More Profit in Mechanical Mining

Through Studies of Loading and Gathering Performance

Mineral Industries Experiment Station
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Price Three Dollars
THE findings described in this bulletin comprise a part of an extensive program of research carried on in many fields as one of the primary functions of The Pennsylvania State College.

The spirit of research which permeates the college is in keeping with the purposes of the Organic Land-Grant Act in bringing the methods and procedures of modern science into relation with the agricultural and industrial pursuits of the nation.

In order to accomplish this, the application of scientific and technologic research is frequently necessary. In the field of the mineral industries, the planning and supervision of such research is one of the functions of the Mineral Industries Experiment Station. The results of research are reported in bulletins of this Station and in numerous contributions to scientific and professional journals.

FIELDS OF WORK

Earth Sciences: Geology, Mineralogy, Geography, Geophysics, and Meteorology.


More Profit in Mechanical Mining

Through Studies of Loading and Gathering Performance

By A. Wayne Bitner and David R. Mitchell

Written for the men who produce America's coal

The coal mining industry is one of the firmest foundations upon which our modern economy rests; a sound industry today is our strongest assurance of peace and plenty tomorrow.
THIS bulletin presents a new method of analyzing the operation of underground mine sections and machines within the section—based on more than 100 detailed studies made in many U.S. mines.

As described here, the new method applies mainly to shuttle-car units in bedded deposits of coal, salt and other minerals. However, it can be employed to study and rate other types of mechanized sections.

The procedures detailed herein can be used by section bosses and other mine personnel in making similar studies and in evaluating the results of such studies.

These results can be used in establishing standards for low-cost operation. They will be particularly helpful in planning new production units.
Does Your Coal Cost Too Much?

Of every dollar spent in producing coal, an average of 33 cents goes just to load the coal at the face and move it to main-line transportation. In some mines this coal-handling bill skyrockets to 50 cents.

It is often hard to determine the section loading and gathering expense, as such. Yet the fact remains that more is spent just to load and move coal in the section than is spent on any other mining process.

This massive coal-handling bill can be cut down. Studies made in many mines, under a wide variety of conditions, show that a good part of the loading-gathering cost is avoidable. In some mines, better maintenance and better use of equipment have reduced costly mechanical breakdowns. In others, simple layout changes have made it easier for men and machines to work productively a greater part of the shift.

Whatever the cause of excessive loading-gathering cost, you can always find it, usually reduce it, often eliminate it entirely.

This bulletin shows how to put the finger on high loading and gathering costs. By using the study methods outlined herein, you can determine which machine or which group of machines is running up the cost of your coal. Once this is known, you can begin to eliminate unnecessary high costs from your loading and gathering system. The result will be greater productivity and a more profitable operation.

33% of the cost of producing coal is due to loading and gathering.

These processes merely move the product from one place to another.

They add nothing to the value of the product.

How efficient are your coal-handling machines?

Are they idle more than half the shift?

Can you cut your production costs?

THERE IS NOW A WAY TO ANSWER THESE QUESTIONS
How MECHANIZED MINING

- Cuts Costs
- Steps up Production
- Saves Effort
- Promotes Safety

American industry has grown great by harnessing machines to do man’s work faster and more efficiently. In America’s mines, machine power is fast replacing muscle power... multiplying the work a skilled man can do in a day... making possible the low-cost mining of coal and other minerals. Mechanization is the most important contributor to the high coal production that enables the United States to maintain its industrial leadership—the envy of the world.

CUTS COSTS—Mechanization makes possible the most economical operation of your present mine layout. Machines can be concentrated to give large output from fewer working places. This cuts down the number of places that must be ventilated, de-watered, and wired for power.

STEPS UP PRODUCTION—In a mechanized loading and gathering system, coal flows smoothly, in quantity, from the face to main-line transportation. This steady movement sets the pace of production; keeps the main-line haulage system and surface preparation plant working at capacity.

SAVES EFFORT—Machines do away with the least desirable aspects of mining. By eliminating many “muscle” jobs, they permit men to concentrate on more productive work. Skilled technicians tending machines eliminate the back-breaking toil of the hand miner.

PROMOTES SAFETY—Machine operation enables more men to work at a distance from the face, under safer roof conditions. Mechanized mining keeps the face moving fast, reducing roof dangers. Greater safety means fewer accidents, lower compensation costs and insurance rates.
FIRST and greatest chapter in the story of modern mine mechanization is the development of the continuous loading machine. More than any other invention, the continuous loader has made possible low-cost, mass-production mining.

In 1938, less than 27% of underground coal production was loaded by machines. Of that amount, 95% was loaded directly into mine cars. The other 5% was loaded onto conveyors.

Mining history passed another milestone that year: the first modern shuttle car was put to work.

Five years later, in 1943, mechanized loading (49% of total underground production) had almost caught up with hand loading (51%). Of the 249 million tons mechanically loaded underground that year, shuttle cars hauled nearly one-fifth. Conveyor loadings remained fairly steady at 3%. But tonnage mechanically loaded directly into mine cars had slumped from 95% to 80% of the total.

In 1947, the picture was even clearer. Nearly 59% of underground production was mechanically loaded; only 41% was hand loaded. Of the 59%, more than one-fourth was loaded into shuttle cars—a tremendous gain. Loadings direct into mine cars dropped to two-thirds of the total, and conveyors accounted for the remaining 7%.

The conclusion is obvious: in ten years the continuous loader and the rubber-tired “shuttle buggy” have made a place for themselves in underground mining. Today nearly 3,000 shuttle cars are operating in mines throughout the country. The trend is unmistakable: time-honored ways of loading and gathering are gradually but steadily being replaced.
A smooth, steady flow of coal from face to tipple—that's efficient production. Profits go up when machines do productive work a greater part of the shift... when men spend more time operating machines, less time on "muscle" jobs... when section layout lets men and machines work together to best advantage.
Where Are the Weak Spots that Sap Your Profits?

Some sections in your mine produce better than others. But do you know why?

If you could find out what it is that makes one section click better than another; if you could put your finger on any one operation that is slowing up a section—you would be on the way to higher production and bigger profits.

Progressive operators are now pretty well agreed that you can’t tell much about a section merely by knowing how much coal it turns out, or how much of the time is engaged in useful work.

True, these figures are important. But they don’t tell you the whole story. They don’t show you why a section is above average, or below average. They don’t tell you what makes the section tick.

This is because usual systems of measurement don’t take into account all three vital elements of a working section—its men, its machines, its layout.

To discover what makes a section function, you must go into the section and study its operation thoroughly. Your study must look at all three vital elements—men, machines, layout. This kind of measurement will guide you surely and accurately to higher efficiency, more productivity, increased profits.

To measure section efficiency accurately the method of measuring must take into account

Existing Methods of Rating Efficiency
Don’t Find Costly Profit Leaks

Method No. 1—Section Production

![Diagram of Section Production]

This measurement, usually expressed in tons or tons per man-shift, tells you the effectiveness of the section as a whole. It gives you no useful facts about men and machines within the section.

Method No. 2—% of Shift Time Engaged

![Diagram of Time Engaged]

This measurement tells you how much of the time your men and machines are working. It does not tell how productive they are. It gives you no idea why the section is good, or how it could be improved.

Men

Machines

Layout

Production
Penn State

COMBINED STUDY

Method

Rates All Elements of Section Performance.

Finds Weak Spots and Profit Leaks.

Puts the Finger on High Production Costs.

Tells You What to Do to Get:

More Tons per Man-Shift
More Tons per Machine-Shift
Lower Cost per Ton

This combined study is really three studies in one: a time study of the loading and gathering cycles; a method study that examines the section layout; and a production study by which you can rate any of your sections.

The results show whether the section is above or below normal in any respect. They clearly indicate what should be done to get higher efficiency.

NOTE—The study method as presented is designed for testing shuttle-car production units, which generally include a mobile loader, one or more shuttle cars, a drill and a cutting machine. Slight modifications permit using this method for other types of mechanized sections.
1 TIME STUDY

One observer is stationed at the loader; another at the discharge station. Both keep a time record, and note all loading and gathering activity within their scope of observation. This gives you a complete, continuous time record of the loading and gathering cycles in the section, for further analysis and study.

2 METHOD STUDY

An accurate map of the section is used, on which are noted shuttle-car travel routes and passing points. Distances are scaled from the map, so shuttle-car mileage can be figured. This map helps you plan better section layout.

3 PRODUCTION STUDY

Statistics of the number of men, machines, and production achieved are obtained from mine records. These data are used with the time and method study data to calculate ratings for your production units.
What Part of the Shift Do Your Machines Really Work for You?

A loading machine is working for you when it is actually loading coal, maneuvering into the coal, and during the time the shuttle cars are away performing an operation necessary to the production cycle.

