. The machine cleans the shoulder ballast by burrowing into the material and conveying the excavated material back over its cutting nose to a screen or container.

The disadvantage of all of these machines is the same in that the crib space between the ties receives very little attention unless dug out by hand. To overcome this drawback various types of cribbing machines were put on the Pullman Standard Company. The framework of this machine is shown in Print No.1 in the back cover. The ballast is driven from the center of the tie outward by means of the pointed "toes" which drive outward with a ramming action as the weighted crosshead is dropped. The track is thus skeletonized quickly and efficiently (Figure 3) for addition of either new ballast or the relaying of the old ballast after screening.

Three of the more important machines for ballast operations are those which are discussed in detail below.

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They are the Power Ballaster Tamping Machine, the Matisa Ballast Cleaning Machine, and the Matisa Automatic Tamping Machine.

The Power Ballast Machine

The New York Central System, lines West of Buffalo, for the past three months has been using a new design power trach ballaster and has been getting excellent results with this machine both as to riding quality and uniformity of work.[6]

One of the machines of this type is shown in the illustration in Figure 4. Its output varies from one-half to three-quarters of a mile of track per day, working two shifts and depending to a great extent on traffic interference.

The operation of this machine is fairly simple. A 65 hp gasoline engine lifts a crosshead member which drops in a pile driving action. Attached to this crosshead are twenty-four tamping bars which are directed along the path into the crib and under the bottom of each side of a tie (see Print No. 2--showing tamping frame and Print No. 3--showing position of shoes around tie). This same engine propels the machine in travelling to and from the location of the work. It is also equipped with a power operated set-off which facillitates removal of the machine from the rails in about five minutes.

Previously it was necessary for about four men to keep

Figure 3
Skelotonized Track
by Power Cribber

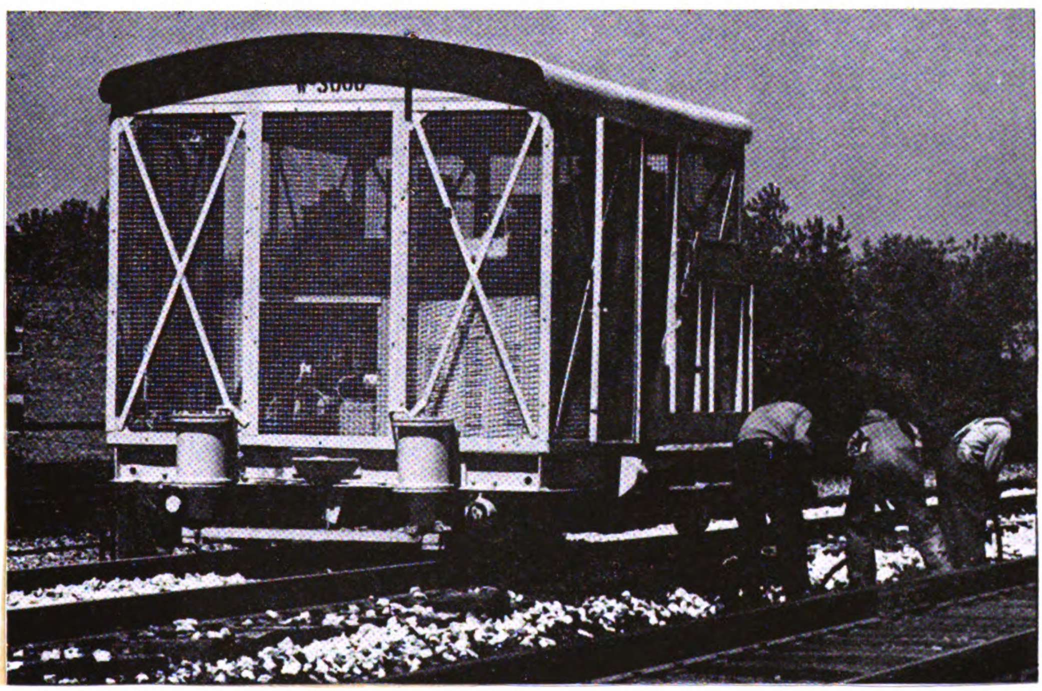

Figure 4
Power Ballast Machine

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feeding fresh ballast under the shoes of the tamper, but an ingenious arrangement for the elimination of the need for these men has been added by the designer of the machine. This consists of the addition of two ballast feed shoes on each side of the machine which are coordinated with the tamping motion such that the ballast is pushed under them just before the weight is dropped. A closeup of these feeder shoes is shown in Print No. 3 in the back cover.

One operator and about sixteen men for raising the track and working the ballast during the tamping operation are required. An additional gang of ten to fifteen men is required for lining and dressing behind the machine.

When the machine is working, the operator manipulates his travel clutch and brake as he locates the position of the crosshead over each tie by looking down through an opening in the floor of the machine. While the brakes hold the machine in position for tamping, he lets the crosshead drop the number of blows required. He then raises the crosshead to a position where the tamping bars just clear the tie end moves on to the next tie. The usual practice is for the foreman in charge of tamping to frequently check so that the correct number of blows is made.

The crosshead member extends the full length of a tie. Linked to it and cross-connected by a common shaft

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operating on each side of a tie are sets of tamping shoes. Each set of shoes has four tamping bars on the outside of each rail and two bars on the inside of each rail, making a total of twenty-four tamping bars. Provision has been made for mounting a lesser or greater number of tamping bars on these shoes, as required.