A shuttle car works for you during the time it is under the boom of the loader, receiving coal; while maneuvering at the face; while moving from the loader to the discharge station with a load of coal; while discharging and while returning empty to the loader.

At all other times during the shift, the loader and shuttle car are considered nonproductive. The shift is thus divided into two kinds of time: productive time and nonproductive time.

Nonproductive time is caused by delays. Some delays are necessary; others are unnecessary. For example, if a shuttle car must stand by and wait for another car to pass, this is termed a necessary delay. If the shuttle car is held up because of a cable blowout, this is termed an unnecessary delay—the assumption being that with proper inspection, maintenance and use, the cable would not have failed.

Obviously, the way to reach higher efficiency is to cut down the time consumed in unnecessary delays, and also to reduce the “necessary” delays as much as possible, to allow the machines to put in more productive time during the shift.

But first we must find out what the avoidable delays are.
To study a section, we primarily observe the machines in the loading-gathering cycles of that section.

These cycles are the heart of the operation. Any delays in cutting, drilling, shooting, or main-line transportation do not affect production until they show up as delays in the loading-gathering cycles.

Separate studies of these operations can be made, to show whether the machines and the cycles involved are efficient. By recording the time intervals required by each activity of the loader and shuttle cars of the section, we can determine how much loader time and shuttle-car time is productive, and how much is nonproductive. We can also find out how much of the nonproductive time is due to necessary delays, and how much is due to unnecessary delays.

Why symbols are used and what they mean

Time study needs a shorthand of its own, because observers underground must fill out forms quickly, while machines are on the move.

Turn to pages 14 and 15 for a moment and look at “Field Form A”—the form used to record nearly everything that happens in the section. You will notice that each loader and shuttle-car activity is described by a symbol.

Most of the time-interval symbols are simple, logical and easily remembered. Their use is explained in the next few pages. Before making the study, your men should know the mechanics of this system and the exact meaning of all symbols.
These time elements put money in your pocket:

**TKZ** means "Total Productive Time." It is that part of the shift during which the machine being studied actually does productive work. TKZ is a summary of the five following time elements:

**TKZ Includes:**

- **L—LOADING TIME.** The time consumed when the shuttle car is under the boom of the loader, receiving coal.

- **M—MANEUVERING TIME.** Movement of the loading machine or shuttle car or both while at the face, which is necessary to the loading process. During this movement no coal passes over the boom.

- **TE—TRAVELING EMPTY.** Movement of the empty shuttle car, usually over the normal travel route from the discharge station to the loading machine.

- **TL—TRAVELING LOADED.** Time used by the shuttle car in traveling with a load of coal from the loader to the discharge station.

- **D—DISCHARGE TIME.** That time during which the discharge conveyor of the shuttle car is running, transferring the load to another carrier or to the ground.

**IMPORTANT**—The five symbols above do not account for any delays that occur while loading, maneuvering, traveling or discharging. All delays have their own special symbols, listed on the next page. Men making the study must record each delay separately, under the appropriate delay symbol.
... but you lose money during these operations:

**TND TOTAL NECESSARY DELAYS**
That part of the shift during which the machine being studied is not producing, but is engaged in unproductive work or is delayed by operations that are a necessary part of the section conditions. TND includes the four time elements at the right:

**WO WAITING FOR OTHER CAR**
The time the shuttle car is standing by, waiting for another car to pass. Note—if the other car is delayed, this delay is not part of the WO time. Observer must record each kind of delay separately, using appropriate symbols for each.

**DL DELAYS IN LOADING**
Any delay that prevents the loader from loading while coal is available and the shuttle car is ready to receive it. Included are: timbering; testing for gas; testing roof; breaking lumps; gobbing rock; digging face.

**HS HANDLING SUPPLIES**
Time consumed in any shuttle-car handling and movement of supplies such as timber, rock dust, bits, tools, parts.

**PC PLACE CHANGE**
Time consumed in moving from one working place to another. Included are: trammimg; handling cable. Note—all delays en route are recorded with appropriate symbols.

...and most of these delays could be avoided:

**TUD TOTAL UNNECESSARY DELAYS**
That part of the shift during which the loader or shuttle car is not engaged in production, because of a delay that is considered unnecessary. TUD includes the six time elements at the right:

**DMs DELAYS, MECHANICAL—SHUTTLE CAR**
Time during which the shuttle car is removed from production by a mechanical delay. Included are: battery failure; cable failure; mechanical or electrical breakdown within shuttle car; battery changing; lubrication.

**DMl DELAYS, MECHANICAL—LOADER**
Time during which the loader is unable to operate because of a mechanical failure. Included are: mechanical or electrical breakdown within loader; failure of cable; lubrication.

**DS DELAYS AT DISCHARGE STATION**
That time during which the shuttle car is ready to discharge but is prevented from doing so. Included are: belt stoppage; car spotting; no empties; belt loaded inby; failure of auxiliary discharge equipment.

**DP DELAYS IN FACE PREPARATION**
Time consumed while the unit is delayed by the preparation crew. Included are: waiting for drilling, cutting and shooting to prepare an immediate place; shooting adjacent places.

**DN DELAYS—NATURAL CONDITIONS**
The time consumed by a delay due to bottom or roof conditions. Included are: roof falls; roadway maintenance; rough or muddy bottom; upheaval of bottom; subsidence of roof.

**DO DELAYS, OTHER**
All delays not mentioned above are placed under this category. When filling out field forms, each DO item requires a note in the “Remarks” column. Included are: lunch; ventilation; other equipment failures; power failure.
Both observers start their watches at the same instant, with a reading of 00.00 (line 1, left side of both forms). Watches are then allowed to run without interruption until the study ends.

Under “Remarks” each observer has noted the actual starting time, 0800 (8 A.M.).

**AT LOADER**, observer records as follows:

- **Line 2** (left side of form)—Shuttle Car No. 1 is not operating, because of a mechanical delay (noted by both observers). Shuttle Car No. 2 is held up by a place change to No. 4 South, Face, which takes 9.10 minutes.
- **Line 3**—Shuttle Car No. 2 is loaded, this operation continuing until 11.25 on the stop watch.

**Instructions**

**How to record field data**

These sample forms show how an actual time study is made. The form at left has been filled out by an observer at the loader; the one at right, opposite, by an observer at the discharge station.

Copies of Form A, and other forms making up the Combined Study Kit, are enclosed with this Bulletin. Enough forms have been included to permit a complete study of one section. Extra kits of forms may be ordered as needed.

**Lines 12-14**—Car No. 2 takes on coal until 31.55 and leaves on Trip 4. Car No. 1 waits (WO) until 31.80 for Car No. 2 to pass, then travels empty to loader, arriving at 32.20.

**Lines 15-18**—Car No. 1 loads until 33.60, then departs on Trip 1. Car No. 2 returns to loader, loads until 37.50, maneuvers until 37.55, then resumes loading until 39.15. Meanwhile No. 1 arrives empty at waiting point (38.20) and waits (WO).

**Lines 19-20**—A place change, to No. 4 South, Crosscut Left, takes until 39.85; then Car No. 2 loads until 40.45, when it leaves on Trip 5.

**Lines 21-28**—These notations sum up the movement of Car No. 1, prior to leaving on Trip 2 at 44.95.

**Line 28**—Place is changed, the loader tramming to No. 3 South, Face.

**Lines 1-5** (right side of form)—Car No. 2 loads until 49.15 and leaves on Trip 6. Car No. 1 arrives empty at waiting point, waits for No. 2 to pass, moves to loader and loads until 51.70, then departs on Trip 3. Car No. 2 returns at 54.10, loads and starts Trip 7.
Observers record each activity of the loader and shuttle cars by writing in:

1. The proper symbol.
2. The "observed continuous time." This is the watch reading at the completion of each recorded activity.

Note that "working time" column on the forms has been left blank. Working time is computed later.

Study both forms until you can expertly follow the actions of loader and shuttle cars. Trace the movement of each car from one observer to the other, as the car moves from loader to discharge station and back. Be sure you understand how these forms work before attempting to make a time study.

AT LOADER (continued)

Lines 6-11—Car No. 1 arrives empty at loader, but is held up (DL) while place is cleaned. It then loads for Trip 4.

(Note that after reaching 60.00, the stop-watch readings begin again at 00.00. Some stop watches run for 30-minute periods before repeating. Either type may be used.)

Observer continues to record as shown. This sample covers only part of a shift. Normally a study covers one entire shift.

AT DISCHARGE, the other observer picks up the action where first observer leaves off. Note that this record, like the other, is divided into trips or cycles.

Line 2 (left side of form)—Shuttle Car No. 2 arrives loaded at discharge station. The time of arrival (13:35) is recorded as "TL" time. The true TL time will be figured later by comparing both forms.

Lines 3-6—Car No. 2 discharges until 13:55. Then observer notes delay (DO), explained in "Remarks." The car resumes discharging until 15:70, when it leaves the discharge station on its way back to the loader.

Note that observer records the completion of Trip 1 by using mark, 1>, the same mark used by other observer to record the beginning of the trip.

Lines 7-9—The TL and D portions of Car No. 2's second trip are recorded.

Lines 10-14—On Trip 3, discharge is held up by car spotting. See Remark.

Lines 15-18—On Car No. 2's fourth trip, there is another slight delay due to conversation.

Lines 18-20—Car No. 1 finally arrives, discharges and leaves, completing its first trip.

Lines 20-24—Car No. 2 finishes Trip 5, which includes a short delay caused by car spotting.

Lines 23-27—Car No. 1 arrives loaded at 47:10, discharges until 47:50. After traveling empty until 48:00, it is held up (DO) while driver stops for instructions.

Note that, while TE time is usually recorded by observer at loader, in this case a definite part of the TE occurred within sight of the discharge observer, so he recorded it.

Lines 1-5 (right side of form)—Car No. 2 completes Trip 6, and Car No. 1 completes Trip 3.

Lines 5-9—On Car No. 2's seventh trip, discharge is interrupted for more than a minute by car spotting.

The rest of the form is easy to follow. Each shuttle car makes two additional trips. Then there is a delay occasioned by an early quit, and the study concludes. Notice that this final DO item (Line 18) affects both shuttle cars, so is entered in both columns.

Also note that observers check their watches at the conclusion of the study. The time difference is slight, so it is ignored. A large discrepancy would have to be prorated over the studies.
What to do before entering section

1. Choose observers carefully. Impress upon them the importance of being accurate and alert.

2. Study this field procedure. Observers must know the meaning of symbols. They must also know exactly what to do when they enter the section.

3. Study the sample field forms on these pages. Be sure observers understand how to fill out these forms.

4. Assign observation points. Usually one observer will be stationed at the loader, another at the discharge station. If the method of travel of the shuttle car is complex, a third observer should be stationed so he can record operations at standby or passing points. Do not be concerned if observers' zones seem to overlap. It is better for observers to duplicate a few entries, than to miss vital information.

5. Decide on the precision desired in the study. Sample studies in this bulletin show time intervals in minutes and hundredths of minutes. However, a study that breaks down time into minutes and tenths may be accurate enough for your purposes.

6. Obtain a freshly posted map of the section to be studied, and a list of the equipment used in the section. Become familiar with the section layout and equipment before going underground.

7. Fill out Field Form B as completely as possible.

8. Supply each observer with:
   a. A stop watch.
   b. Chalk for numbering shuttle cars and other equipment, for quick identification.
   c. Clipboard to which are attached seven or eight copies of Field Form A. Observers should also take along the partly-filled-out Field Form B, to be completed during or after the time study.
   d. Pencils, erasers, straight edge, measuring tape.

Field Form B is for listing basic information you will need later. This includes: places worked during the time study; standby positions; travel distances; and data on section equipment. Form B is filled out as completely as possible before going underground. It is completed during or after the time study.
What to do in the section

Upon reaching the section, observers should:

1. **Synchronize watches.**

2. **Mark shuttle cars** with large chalk numerals, so either observer can identify car at a glance.

3. **Record starting time** on Form A; then move to observation points where all action of the loader and shuttle cars can be noted.

4. **Keep continuous record,** on Form A, of loader and shuttle-car activity. Record each activity or delay with the proper symbol, and enter the "Observed Time" for each. Leave blank the "Working Time" column. Use the "Remarks" column freely to describe place changes, and to explain any other happenings not fully described by the symbol.

5. **Check watches again** at close of shift. Note any difference, and enter on Form A. If watches differ by a few seconds, difference may be ignored. If difference is large, it can be prorated.

6. **Fill out Field Form B** as fully as possible. Complete it upon return to the surface, before leaving the mine. Distances from different working faces to discharge station may be measured with tape while in the section, or may be scaled from section map.
How to Sum Up the Time Study

Use These Time-Interval Symbols

**CC—Change-Car Time.** Time during which the loader is ready to load but the shuttle car is absent, doing other productive work. Delays that keep the shuttle car from returning to the loader in a normal time are not counted as part of CC.

In a single-shuttle-car system —

CC = TL + D + TE

Change-car Time  Traveling Loaded  Discharge Time  Traveling Empty

In a multiple-car system, true CC must be calculated, by subtracting all delays that affect the normal return of the shuttle car to the loader. The summary form used (Form D) is arranged to make this task simple. CC is used in summing up loader operations.

**US—Unnecessary Delays to Shuttle Car.** Total unnecessary delays that prevent the shuttle car from returning promptly to the loader. Such delays increase the apparent CC time, but must be subtracted from it to obtain the true CC time. US includes: DMs, DS, DN and DO of the study. But it includes these delays only in so far as they affect the prompt return of the shuttle car. This is a point that requires careful study.

The total time the loader is in position ready to load and the shuttle car is not available.

US is used in summing up loader operations.

**TZ—Travel Time.** Time spent by the shuttle car traveling in the production cycle. TZ is a shuttle-car summary item.

TZ = TL + TE

Traveling Loaded  Traveling Empty

**TOTAL LOADING TIME.** Time during which the shuttle car and loader are in position at the face engaged in the work of loading the shuttle car. LZ is used in summing up loader and shuttle-car operations.

LZ = L + M

Actual Loading Time  Maneuvering Time

LZ

The completed field study must now be summed up, to give useful totals that will tell you something about section efficiency. Time-interval symbols shown on these two pages are used in condensing the mass of time-study data from Form A, and in arranging this data so you can analyze and study it.
**SUMMING UP THE TIME STUDY**

**TOTAL PRODUCTIVE TIME.** That part of the shift during which the machine being studied does productive work. TKZ is used to sum up both the loader study and the shuttle-car study.

In the loader study,

\[
TKZ = LZ + CC
\]

In the shuttle-car study,

\[
TKZ = LZ + TZ + D
\]

**TOTAL NECESSARY DELAYS.** That part of the shift during which the machine being studied is not producing, but is engaged in unproductive work or is delayed by operations that are a necessary part of the section conditions. TND is a summary item for both loader and shuttle car.

In the loader study,

\[
TND = HS + DL + PC
\]

Handling Supplies, Delays in Loading, Place Change

In the shuttle-car study,

\[
TND = WO + DL + PC + HS
\]

Waiting for Other Car, Delays in Loading, Place Change, Handling Supplies

**TOTAL UNNECESSARY DELAYS.** That part of the shift during which the loader or shuttle car is not engaged in production, because of a delay that is considered unnecessary. TUD is a summary item for both loader and shuttle car.

In the loader study,

\[
TUD = US + DM_L + DP + DN + DO
\]

Unnecessary Delays, Delays to Shuttle Car, Leader Preparation, Natural Conditions, Other

In the shuttle-car study,

\[
TUD = DM_S + DM_L + DP + DN + DS + DO
\]

Delays, Mechanical—Shuttle Car, Leader, Mechanical—Shuttle Car, Leader Preparation, Natural Conditions, Discharge Station, Other

**TYZ—TOTAL SHIFT TIME.** The time that is spent in the section. TYZ for the loader is of course the same as TYZ for each shuttle car. But the separate time intervals that make up TYZ are different for the loader than for the shuttle cars. That is why the loader and shuttle-car operations must be summed up separately.

**NOTE.** The groupings under TND and TUD are somewhat controversial. Some delays in each group may be placed in the other, according to the individual view of mine management as to whether the delays are "necessary" or "unnecessary." The groupings given here were set up to cover many mines.
This summary shows how loader spends the shift

- **L** ACTUAL LOADING TIME
- **M** MANEUVERING TIME
- **CC** CHANGE-CAR TIME

- **HS** HANDLING SUPPLIES
- **DL** DELAYS IN LOADING
- **PC** PLACE CHANGE

- **US** UNNECESSARY DELAYS TO SHUTTLE CAR
- **DP** DELAYS IN FACE PREPARATION
- **DM_L** DELAYS, MECHANICAL—LOADER
- **DN** DELAYS—NATURAL CONDITIONS
- **DO** DELAYS, OTHER

**TKZ**
- PRODUCTIVE TIME (LOADER)

**TND**
- TIME SPENT IN NECESSARY DELAYS (LOADER)

**TUD**
- TIME SPENT IN UNNECESSARY DELAYS (LOADER)

**TYZ**
- TOTAL SHIFT TIME (LOADER)
Shuttle-car activities are summed up like this:

| L | ACTUAL LOADING TIME |
| M | MANEUVERING TIME    |
| TE| TRAVELING EMPTY     |
| TL| TRAVELING LOADED    |
| D | DISCHARGE TIME      |
| WO| WAITING FOR OTHER CAR |
| DL| DELAYS IN LOADING   |
| PC| PLACE CHANGE        |
| HS| HANDLING SUPPLIES   |

TZ
TRAVEL TIME

TKZ
TIME AT LOADER
PRODUCTIVE TIME (SHUTTLE CAR)

TND
TIME SPENT IN NECESSARY DELAYS (SHUTTLE CAR)

TYZ
TOTAL SHIFT TIME (SHUTTLE CAR)

TUD
TIME SPENT IN UNNECESSARY DELAYS (SHUTTLE CAR)
These are the Forms to Use

1. Fill in "Working Time" on Forms A. Find the time taken by each recorded operation. Just subtract the "Observed Continuous Time" at start of operation from the "Observed Continuous Time" at finish of operation.