The crosshead drops by its own weight for the tamping blow. The shoes are guided by a control cam with connecting links and toggle action so that movement of the tamping bars is downward into the crib on each side of the tie and slanting toward each other under the tie. This action can be adjusted in the cab to suit various rail and tie sizes.

Because of the force with which the crosshead drops, aforementioned slanting motion actuated by the cam and toggle can best be visualized as a whip action which increases its force on the slanting stroke. This action and the design features which make it possible account for the establishment of a more uniform and compact tie base.

Except for information gained from the manufacturers, very little information is available on the savings resulting from the machines. The company's claim of 50 per cent savings in cost seems to be no exaggeration based on my experience. Following is the comparative cost of operation with and without the machine.

Pneumatic Hammers		Power Ballaster	
1 Foreman	$10.00	2 Foremen	$20.00
8 Hammer Operators at $1.02	65.28	2 Operators	30.00
4 Laborers To fork ballast and operate jacks	32.64	8 Jack Operators	65.28
1 Flagman	8.16	4 Laborers To handle ballast	32.64
		1 Flagman	8.16
	$116.08		$156.08
Production:	.600 ft.	Production:	2000 ft.
Cost per ft.:	$0.193	Cost per Ft.	$0.078
Cost per mi.	$1019.04	Cost per mi.	$411.84

Even allowing for depreciation, maintenance, and investment expense the saving is considerable.

The Matisa Automatic Ballast Cleaning Machine

Considering the many reasons for maintaining a clean ballast bed and the amount of cleaning necessary to acclomplish all of them, I believe this one machine to be the most efficient unit on the market in achieving its ends.

A line sketch illustrating the features of its operation is shown in Figure 5 on page 24. This machine has been designed to: (a) completely remove the deteriorated ballast from beneath the track and between ties, (b) cleanse it by separating undesirable accumulations from good stone and chippings, (c) elevate waste screenings