On sample forms at right, loader observer has noted a place change which started at 09.00 and ended at 09.10. Obviously, the place change took 9.10 minutes to complete. Line 3 shows a loading operation, from 09.10 to 11.25—a "working time" of 2.15 minutes.

Line 5 shows a TE reading of 17.45. The TE operation started at the discharge station; so we turn to the discharge observer's form. There we find that the shuttle car finished discharging and started back to the loader at 15.70. Subtracting, we get a working time of 1.75 minutes, the actual time spent traveling empty.

2. Fill in Summary Form C for Each Shuttle Car. This form merely groups the "working time" intervals under their proper headings, so you can find the total time spent on each kind of operation.

Make out a separate form for each shuttle car. Use one line for each trip, as shown. Take "working time" from Forms A, and enter under the proper headings. Then total each column.

If the trip includes an operation that is repeated two or more times, total the "working time" for these operations and enter the total in the space provided.

Copy TE and TL distances from Form B. Remember that these distances change as working places change. Use "Remarks" column to note place changes, starting and quitting times, and any other relevant information.

Note that the sample form here is the summary of Shuttle Car No. 2, from pages 14 and 15.
3 Fill in Summary Form D for Loader. This form sums up loader operations, much as Form C sums up shuttle-car activity. Use one line for each load. Take "working time" from Forms A, and enter under the proper headings. Then total each column.

How to figure true CC

It is important to know the time during which the loader is ready to load, but the shuttle car is absent doing other productive work. Change-car time is calculated as follows:

1. Find on Form A (loader study) the time interval between the first departure of a shuttle car from the loader, and the next arrival of a shuttle car at the loader. This is called "apparent CC." It is the time that the loader is in position ready to load and the shuttle car is not available. Enter this time under "Apparent CC" on Form D.

2. Examine Form A (loader and discharge studies) for any unnecessary delays (US) that slowed the return of the shuttle car to the loader on that particular trip. Remember that US includes DMs, DS, DN and DO. Enter the total of such delays under "Affecting Delays—US" on Form D.

3. Examine Forms A for any HS "working time" that may have delayed the return of the shuttle car. Enter such time under "Affecting Delays—HS" on Form D.

4. Subtract the "Affecting Delays—HS" and "Affecting Delays—US" from "Apparent CC." Enter the result under "True CC."

5. Repeat these steps for each load in the study.

NOTE—Sometimes one shuttle car in a multiple-car system is disabled for several cycles during the time study. When this happens, it is best to sum up that part of the shift separately, covering only the cars that are operating.

Thus far, you have completed the basic time study. The figures you have gathered will be used, in the third step of the Combined Study, to analyze the productiveness of the section, its men and its machines.

But first, let's take a look at the section layout . . .
# Time Study of Loader and Shuttle Car Cycles

<table>
<thead>
<tr>
<th>MINE</th>
<th>SECTION</th>
<th>DATE</th>
<th>FIRST PLACE WORKED</th>
<th>OBSERVER</th>
<th>AT LOADER AT DISCHARGE AT</th>
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</thead>
</table>

<table>
<thead>
<tr>
<th>SHUTTLE CAR NO.</th>
<th>SHUTTLE CAR NO.</th>
<th>REMARKS</th>
<th>SHUTTLE CAR NO.</th>
<th>SHUTTLE CAR NO.</th>
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</thead>
<tbody>
<tr>
<td>Symbol</td>
<td>Observed Continuous Time</td>
<td>Working Time</td>
<td>Symbol</td>
<td>Observed Continuous Time</td>
</tr>
<tr>
<td>Symbol</td>
<td>Observed Continuous Time</td>
<td>Working Time</td>
<td>Symbol</td>
<td>Observed Continuous Time</td>
</tr>
</tbody>
</table>

**Starting Time**

---

**Symbols**:

- **L**—Loading Time
- **M**—Maneuvering Time
- **TE**—Traveling Empty
- **TL**—Traveling Loaded
- **D**—Discharging

- **WO**—Waiting for Other Car
- **DL**—Delays in Loading
- **HS**—Handling Supplies
- **PC**—Place Change

- **DMs**—Delays, Mechanical—Shuttle Car
- **DMl**—Delays, Mechanical—Loader
- **DS**—Delays at Discharge Station
- **DP**—Delays—Face Preparation
- **DN**—Delays—Natural Conditions
- **DO**—Delays, Other
# Field Data Form

<table>
<thead>
<tr>
<th>MINE</th>
<th>SECTION</th>
<th>DATE</th>
<th>SHIFT</th>
<th>NO. OF SHIFTS PER DAY</th>
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</table>

<table>
<thead>
<tr>
<th>NO. OF MEN IN SECTION</th>
<th>TONNAGE OF SHIFT STUDIED</th>
<th>AVERAGE SHIFT TONNAGE FOR PAST SIX MONTHS</th>
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</thead>
<tbody>
<tr>
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</table>

<table>
<thead>
<tr>
<th>PLACES WORKED</th>
<th>CUT</th>
<th>STANDBY POSITIONS</th>
<th>DISTANCE (FT.)—FACE TO DISCHARGE</th>
</tr>
</thead>
<tbody>
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## Equipment

<table>
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<tr>
<th>EQUIPMENT</th>
<th>TYPE</th>
<th>AGE</th>
<th>INTERVAL BETWEEN OVERHAULS</th>
<th>CAPACITY</th>
<th>REMARKS</th>
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<tr>
<td>Loader</td>
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<td>Shuttle Cars</td>
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<tr>
<td>Drills</td>
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<td>Cutter</td>
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<td>Discharge</td>
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<td>Mine Cars</td>
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<tr>
<td>Belt</td>
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<tr>
<td>Car Spotter</td>
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<tr>
<td>Other Equipment</td>
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508—5M—3-49
<table>
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<th>Remarks</th>
<th>Trip No.</th>
<th>L</th>
<th>M</th>
<th>TE Distance</th>
<th>TL Distance</th>
<th>D</th>
<th>WO</th>
<th>DL</th>
<th>HS</th>
<th>PC</th>
<th>DMs</th>
<th>DML</th>
<th>DS</th>
<th>DP</th>
<th>DN</th>
<th>DO</th>
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</tr>
<tr>
<td>Remarks</td>
<td>Load No.</td>
<td>L</td>
<td>M</td>
<td>Apparent CC</td>
<td>Affecting Delays US</td>
<td>Affecting Delays HS</td>
<td>True CC</td>
<td>DL</td>
<td>PC</td>
<td>DP</td>
<td>DML</td>
<td>DN</td>
<td>DO</td>
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</tbody>
</table>
This travel diagram was prepared from the map on Page 23. It permits a close study of gathering methods in the section. Such study often reveals conditions that can be improved in the existing layout... and shows how to streamline the section for most efficient future operation.
Streamlining the Section for Greatest Efficiency

Section methods may be analyzed by obtaining a map of the section and preparing from it an enlarged diagram that accurately shows how coal is transported from the face to the main-line transportation.

Include in your diagram the various places at which the loader works, and indicate clearly by what routes the gathering system serves each place.

In a shuttle-car system, diagram the travel route to each place. Also locate standby points, discharge stations, cable anchorages, battery stations, ventilation doors, and main-line transportation serving the section. To complete the diagram, show projected location of conveyors, discharge stations and battery stations as development proceeds.

In your analysis also consider: travel distances; seam thickness; width of travelways; direction and percent of grade; roof and bottom conditions; timbering; methods of discharging.

Careful study of the diagram may bring to light many conditions that interfere with smooth operation. In studying a shuttle-car system, watch particularly for: complicated travel routes that could be simplified; right-angle turns that could be eliminated by angling cross-cuts or by re-routing; standby points unnecessarily far from the loader, causing excessive change-car time; cable interference, especially at ventilation doors; discharge points accessible from only one side of the entry; track layouts inadequate to provide empties as needed.

For further information — An extensive treatment of this subject, including typical layouts, has been prepared by D. R. Mitchell and W. Bellino: Shuttle-Car Gathering Studies of Layout, Method and Performance, Mechanical (1946).
3 PRODUCTION STUDY

Rating the Section

Your final step is to take the facts you have gathered and boil them down into key Performance Ratings.

These ratings help to make section performance an open book. When compared with similar data, they indicate the relative productivity of the men and machines in the section.

The graphs (Figs. 1 to 18, inclusive) showing numerical averages, were constructed from actual case studies obtained during 1946 and 1947 in a survey covering a representative sample of U. S. coal mines.

Thus a technical basis has been established for comparing a section with other mechanized sections throughout the country. These comparisons show whether your productivity is above or below average. A study of contributing factors will indicate why.
How to calculate performance ratings

1. Use Master Summary Form. First fill in the shuttle-car and loader summaries on left side of form:
   a. Copy in time totals from Forms C and D.
   b. Calculate LZ, TZ, TKZ, TND, TUD and TYZ by adding time totals as shown. In each case, add items next to arrow to get item to which arrow points. (As a check, TVZ for each machine should equal the total time spent observing.)
   c. Figure the percentage of shift time taken by each operation, and enter under "% of TVZ."
   d. Note that each shuttle car is rated individually. This permits comparison between shuttle cars in the same section and with cars in other sections. Loaders are rated individually for the same purpose.
   e. Complete the summaries by copying in number of trips, number of loads, section personnel, travel distance and tonnage information from Forms B, C and D.

2. Calculate Performance Ratings. Follow directions on Master Summary. Use space provided for calculating. Copy totals and percentages needed from summaries at left side of form. Enter the results in "Your Rating" column.

3. Copy Averages from Graphs Below. Graphs on these two pages are numbered to correspond with Performance Ratings. Each bar on the graphs represents one unit studied. These units are divided into three groups according to seam height: low coal (less than 48") medium coal (48" to 71", inclusive); and high coal (72" and above). Average Performance Ratings for these sections are shown in red.
   Starting with Graph No. 1, find the average shift tonnage for sections in your seam height (low, medium or high). Copy this average into the "Average Rating" column on the Master Summary. Repeat with other averages for your seam height.
   Bars also show the range of sections studied, above and below the average. This enables you to compare your section with all sections graphed.

   NOTE—There is no graph for Performance Rating No. 4, "Ratio of Shift Tons to Average."

4. Interpret Results. Study performance ratings and compare them with the appropriate averages. Where ratings are unfavorable, analyze the contributing factors. Ratings that are particularly favorable can be analyzed in order that they may serve as examples for other sections. How to make this analysis is explained on Pages 26 and 27.
<table>
<thead>
<tr>
<th>PERFORMANCE RATING</th>
<th>USE TO:</th>
<th>PERFORMANCE RATING</th>
<th>USE TO:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. SHIFT TONNAGE</td>
<td>Predict new or improved section performance.</td>
<td>10. PRODUCTIVE USE OF SHUTTLE CAR</td>
<td>Concentrate efforts to increase and output will rise.</td>
</tr>
<tr>
<td></td>
<td>The output of an integrated production unit, the section.</td>
<td>11. AVERAGE DISTANCE PER ROUND TRIP</td>
<td>Evaluate section travel routes and layout. Determine value of time lost vs. move-up costs. Compare car types.</td>
</tr>
<tr>
<td>2. NUMBER OF MEN</td>
<td>Show productivity of labor in section. Estimate overall section costs.</td>
<td>12. AVERAGE SPEED TRAVELING EMPTY</td>
<td>Rate shuttle-car operators. Rate system of mining. Rate roadway maintenance. Predict theoretical cycle times. Predict new or improved section and layout performances. Indicate mechanical condition of shuttle cars. Compare types of shuttle cars.</td>
</tr>
<tr>
<td>IN SECTION</td>
<td></td>
<td>13. AVERAGE SPEED TRAVELING LOADED</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Indicate desired investigation of all delays, if low. Indicate desired investigation of speeds and travel routes of shuttle cars, if low. Concentrate efforts to increase, and production will rise. Indicate possibility of inefficient engineering layout and face preparation equipment.</td>
<td>15. AVERAGE DISCHARGE TIME PER TON</td>
<td>Predict new or improved section performance. Indicate slow loading due to maneuvering or poor face preparation. Indicate poor coordination of shuttle car and loader during loading. Indicate lack of loader preparation for shuttle car.</td>
</tr>
<tr>
<td>4. RATIO OF SHIFT</td>
<td></td>
<td>16. AVERAGE TIME AT LOADER PER TRIP</td>
<td>Indicate need to investigate loading and discharging, if this item is high and Item 18 is low.</td>
</tr>
<tr>
<td>TONS TO AVERAGE</td>
<td></td>
<td>The average time the shuttle car spends at the loader per trip.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>17. TON-MILES PER SHUTTLE-CAR-HOUR (Transportation Time)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A rating of the shuttle car indicating the ability of the car to transport material.</td>
<td></td>
</tr>
<tr>
<td>5. WORKING TIME</td>
<td></td>
<td>18. TON-MILES PER SHUTTLE-CAR-HOUR (Productive Time)</td>
<td>Indicate need to investigate speed, travel routes and roadways, if this item is high and Item 17 is low.</td>
</tr>
<tr>
<td>OF LOADER</td>
<td>Indicate loader operator technique. Indicate percentage of rated capacity used. Predict new or improved section performance. Indicate effectiveness of face preparation.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>The percentage of the shift that the loader is actively engaged in production.</td>
<td>6. TONS PER LOADER-HOUR</td>
<td>Predict new or improved section performance. Indicate slow loading due to maneuvering or poor face preparation. Indicate poor coordination of shuttle car and loader during loading. Indicate lack of loader preparation for shuttle car.</td>
</tr>
<tr>
<td></td>
<td>The average number of tons the loader loads for each hour worked.</td>
<td>7. AVERAGE LOADING TIME PER TON</td>
<td>Predict new or improved section performance. Indicate slow loading due to maneuvering or poor face preparation. Indicate poor coordination of shuttle car and loader during loading. Indicate lack of loader preparation for shuttle car.</td>
</tr>
<tr>
<td></td>
<td>The average time the loader requires to load one ton.</td>
<td>8. NUMBER OF TRIPS</td>
<td>Indicate need to investigate loading and discharging, if this item is high and Item 18 is low.</td>
</tr>
<tr>
<td></td>
<td>The number of “payloads” the shuttle car carries per shift.</td>
<td>9. TONS PER SHUTTLE CAR</td>
<td>Indicate need to investigate speed, travel routes and roadways, if this item is high and Item 17 is low.</td>
</tr>
<tr>
<td></td>
<td>The measure of the tonnage handled by each car per shift.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Instructions

A. Fill in loader and shuttle-car summaries directly below. Copy time totals and other information from Forms B, C and D. Calculate percentages of TYZ for Shuttle Car Totals and average time by adding time totals as shown. Enter in "% of TYZ" in "% of TYZ" column.

B. Calculate Section Performance Ratings in spaces at right. Enter "Average Ratings" from Bulletin, pages 24 and 25. Enter these in the proper spaces, and compare with your results.

C. Refer to Bulletin for analysis of ratings (page 26) and time percentages (pages 27 and 28).

### Shuttle-Car Summary—Totals from Form C

<table>
<thead>
<tr>
<th>Add Items</th>
<th>Shuttle Car No. 1</th>
<th>Shuttle Car No. 2</th>
<th>Shuttle Car No. 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>% of TYZ</td>
<td>Time</td>
<td>% of TYZ</td>
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<tr>
<td>L</td>
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<td>LZ</td>
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### Section Performance Ratings