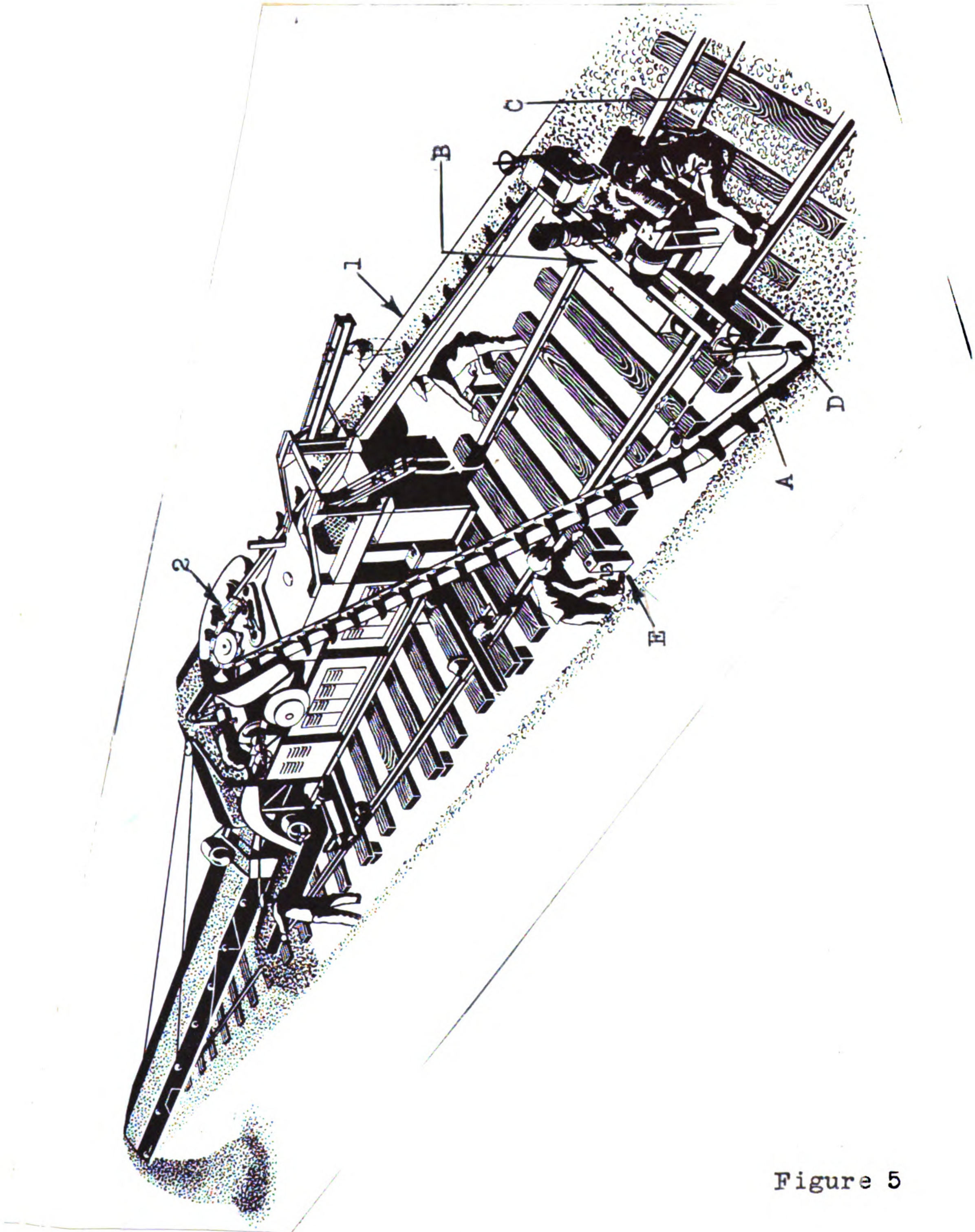

Figure 5

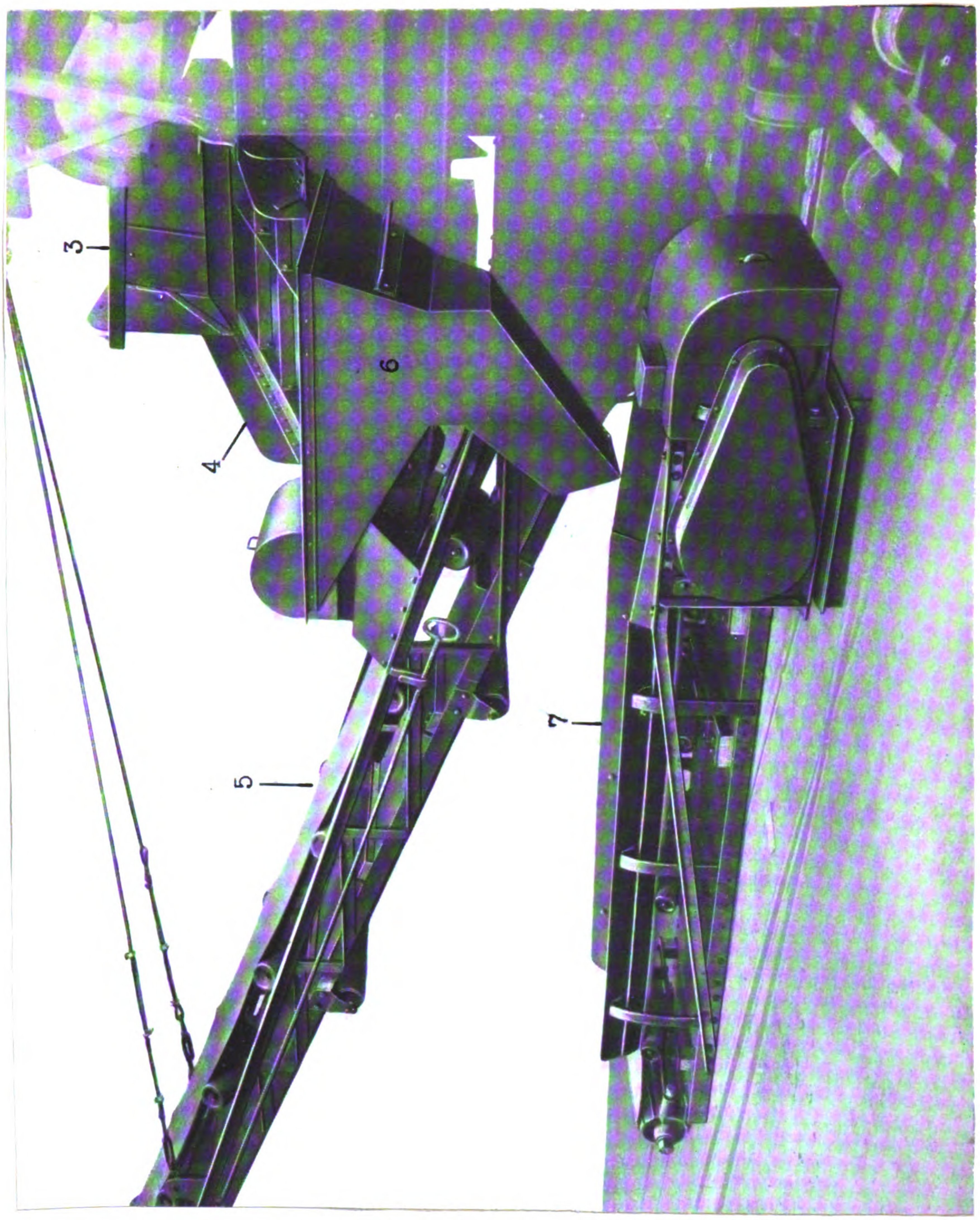

Figure 6

to cars for removal or eject them by the track side, and (d) return the good recovered ballast to the track side or re-lay it on the previously cleaned formation.

The machine is in the form of a rail trolley on two four-wheeled bogeys having electrically insulated bearings which eliminate all risk of short circuits between the running rails. All units form integral parts of the machine with centralised control. The machine is mobile under its own power for travelling from the depot to the site of operations.

There is only one operation that requires any amount of hard labor and that is for the preparation of the machine for operation. One tie must be removed and the tie space further dug out to facillitate the placing of the endless bucket or scraper dhain under the rail at A (Figure 5). The endless chain is opened at any one of a number of links along it and linked together again under the separate bogey on which the operator rides.