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<tr>
<th>RATED ITEM</th>
<th>HOW TO CALCULATE</th>
<th>YOUR RATING</th>
<th>Average Rating</th>
<th>Desired Trend</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 SHIFT TONNAGE</td>
<td>Copy &quot;Shift Tonnage&quot; from Summary at Left</td>
<td>Tons</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 NUMBER OF MEN IN SECTION</td>
<td>Copy this item from Summary at Left</td>
<td>Men</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>3 TONS PER MAN-SHIFT</td>
<td>Shift Tonnage (Item 1 above) / No. of Men in Section (Item 2)</td>
<td>( ) Tons / ( ) Men</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 RATIO OF SHIFT TONS TO AVERAGE</td>
<td>Studied Shift Tonnage (Item 1) / Average Shift Tonnage (Copy from Summary at Left)</td>
<td>( ) Tons / ( ) Tons</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 WORKING TIME OF LOADER</td>
<td>Copy &quot;LZ%&quot; from Loader Summary at Left</td>
<td>Loader No. 1 %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 TONS PER LOADER/HOUR</td>
<td>Shift Tonnage or Loader Tonnage \times 60 / LZ Time, in Minutes</td>
<td>( ) Tons \times 60 / ( ) Min.</td>
<td>Loader No. 1 Tons/Hr.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 AVERAGE LOADING TIME PER TON</td>
<td>LZ Time / Shift Tonnage or Loader Tonnage</td>
<td>( ) Min. / ( ) Tons</td>
<td>Loader No. 1 Min./Ton</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 NUMBER OF TRIPS</td>
<td>Copy from Summary at Left</td>
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</tr>
<tr>
<td>9 TONS PER SHUTTLE CAR</td>
<td>Shift Tonnage \times No. of Trips / No. of Loads</td>
<td>( ) Tons \times ( ) Trips / ( ) Loads</td>
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<td></td>
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</table>
**LOADING SUMMARY—Totals from FORM D**

<table>
<thead>
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<th>Add Items Needed to Average TE Into Which Acme Points</th>
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<th>% of TYZ</th>
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<tr>
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<tr>
<td>DM</td>
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<tr>
<td>DO</td>
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<td></td>
</tr>
<tr>
<td>TUD</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>TYZ</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Loader No. 1</th>
<th>Loader No. 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>% of TYZ</td>
</tr>
<tr>
<td>L</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td></td>
</tr>
<tr>
<td>LZ</td>
<td></td>
</tr>
<tr>
<td>CC</td>
<td></td>
</tr>
<tr>
<td>TKZ</td>
<td></td>
</tr>
<tr>
<td>DL</td>
<td></td>
</tr>
<tr>
<td>HS</td>
<td></td>
</tr>
<tr>
<td>PC</td>
<td></td>
</tr>
<tr>
<td>TND</td>
<td></td>
</tr>
<tr>
<td>US</td>
<td></td>
</tr>
<tr>
<td>DM</td>
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<tr>
<td>DO</td>
<td></td>
</tr>
<tr>
<td>TUD</td>
<td>100.0</td>
</tr>
<tr>
<td>TYZ</td>
<td>100.0</td>
</tr>
</tbody>
</table>

**Shuttle Car Summary**

<table>
<thead>
<tr>
<th>Shuttle Car No. 1</th>
<th>Trips</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shuttle Car No. 2</td>
<td></td>
</tr>
<tr>
<td>Shuttle Car No. 3</td>
<td></td>
</tr>
</tbody>
</table>

**PRODUCTIVE USE OF SHUTTLE CAR**

<table>
<thead>
<tr>
<th>Shuttle Car No. 1</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shuttle Car No. 2</td>
<td>%</td>
</tr>
<tr>
<td>Shuttle Car No. 3</td>
<td>%</td>
</tr>
</tbody>
</table>

**AVERAGE SPEED TRAVELING EMPTY**

<table>
<thead>
<tr>
<th>Shuttle Car No. 1</th>
<th>Ft./Min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shuttle Car No. 2</td>
<td></td>
</tr>
<tr>
<td>Shuttle Car No. 3</td>
<td></td>
</tr>
</tbody>
</table>

**AVERAGE SPEED TRAVELING LOADED**

<table>
<thead>
<tr>
<th>Shuttle Car No. 1</th>
<th>Ft./Min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shuttle Car No. 2</td>
<td></td>
</tr>
<tr>
<td>Shuttle Car No. 3</td>
<td></td>
</tr>
</tbody>
</table>

**AVERAGE DISCHARGE TIME PER TRIP**

<table>
<thead>
<tr>
<th>Shuttle Car No. 1</th>
<th>Min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shuttle Car No. 2</td>
<td></td>
</tr>
<tr>
<td>Shuttle Car No. 3</td>
<td></td>
</tr>
</tbody>
</table>

**AVERAGE DISCHARGE TIME PER TON**

<table>
<thead>
<tr>
<th>Shuttle Car No. 1</th>
<th>Min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shuttle Car No. 2</td>
<td></td>
</tr>
<tr>
<td>Shuttle Car No. 3</td>
<td></td>
</tr>
</tbody>
</table>

**TON-MILES PER SHUTTLE-CAR-HOUR (Transportation Time)**

<table>
<thead>
<tr>
<th>Shuttle Car No. 1</th>
<th>Ton-Mi.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shuttle Car No. 2</td>
<td></td>
</tr>
<tr>
<td>Shuttle Car No. 3</td>
<td></td>
</tr>
</tbody>
</table>

**TON-MILES PER SHUTTLE-CAR-HOUR (Productive Time)**

<table>
<thead>
<tr>
<th>Shuttle Car No. 1</th>
<th>Ton-Mi.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shuttle Car No. 2</td>
<td></td>
</tr>
<tr>
<td>Shuttle Car No. 3</td>
<td></td>
</tr>
</tbody>
</table>

**THIS FORM CAN BE BLUEPRINTED**

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Litho in U.S.A.
Interpreting the Study

In interpreting the results of a study of this kind, there is no absolute criterion. Factors affecting the ratings are so numerous that many things cannot be called good or bad, right or wrong. Therefore the results should be analyzed by one who is familiar with the mine and its equipment, and understands the purpose and limitations of the study.

Comparisons should be made with: previous shifts; other sections; other mines; other systems; and published material.

The field work from which these ratings were compiled is still continuing, and the graphs on pages 24 and 25 are a sample of what is happening in the field today. Since shuttlecar units are comparatively new in mining, these ratings are far from ideal. Operators should not be satisfied with "average" performance, but should strive for ratings as high as possible above average.

Engineers and operating men are constantly improving machines and their use. It is fast becoming apparent that best ratings are obtained from sections specifically designed for mechanized mining.

**Table:**

<table>
<thead>
<tr>
<th>LARGE TIME TOTALS</th>
<th>INDICATE</th>
<th>LARGE TIME TOTALS</th>
<th>INDICATE</th>
</tr>
</thead>
</table>
| $D_{M_s}$ and $D_{M_L}$ | Faulty equipment  
Overloading  
Poor maintenance  
Unsuitability of machines |  |  |
| $D_S$ | Primary haulage operated inefficiently  
Primary haulage poorly coordinated with section requirements  
Discharge methods poor—particularly car spotting  
Poor engineering layout |  |  |
| $D_P$ | Poor maintenance of preparation equipment  
Poor coordination of preparation equipment  
Unsuitability of preparation equipment  
Poor section supervision  
Poor engineering layout |  |  |
| $D_L$ | Poor preparation (cutting and shooting)  
Bad seam conditions  
Poor loader operator |  |  |
|  |  | $D_N$ | Bad mining conditions  
Poor roadway and roof control  
Lack of runarounds for shuttle cars  
Lack of working places for loaders |
|  |  | $W_O$ and $C_C$ | Wrong standby position  
Too lengthy hauls  
Insufficient number of shuttle cars |
|  |  | $T_E$, $T_L$, $D_N$ and $D_L$ | Adverse natural conditions |
|  |  | $P_C$ | Slow tramming speeds  
Poor engineering layout  
Poor section supervision |
|  |  | $L$, $M$, $D_L$ and $D_O$ | Poor loader operator  
Inefficient operation of loader |
|  |  |  | Poor roadway maintenance  
Operator inefficient  
Poor machine maintenance  
Poor engineering layout |
Significant time totals

**Working Time of Loader (LZ%)** is the key to high section productivity. It is much too low in many instances. Investigate all delays that cause low Lz ratings. Check on shuttle-car speeds and travel routes which may prolong CC time, thus cutting down loader efficiency. If these are not at fault, examine face preparation methods and engineering layout. Increase loader working time to the maximum that can be handled by the rest of the section, and production will rise.

**Waiting for Other Car (WO).** This time total is much too high at a number of mines. The average for 95 units studied is 12.25% of total shift time. However, the range is from 1.11% to 26.78%, showing that at some mines poor layout and poor unit coordination cause the shuttle car to spend over one-fourth of the shift waiting for the other car to get out of the travelway.

**Place Change (PC).** The average for 74 sections is 8.59% of total shift time. The range is from 0.30% to 21.6%. Poor layout and inefficient supervision is indicated for sections in which a high percentage of the shift is used up by place changing.

**Maneuvering (M).** An average of 4.83% of the total shift time was found in 73 cases studied. The range is from 0.15% to 17.20%. A high percentage of the shift spent in maneuvering the loading machine indicates a poor operator, faulty face preparation, or bad roof.

**Mechanical Delays.** Tables at right analyze the items DMs and DML. About half the sections had shuttle-car breakdowns during the shifts studied—and those sections averaged better than two breakdowns each. The same is true of loading machine breakdowns. Next to mechanical breakdowns, cable failures were the greatest cause of lost time, both for shuttle cars and for loaders. Delays averaged more than 20 minutes in each case.