The operator bogey (B) is connected to the rail trolley by means of adjustable and detachable tie rods which provide for the progressive advance in action of the entire unit simultaneously. The forward motion is controlled through a variable speed reduction gear to a winding drum to which is attached a steel hawser (C) anchored some distance ahead on the track. The speed of progress can be thus easily and accurately adjusted according to the depth of excavation and hardness of the ballast bed. This bogey supports the horizontal frame member guiding the circulating scraper chain beneath the ties. Two adjusting screws (D) govern the depth of excavation and compensate for the angle of inclination of the formation.

As the machine progresses, blocks are placed under the ties (about every few ties) to support the load on the track until the machine has progressed enough to deposit the cleaned ballast at the rear of the unit. Hand jack (E) aid the workmen in placing and removing these blocks.

The horizontal chain guide is transversely adjustable under the action of an auxiliary electric motor and this device makes it possible to avoid interference with many of the normal fixtures or structures of the permanent way without interrupting or slowing down progress of the machine.

The excavated ballast and dirt pass up the conveyor (1) and drop down at (2) onto a vibrating grid or screen at the rear of the machine. The unit which receives the dirty ballast is illustrated in Figure 6, page 25, and consists of: (3) the hopper box for receiving dirty ballast, (4) the inclined vibrating grid or screener, (5) the pivotted elevator for ejecting the waste screening to the side of the track or into cars, and (6) the subsidiary hopper for receiving the cleansed ballast and delivering to (7) the pivotted conveyor chute adjustable for redistribution of the recovered ballast over the cleared formation or for piling it at the track side.

The only disadvantage of the machine is that, in the absence of a nearby siding, a parking trestle must be previously erected in a suitable position at the side of the track in order to allow scheduled trains to pass. When the track is required to be cleared, the chain and guide frames are disconnected and dropped alongside and under its own power the machine is maneuvered upon the parking trestle. The machine is equipped with a hoisting device for disconnecting and reassembling the chain and guide frame when work is stopped or resumed. The same device is used to raise and support the scraper chain and control bogey when the machine is travelling to and from the site of operation.

The two special advantages which should be noted are the facts that the bed is completely cleared of all ballast so that the cleaning process is complete and the machine is controlled by only one skilled workman thereby realizing a great economy in labor.

The cleaning process leaves the track in poor line and surface, however, and must be followed by resurfacing operations with the power tampers.

The Matisa
Automatic Tamping Machine

This machine is perhaps the latest and the most outstanding of the machines which are used in ballast tamping operations. The machine is used principally, now, in reballasting and resurfacing operations, but due to the special features of vibratory motion coupled with the positive ramming action, these machines will no doubt be a necessity in the operations connected with surfacing both new and old track. The vibration gives assurance that each unit chip will more rapidly seek its final position of rest. It more closely approaches the vibratory effect of the wheels of the trains than any I have studied, thus eliminating to a great extent the need for the "light traffic" period after surfacing operations.

The operation of the machine is very simple. The entire unit is moved into position so that the tamping tools straddle the tie as shown in Figures 7 and 8. Figure 9 shows a closeup of the tools. The tools are set in motion in high-frequency vibration by means of eccentrics as shown in Figure 10 at E. The mobile tool frame with its chrome-manganese tamping tools are lowered vertically into the ballast by means of compressed air to the required depth. The tamping tools are now drawn together with a ramming action by means of the shaft (S) until it is automatically released by the friction coupling