Totals indicate a general need for better maintenance procedure.

---

**Delays due to WO, PC and M in units studied**

<table>
<thead>
<tr>
<th>Type of Delay</th>
<th>No. of Units Studied</th>
<th>Average Delay (% of TY)</th>
<th>Minimum Delay (% of TY)</th>
<th>Maximum Delay (% of TY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WO</td>
<td>95</td>
<td>12.25</td>
<td>1.11</td>
<td>26.78</td>
</tr>
<tr>
<td>PC</td>
<td>74</td>
<td>8.59</td>
<td>0.30</td>
<td>21.60</td>
</tr>
<tr>
<td>M</td>
<td>73</td>
<td>4.83</td>
<td>0.15</td>
<td>17.20</td>
</tr>
</tbody>
</table>

**Loading machine equipment time losses from 74 loader studies**

<table>
<thead>
<tr>
<th>Type of Failure</th>
<th>No. of Studies</th>
<th>Total No. of Failures</th>
<th>Average Time Loss per Failure (Min.)</th>
<th>Minimum Time Loss per Failure (Min.)</th>
<th>Maximum Time Loss per Failure (Min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical Failures</td>
<td>32</td>
<td>75</td>
<td>14.58</td>
<td>0.05</td>
<td>217.65</td>
</tr>
<tr>
<td>Cable Failures</td>
<td>6</td>
<td>9</td>
<td>21.85</td>
<td>2.00</td>
<td>50.60</td>
</tr>
<tr>
<td>Main Power Failures</td>
<td>24</td>
<td>47</td>
<td>2.46</td>
<td>0.15</td>
<td>30.65</td>
</tr>
<tr>
<td>Lubrication and Inspection</td>
<td>16</td>
<td>25</td>
<td>5.27</td>
<td>0.30</td>
<td>24.85</td>
</tr>
</tbody>
</table>

**Shuttle-car equipment time losses from 122 shuttle-car studies**

<table>
<thead>
<tr>
<th>Type of Failure</th>
<th>No. of Studies</th>
<th>Total No. of Failures</th>
<th>Average Time Loss per Failure (Min.)</th>
<th>Minimum Time Loss per Failure (Min.)</th>
<th>Maximum Time Loss per Failure (Min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical Failures</td>
<td>60</td>
<td>126</td>
<td>15.88</td>
<td>0.10</td>
<td>290.20</td>
</tr>
<tr>
<td>Cable Failures</td>
<td>19</td>
<td>31</td>
<td>20.16</td>
<td>0.20</td>
<td>57.30</td>
</tr>
<tr>
<td>Battery Failures</td>
<td>13</td>
<td>28</td>
<td>13.37</td>
<td>0.05</td>
<td>62.15</td>
</tr>
<tr>
<td>Main Power Failures</td>
<td>35</td>
<td>66</td>
<td>3.19</td>
<td>0.15</td>
<td>30.65</td>
</tr>
<tr>
<td>Lubrication and Inspection</td>
<td>19</td>
<td>21</td>
<td>3.91</td>
<td>0.10</td>
<td>15.50</td>
</tr>
<tr>
<td>Change Batteries</td>
<td>23</td>
<td>25</td>
<td>18.07</td>
<td>6.60</td>
<td>41.90</td>
</tr>
</tbody>
</table>
## Use of Shuttle Car

### Depends upon Type of Service and Mine Conditions

The shuttle car has been used or may be applied for:
- gathering service in room-and-pillar, longwall and block systems of mining;
- transporting material from stopes to transfer raises;
- storage of waste underground;
- filling of stopes and worked-out areas;
- tunnel driving;
- handling supplies.

The layout and operation of shuttle-car sections require a careful consideration of many factors. Practice has been developed by a method of trial and error on the part of most mine operators. A proper layout and plan of operation are necessary to insure maximum production and a profitable operation.

At right is a list of factors that affect the choice of shuttle-car types.

### Table of Factors

<table>
<thead>
<tr>
<th>Mining and Other Conditions</th>
<th>Favorable to listed Shuttle-Car Type</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof:</td>
<td>Bad</td>
<td>Battery</td>
</tr>
<tr>
<td>Bottom:</td>
<td>Wet and soft</td>
<td>Cable</td>
</tr>
<tr>
<td></td>
<td>Wet and hard</td>
<td>Either type Battery Battery</td>
</tr>
<tr>
<td></td>
<td>Dry and soft</td>
<td>Battery Battery</td>
</tr>
<tr>
<td></td>
<td>Dry and hard</td>
<td>Battery Battery</td>
</tr>
<tr>
<td></td>
<td>Heaving bottom</td>
<td>Battery Battery</td>
</tr>
<tr>
<td>Inclination of seam; distance between synclines and pitch:</td>
<td>Over 1000 ft:</td>
<td>Cable Either type</td>
</tr>
<tr>
<td></td>
<td>Over 8 pct</td>
<td>Cable Either type</td>
</tr>
<tr>
<td></td>
<td>Under 8 pct</td>
<td>Cable Either type</td>
</tr>
<tr>
<td></td>
<td>Over 6 pct</td>
<td>Cable Either type</td>
</tr>
<tr>
<td></td>
<td>Under 6 pct</td>
<td>Cable Either type</td>
</tr>
<tr>
<td></td>
<td>Over 4 pct</td>
<td>Cable Either type</td>
</tr>
<tr>
<td></td>
<td>Under 4 pct</td>
<td>Cable Either type</td>
</tr>
<tr>
<td>Gas and dust:</td>
<td>Gassy and dusty</td>
<td>Battery Battery</td>
</tr>
<tr>
<td></td>
<td>Gassy and non-dusty</td>
<td>Battery Battery</td>
</tr>
<tr>
<td></td>
<td>Nongassy and dusty</td>
<td>Battery Battery</td>
</tr>
<tr>
<td></td>
<td>Nongassy and non-dusty</td>
<td>Either type</td>
</tr>
<tr>
<td>Ventilation equipment:</td>
<td>Doors</td>
<td>Battery Battery</td>
</tr>
<tr>
<td></td>
<td>Brattice cloth</td>
<td>Battery Battery</td>
</tr>
<tr>
<td>Thickness of seam:</td>
<td>High coal (over 6 ft.)</td>
<td>Either type</td>
</tr>
<tr>
<td></td>
<td>Medium (4 to 6 ft.)</td>
<td>Either type</td>
</tr>
<tr>
<td></td>
<td>Low (less than 4 ft.)</td>
<td>Battery Battery</td>
</tr>
<tr>
<td>Stowing or gobbing impurities underground:</td>
<td></td>
<td>Battery Battery</td>
</tr>
<tr>
<td>State or Federal laws and regulations:</td>
<td>Permissibility Three-conductor cable</td>
<td>Battery Battery</td>
</tr>
<tr>
<td></td>
<td>Separate split of air required for changing and charging</td>
<td>Battery Battery</td>
</tr>
<tr>
<td></td>
<td>Fireproof changing and charging stations</td>
<td>Battery Battery</td>
</tr>
</tbody>
</table>
These SUGGESTIONS Will Help You Get:

- Higher Efficiency
- Greater Safety
- More Tons per Man-Shift
- Lower Cost per Ton

Analysis of the data accumulated by the Penn State Combined Study Method, comparison with the survey results, and application of the following suggestions will lead to MORE PROFIT IN MECHANICAL MINING.

Step up loader output by seeing that coal is properly prepared. Remember that a loader is not a digging machine. Loader operator should keep both the right and left arms of the loader engaged in loose coal so the machine can load to capacity. Do not tram coal with the loader; keep shuttle car, mine car or conveyor under the boom.

Increase productive time. Design the section around the loading and gathering cycles. If shuttle cars are used, keep CC and WO time to a minimum with short haul distances, standby positions close to the loader, and runaround travel routes. Use as large shuttle cars as possible, consistent with easy handling. Avoid sharp turns and right angles.

Speed up shuttling and save power by keeping travelways level and dry. Time, labor and materials spent in maintaining a good roadway may return dividends in the form of increased production. Soft bottom may require leaving some bottom coal to keep cars from breaking through. In pitching seams, drive rooms and working places upgrade where possible, so loaded shuttle car travels downgrade.
**Keep shuttle cars rolling** with a full-time, well-enforced maintenance plan. Insist on routine machine inspections and overhauls. Keep maintenance records up to date. Put emphasis on timely lubrication and proper care of tires, batteries and cables. Spare parts and supplies should be spotted where they are quickly available in case of trouble.