Figure 7

Figure 8

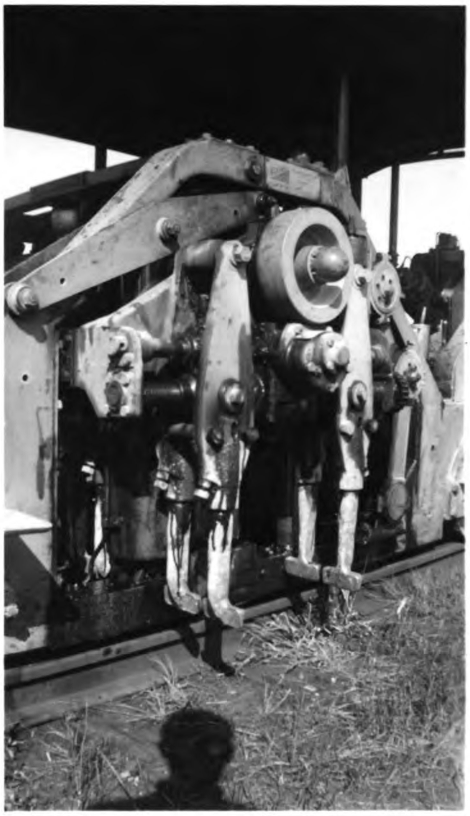

Figure 9

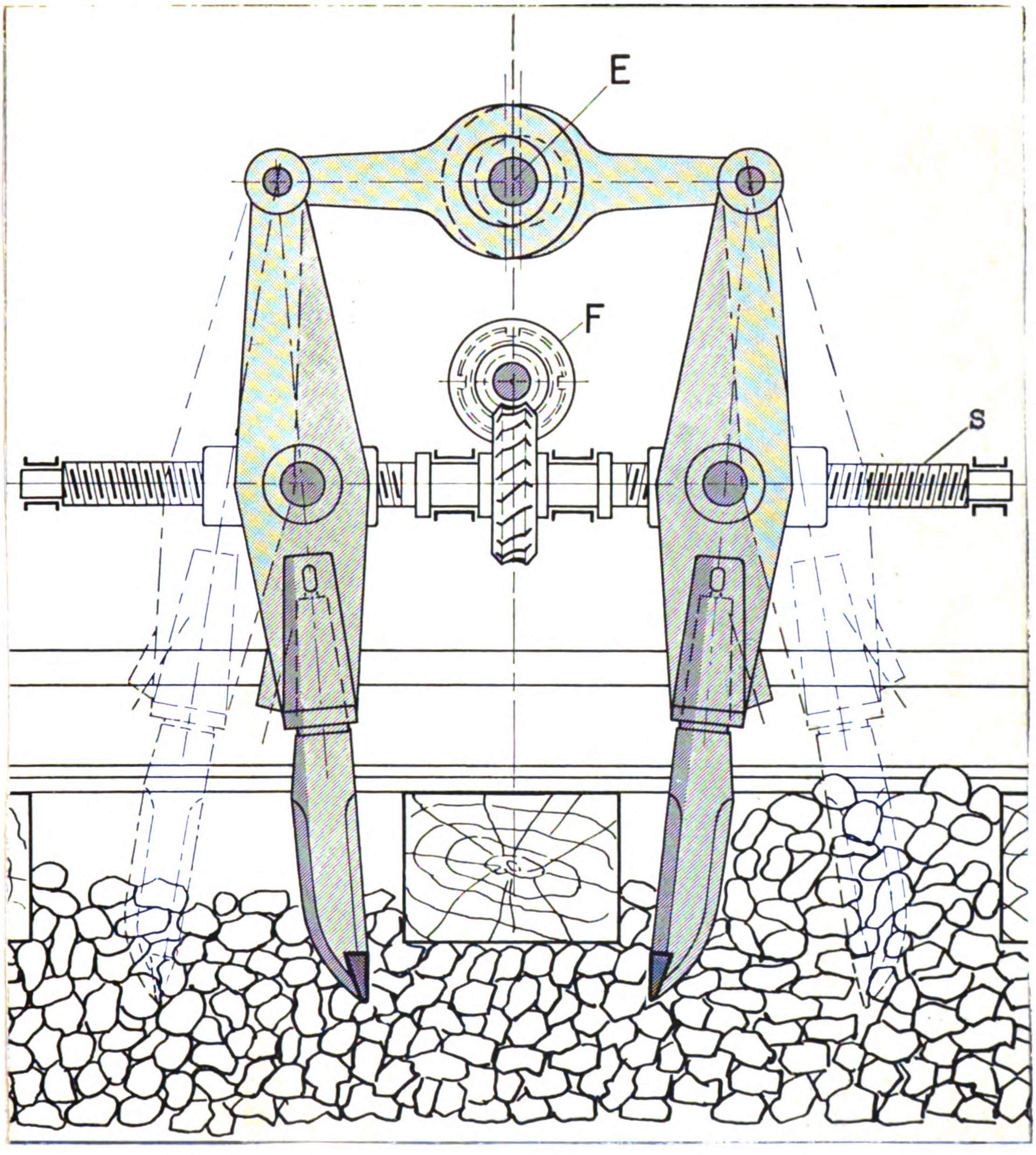

Figure 10

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as shown at (F), when the required predetermined pressure has been reached. The frame is then raised and the machine is moved ahead in position over the next tie. Progress of the machine from tie to tie is made by a simple pedal action.

This automatic mechanical action of the machine is far in advance of other methods of tamping and eliminates any reliance upon the human element in its operation.

The machines can be used anywhere on the permanent way and is suitable for all purposes such as upkeep, the raising or adjustment of the track, or the building of new tracks, whether the ballast is made up of stone, round stone, or mixed with sand.

Both the Power Ballast Machine and the Matisa Automatic tamper are equipped to be moved easily to the side of the track while waiting for necessary trains to pass.

OUTLINE OF BUILDING A TRACK BED

Preliminary Operations

The operations preliminary to laying out a new track bed are similar to those of laying out a highway. They include the reconnaissance survey and the preliminary survey, followed by the detailed cost analyses of the various possible routes.

It is not merely a matter of taking the most direct route between the two points no matter how much finance is allowed for the grading operations. Limiting factors such as grade (usually about 1% for Class "A" roads) and curvature (about 2 degrees for Class "A" roads) must also be considered.

Further considerations incidental to the selection of the route are based on decisions made after balancing the increased costs of excessive excavation and embankment with the decrease in the costs of operation of the prime movers and the perennial costs of maintenance.

Ballast and Cross-Section

The selection of the ballast and the cross-section has already been discussed. We will assume that a superior crushed stone ballast and the cross-section for a Class "A" road are chosen.

Roadbed Construction

Advertising for bids is circulated after the plans and profile, selection of ballast and cross-section, borings, etc. have been arranged for.

The engineering crew begins setting their line and slope stakes and planning for their responsibility with regard to general inspection and supervision and the maintenance of standards.

A multiplicity of machines are brought to the site for the purpose of preparing the subgrade. This equipment includes draglines and backhoes for the more irregular sections of the grading, and is followed by the new type carry-all scrapers which efficiently transport the excavated material to the distant fill with a minimum of operations. The grading is facillitated by the additional use of bulldozers, graders, sheepsfoot rollers, and many others.

The preparation of the roadbed is a subject in itself and beyond the scope of this work. The great importance in the superior preparation of this roadbed cannot be too greatly stressed, however, and future maintenance depends a good deal on the care exercised in this regard.

Ballasting

The ballasting operation may be compared to the laying out of the velvet carpet for his royal maharajan majesty---the amount of attention and care with which it is done determines, to a large extent, the future well-being of everyone concerned.

Since much of the equipment used for all of the subsequent operations has been designed for use on the rails, and it will be most efficient from the standpoint of supply, the skeletonization of the track structure is begun immediately.

Skeletonization

The ties, rail fastenings, rails, spikes, and the other necessary equipment is usually brought to the starting point by rail and distributed by truck therefrom. The rails must be handled with some type of off-track crane and it will depend on the individual contractor how, most efficiently, they can be distributed.

The ties are then spread on the roadbed according to the predetermined number (usually 24 per 39 ft. rail length). They are placed in line and then machine-adzed to close gage in order to facillitate the placing of the tie plates which receive the rail and distribute the pressure over the ties. A crane or an adaption of the Meco Power Rail Layer (see page 14) is used to place the rail in position. The latter machine requires one rail to be securely in place, however, and is more effectively used for the replacement of rails than for the initial laying.

The spike driving machinery is next brought up, one efficient type of which is the pile-driver type previously described. The one rail is checked against the line stakes, the other is set to the standard gage of 4 ft., $8\frac{1}{2}$ inches and the spikes driven in---two hold down spikes and two line spikes.

Limiting speeds and weights must be enforced throughout this skeletonizing operation since the subgrade was not meant to take very much of this relatively concentrated loading.

The rail laying is continued and a new crew is brought in for the ballasting of the roadway. There will be a minor scheduling problem on the hands of the contractor to keep the uninterrupted flow of both the rail laying and the ballast material in action.

Ballast Spreading

The ballast cars are of the side-center bottom-dump type so that the ballast may be spread evenly in the middle and at the ends of the ties. If the first lift is to be an excessive one as could be the case when the new type power tampers are used, it will be advantageous to spread a first layer of about four inches before skeletonizing the track structure. This is handled by trucking the ballast and spreading it by use of some type of bulldozer.

Surfacing and Tamping

The roadway is now ready for tamping and the first of several surfacings. Originally the ballast was entirely hand tamped with sledges and later with pneumatic hammers or electric tampers to aid the settling of the stone particles into a firm mass. The ballast tamping supercedes, in importance, all of the operations subsequent to initial unloading of ballast, however, and the automatic tampers to assure a firm, uniform, unchanging base for the ties should be used.

Figure 11 shows the surfacing crew at work. The Power Ballaster in the foregound is capable of tamping about 2000 feet in an 8-hour shift. The power jack is shown in the background.

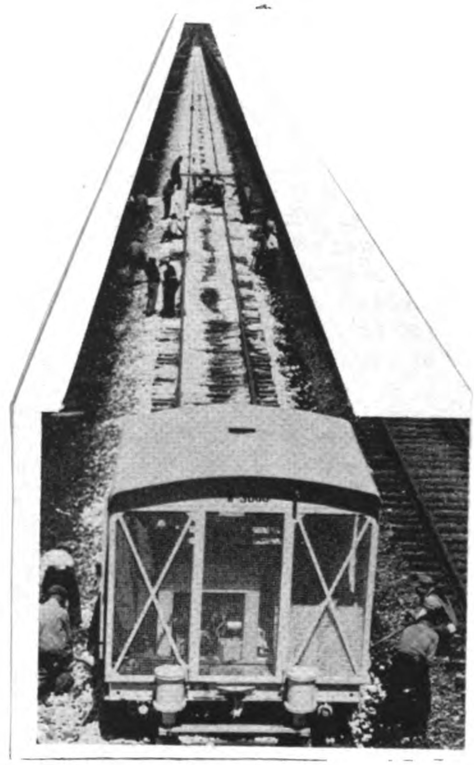

Figure 11.

The engineering force has previously set the grade stakes according to a definite difference from the final grade line depending on the number of lifts required to get the track to final grade. The power jack lifts the rail to the required height and some ballast material is shovelled or forked under the tie to temporarily hold it to grade. The lifting crew usually operates about 200 to 300 feet ahead of the tamping machine. The method of setting the rails to the right height varies, but one method of doing this will be described below.

A straight board long enough to extend from the grade stake to a point on the opposite side of the track is placed in position about 200 feet ahead of the jack with one end on the grade stake and the other supported on an adjustable levelling leg. A marking is placed exactly one foot above the bottom of the board. Behind the jack where the track has already been lifted to grade, the foreman sets his "peep-sight". This consists merely of an arm which can be set on the rail with a small hole exactly one foot above the rail. The foreman looks through this sight ahead to the marking on the grade board and directs the lifting crew until the marking on the jack (also one foot above the rail) comes level with his line of sight.

Meanwhile the tamping machine is banging away at the ballast with its powerful pounding action, forcing the relenting ballast to a solid finished surface.

The track will require about four such surfacing lifts--two of about seven inches and five inches respectively for the sub-ballast and two each of six inches for the placement of the top-ballast. Higher lifts will usually result in too great a distribution of pressure throughout the bottom layers of the ballast, and soft spots will usually develop to increase the future costs of maintenance.

Previously it was necessary to allow a considerable

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time to elapse between successive surfacing lifts to assure thorough compaction from the vibration from the passing trains. The use of the new automatic tampers will reduc such "light traffic" time to a minimum and perhaps eventually eliminate its necessity altogether. It is highly possible to imagine three or four of the tamping machines and surfacing crews in successive operation along the line separated only by the ballast-laying work train and a few thousand feet of idle track.

The final operation in finishing the job is the shoulder dressing procedure. The machines such as the Jordan Spreader-Ditcher, as previously described in the machinery section, is brought to the line and the aprons set to the predetermined slopes of the road section. Laborers follow behind to touch up the work and remove the excess ballast from the roadway. If any drainage ditches are required along the way the ditch-cutting tool of the Jordan machine is lowered into position.

The successive combination of all of these operations results in a track bed which is exceptional in both riding quality and appearance.

REBALLASTING OPERATIONS

Reballasting a railroad line is like shining a pair of shoes---it gives a superior finish to either a new or an old one. This "polish" is added about every two or three years by most of the better railroads. Use of the new ballast cleaning machines accomplishes the same purpose with the added advantage that the old grade line is more nearly maintained.

The ballast is dumped in the middle and along the side of the track as in the ballasting operation by the use of the side-center bottom-dump cars. It should be spread to a uniform depth and at places where excessive lifts are required, the engineering crew should provide marking in order to allow an additional amount of ballast for the lift.

A profile of the track surface is run prepatory to reballasting in order to avoid excessive lifts (and the consequent non-uniformity of compaction) when the new grade line is established. This grade line is established by allowing a lift averaging from 2 to 4 inches for crushed stone ballast. At tunnels, grade separations, underpasses, and street crossings it is necessary usually to keep the lift to a minimum. A gradual runoff is therefore necessary and pneumatic tampers are sometimes used for touching up these small lifts.

The lifting of the track structure and the subsequent tamping operations are accomplished the same as in the original ballasting operations.

STATION BALLASTING

Station areas are necessarily surrounded by many impervious man-made structures such as unloading docks, concrete runways, and buildings, which add to the problem of drainage by shedding most of the rainfall to the nearby tracks. The ballast material is additionally taxed by the fact that it is more quickly fouled in spots by the "braking" sand dropped in large quantities by the locomotives stopping at the station. This sand is usually accompanied by the drippings from the locomotives and the other cars. The immediate result is that the water usually stands in puddles around the ties which results in rapid deterioration and constant maintenance attention.

Most railroads solve this problem by a method similar to the one used by New York Central. A report on this method was prepared by J. R. Scoffield, Assistant District Engineer for the Michigan Central Railroad in which he explains the solution.

"Formerly the two main passenger tracks of the New York Central at its South Bend (Indiana) station required an excessive amount of attention by the maintenance forces to keep them in a satisfactory condition. Now, however, as the result of a combination of measures applied in September of 1945, the cost of maintaining these tracks has been greatly reduced. The measures employed included the installation of asphalt coated ballast, the laying of continuous butt-welded rails, and the provision of a drainage system for disposing of surface water.

For a number of years the New York Central System has given careful consideration to the possibilities of correcting bad track conditions in station areas by using ballast coated with emulsified asphalt, the reasoning being that such ballast would be impervious to water and yet could by worked when necessary. As early as 1939, a test installation of such ballast was made in a 600 ft. length of the company's high-speed east bound main track at Bryan, Ohio. The performance of this test section has been carefully observed by the railroad and a sub-committee of the Committee on Roadway and Ballast of the A. R. E. A. and the results of these observations have been recorded by the committee in its annual report to the Association. In a report made to the convention in 1943, the Committee observed that "the track does not heave due to frost; the seal coat sheds water readily, retains foreign-matter and prevents it from getting into the ballast. The track in the test section rides well, remains in good line and surface and continues to give satisfactory results with a minimum of expenditure."

Based on the results of tests at Bryan, it was decided to install in the two main passenger tracks asphalt coated ballast for the approximate lengths of the two concrete island platforms which were on either side of the main line (each of which was 1200 feet long), employing such refinements as were indicated by experience with the Bryan Test. As additional measures to reduce maintenance costs it was decided to eliminate practically all of the joints in the two tracks by installing continuous butt-welded rails and to provide an efficient drainage system for removing surface water.

In preparation for doing the work, an arrangement was made with a contractor to provide a one cubic yard Koehring paver for mixing the ballast and asphalt, the latter consisting of Texaco No. 23 emulsified asphalt. Work on the west bound track was done first. After the old rails and ties had been removed from this track, the roadbed, which had become consolidated almost to the hardness of concrete, was excavated to a depth of about twelve inches below the bottoms of the ties, exposing the original sand fill subgrade. The subgrade was finished by hand after which it was compacted by a 10-ton roller.

When the subgrade had been fully prepared, the asphalt ballast mixture was unloaded from the cars standing on the east bound track and spread over the subgrade to a depth of 9½ inches. The unloading work was done with a crawler crane equipped with a clamshell bucket.

The mixture consisted of two parts of 2-inch stone and one part of 3/4 inch graded stone, to which was added an average of 20 gallons of the asphalt emulsion. The crushed stone in the mixture consisted of a limestone that is regularly used by New York Central for ballast.

After the rails were replaced a seal coat about two inches thick was applied over the entire ballast area between the platforms, including the inter-track space. This coat was a mixture of 25 per cent sand, 75 per cent of 3/4 inch screenings thoroughly mixed with asphalt emulsion and was graded to drain surface water to the inter-track space where a drainage system had previously bee provided. A final step to assure that no water would penetrate the surface consisted of applying a brush coat of a rich mixture of sand and asphalt emulsion over the entire ballast surface.

The drainage system that was installed as part of the project embodies nine catch basins covered with metal gratings, six of which are located at intervals in the inter-track space. A system of outfall lines connects the catch basins with existing manholes at two street underpasses in the vicinity.

In October of 1946, more than a year after the asphalt ballast was installed at South Bend, repairs were made by tamping the track with pneumatic tampers at loose ties and elsewhere to bring low places back to grade. Additional asphalt coated screenings were applied where necessary after liquid asphalt had been placed around the ties for sealing purposes. A final seal coat of fine stone chips mixed with a cut-back asphalt was applied over the area between the platforms. The cut-back asphalt was used because it seemed to be more resistant to the drippings than the other asphalt.

The combination of these operations has produced track that requires very little maintenance."[9]

SUMMARY

The railroads now live in a period of increased competition for survival. They are being rivalled by airplane and bus in their quest for the better means of long-distance transportation.

There is an increased need for increasing comfort and decreasing fares to the all-important cash customer. Speed is a necessity. These seemingly insurmountable problems are being met and attacked by the infantry of the railroad---the maintenance forces. Their more efficient method of attending to the ballast operations has resulted in a smoother, safer, more comfortable high-speed ride. They are cutting costs considerably which will eventually be reflected in the price column of the patron's ticket.

Thus, if the railroad finally desires to find someone to thank for their prolonged life, they must pay a great share of their gratitude to those of the ballast and ballasting crews for a job well done.

APPENDIX

1. Railway Classification

The following classification of railways is based on tonnage and on maximum speed of passenger trains and is the one used by the American Railway Engineering Association as the basis for recommended practice in the construction of roadbed, dimensions and quality of ballast, cross-sections, etc.

Class "A" shall include all districts of a railroad having more than one main track, or those districts of a railway having a single main track with a traffic that equals or exceeds the following: Freight car mileage passing over thedistrict per year per mile, 150,000; or, Passenger car mileage per year per mile of district, 10,000; with a maximum speed of passenger trains of 50 miles per hour.

Class "B" shall include all districts of a railway having a single main track with a traffic that is less than the minimum prescribed for Class "A", and that equals or exceeds the following: Freight car mileage passing over the district per year per mile, 50,000; with a maximum speed of passenger trains of 40 miles per hour.

Class "C" shall include all districts of a railway not meeting the traffic requirements of Class "A" or "B".[10]

2. Ballast Definitions

Chats.---Tailings from mills in which zinc, lead, silver, and other ores are separated from the rocks in which they occur.

Chert.---An impure flint or hornstone occurring in natural deposits.

Cinders.---The residue from the coal used in locomotives and other furnaces.

Clay (Burnt).---A clay or gumbo which has been burned into material for ballast.

Granite (Disintegrated).---A natural deposit of granite formation, which on removal from its bed by blasting or otherwise, breaks into particles of size suitable for ballast.

Gravel.---Pit Run. Worn fragments of rock, occurring in natural deposits.

Gravel.---Screen. Worn fragments of rock, occurring in natural deposits, that will pass through a 2½-inch ring and be retained upon a No. 10 screen.

Gumbo.---A term commonly used for peculiarly tenacious clay, containing no sand.

Sand.---Any hard, granular, comminuted rock which will pass through a No. 10 screen and be retained on a No. 50 screen.

Slag.--- The waste product, in a more or less vitrified form, of blast furnaces, for the reduction of ore; usually the product of a blast furnace.

Stone.---Stone brcken by artificial means into small frzgments of specified sizes.

REFERENCES

1. Raymond, W. G., Elements of Railroad Engineering
   John Wiley and Sons, New York

2. Protzeller, H. W., The Why and How of Ballast Cleaning
   Railway Engineering and Maintenance, January, 1947

3. American Railroad in Laboratory
   American Railway Association, Chicago, Illinois

4. Rebuilding the Moffat Railroad
   Railway Gazette, December, 1937
   Engineering News-Record, September, 1937

5. Engineering Is Playing Its Part in Design and Strength of Track Structure
   Railway Age, June, 1941

6. Sellew, W. H., Railway Maintenance Engineering
   D Van Nostrand Co., New York

7. Railway Maintenance Encyclopedia, 1945
   Simmons-Boardman Publishing Corp., Chicago

8. Power Ballaster Machine
   Modern Railroads, October, 1946

9. Scoffield, J. R., How Station Track Upkeep Was Cut
   Railway Age, April, 1947

10. American Civil Engineers' Handbook, Merriman-Wiggins
    John Wiley and Sons, Fifth Edition-1947

Additional References and Citations

American Railway Engineering Association Committee Report on Roadway and Ballast--Railway Age, March, 1946

American Railway Engineering Association Manual

Maintenance Expenditures, M. H. Dick
Railway Age, January, 1947

Uncle Sam Builds a Railroad Fast!
Railway Age, June, 1941

Fundamental Changes in Construction
Railway Engineering and Maintenance, June, 1941

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D. E. Dresselhouse, Engineer for New York Central, Chicago

Mr. Rodman, President of the Maintenance Equipment Corp.

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