**Save time, power and machines** by training drivers to operate shuttle cars smoothly and to make every motion count. Studies prove that careful driving prolongs shuttle-car usefulness, reduces costly time losses due to cable blowouts, and steps up the productive yield of batteries. Yet a careful driver can haul just as much coal as a "cowboy," if not more.

**Get the most out of batteries** by having a well-trained maintenance man responsible for their care. Change batteries during lunch, off shift, during production stoppages or during loader place changes. Do not allow section foremen to overtax batteries in an effort to increase production.

**Cut discharge time.** For best results, use largest mine cars permitted by size of mine openings. Install facilities that allow rapid unloading of shuttle car, and rapid spotting and moving of cars under the discharge head. Install side tracks or other facilities to permit a continuous supply of empties without delay.

**Streamline conveyor system.** Present belt installations may not have the capacity to handle shuttle-car discharges. If this is the case, much time may be lost discharging onto the belt. The use of a surge bin or belt feeder would speed up the production cycle. Belt stoppages due to lack of empty mine cars, insufficient storage, and inadequate or inefficient transfer equipment should be avoided by correcting the cause.

**Assure high efficiency** by making time and method studies before installing new equipment. Compare the section being studied with previous shifts, other sections, other mines, other types of systems, and latest published material. Use time, method and production studies regularly to check on the performance of existing sections, and to aid in planning new units.
How 4 Outstanding Sections Get High Productivity

Here are case studies that show the layout and methods used in four different mechanized sections to get high production and low unit cost.

These sections are not necessarily proposed as models to be followed. But they are better-than-average examples of what can be done by putting modern equipment and methods to work.

Each case study contains:

- A description of the section, its equipment, and the mining system used;
- a section map, with “close-ups” to show how coal is gathered;
- performance ratings based on time and production studies;
- time-total graphs showing how the shift was spent by each machine.
**Case Study "A"**

**HIGH-PRODUCTIVE SECTION NO. 192-A**

**Room Development**

**Performance Ratings** *(Room-and-pillar Work)*

1. Shift tonnage ............... 523
2. No. of men in section........ 181\(^{\frac{3}{4}}\)
3. Tons per man-shift........... 28.3
4. Ratio shift tons to average 1.05
5. Working time of loader.... 54%
6. Tons per loader-hour.... 63
7. Avg. loading time per ton .... 0.99 min.
8. No. of trips................. 48
9. Tons per shuttle car ........ 127
10. Productive use of shuttle car 62.3%
11. Avg. distance per round trip 820 ft.
12. Avg. speed traveling empty 227 ft./min.
13. Avg. speed traveling loaded 473 ft./min.
14. Avg. discharge time per trip 0.66 min.
15. Avg. discharge time per ton 0.25 min.
16. Avg. time at loader per trip 2.51 min.
17. Ton-miles per shuttle-car hour (transportation time) 442
18. Ton-miles per shuttle-car hour (productive time) ..... 199

**Physical Characteristics**
- Location of Mine—Pennsylvania
- Seam mined—Lower Kittanning
- Seam thickness—44 in.
- Seam grade—5 percent
- Thickness of cover—400 ft.
- Roof—hard shale
- Floor—shale under 10-in. bottom coal

**Mining Particulars**
- Mining system—room and pillar
- Entry widths—15 ft.
- Entry centers—65 ft.
- Entry lengths—1600 ft.
- Room widths—30 ft.
- Room centers—65 ft.
- Room lengths—700 ft.

**Equipment in Sections**
- Loading machines—2 crawler-mounted
  - Rated capacity—5 tons/min.
- Cutting machines—2 shortwall
  - Bar length—8 ft.
  - Cut and depth—undercut 7\(^{\frac{1}{2}}\) ft.
  - Mounting—self-propelled crawler truck
- Drills—electric
  - Mounting—hand-held
  - Holes per cut—5
- Shuttle cars—4 battery
  - Rated capacity—3 tons
  - Shuttle-car discharge—into elevating conveyor
- Cars spotted by—hoist
  - Mine-car capacity—3\(^{\frac{1}{2}}\) tons

**Section Personnel**
- \(\frac{3}{4}\) section foreman, 2 shotfirers, 2 cutting machine operators, 2 cutting machine helpers, 2 loading machine operators, 2 loading machine helpers, 4 shuttle-car operators, 2 elevator operators, 1 mechanic, 1 timberman. Total, 18\(^{\frac{1}{2}}\).

---

This system is specially designed for mechanical mining. All rooms are driven at a 60-degree angle with the butt entries and upgrade, so that the 5-percent grade favors the loaded cars.

Each panel is opened by driving three butt entries, 15 feet wide on 65-foot centers, for a total length of 1600 feet. Rooms are driven simultaneously on both sides of the entries in sets of three, 30 feet wide on 65-foot centers, to a depth of 700 feet, with crosscuts on 80-foot centers. There is a working unit on each side of the butt entries.

Shuttle cars discharge into an elevating transfer conveyor which in turn discharges into 3\(\frac{1}{2}\)-ton mine cars.

Studies were made on the loader and one shuttle car.
Case Study "B"

HIGH-PRODUCTIVE
SECTION NO. 072-A

Pillar Recovery

PHYSICAL CHARACTERISTICS
Location of Mine—Pennsylvania
Seam mined—Upper Freeport
Seam thickness—96 in.
Seam grade—2 percent
Thickness of cover—300 ft.
Roof—slate
Floor—lire clay

MINING PARTICULARS
Mining system—block
Entry and room widths—14 ft.
Enter and room centers—80 ft.
Crossect widths—14 ft.
Crossect centers—100 ft.
Pillar cuts, width—22 ft.
Pillar cuts, depth—9½ ft.

EQUIPMENT IN SECTION
Loading machine—1 crawler-mounted
Rated capacity—1½ tons/min.
Cutting machine—universal
Bar length—10 ft.
Cut and depth—undercut 9½ ft.
Mounting—Tire-mounted, self-propelled
Drill—electric
Mounting—post
Holes per cut—8
Shuttle car—1 cable-reel
Rated capacity—6 tons
Shuttle-car discharge—direct into mine cars
Cars spotted by—locomotive
Mine-car capacity—3½ tons

SECTION PERSONNEL
½ ½ section foreman, 1 driller, ½ shotfirer, ½ cutting machine operator, ½ cutting machine helper, 1 loading machine operator, 1 shuttle-car operator, 1 timberman, 1 motorman. Total 7.

BREAKDOWN OF SHIFT TIME
Percentages of TYZ

Shuttle Car

Performance Ratings
(Pillar Recovery)

1. Shift tonnage ................. 210
2. No. of men in section ....... 7
3. Tons per man-shift ......... 30
4. Ratio shift tons to average 1.27
5. Working time of loader .... 30.3 %
6. Tons per loader-hour ...... 93
7. Avg. loading time per ton .. 0.66 min.
8. No. of trips ................. 31
9. Tons per loader-hour ...... 210
10. Productive use of shuttle car 55%
11. Avg. distance per round trip 490 ft.
12. Avg. speed traveling empty 399 ft./min.
13. Avg. speed traveling loaded 303 ft./min.
14. Avg. discharge time per trip 1.92 min.
15. Avg. discharge time per ton 0.26 min.
16. Avg. time at loader per trip 4.55 min.
17. Ton-miles per shuttle-car-hour (transportation time) 828
18. Ton-miles per shuttle-car-hour (productive time) 145

METHOD OF TRAVEL

Rooms and entries are driven 14 ft. wide on 80-ft. centers. Crosscuts are driven 14 ft. wide on 100-ft. centers. Production in this section is obtained from recovery of pillars. Each cut in the pillars is 22 ft. wide and 9½ ft. deep. The coal is loaded by a crawler-mounted loading machine with a capacity of 1½ tons per minute. A cable-reel shuttle car with a capacity of 6 tons transports the coal to the discharge station where it is discharged directly into mine cars of 3½-ton capacity.
Case Study "C"

HIGH-PRODUCTIVE SECTION NO. 851-A
Room and Entry Work

PHYSICAL CHARACTERISTICS
Location of Mine—Illinois
 Seam mined—No. 5
 Seams thickness—56 in.
 Thickness of cover—250 ft.
 Roof—limestone over 72-in. shale
 Floor—fire clay

MINING PARTICULARS
Mining system—room and entry
Entry widths—16 ft.
Entry centers—36 ft.
Entry lengths—not yet determined
Room widths—24 ft.
Room centers—36 ft.
Room lengths—240 ft.

EQUIPMENT IN SECTION
Loading machine—1 crawler-mounted
cutters, 1 cutting machine operator, 1 cutting machine helper, 1 loading machine operator, 1 loading machine helper, 2 shuttle-car operators, 1 elevator operator, 1 mechanic, 1 timberman, 1 motorman, 2 ventilation men, Total 16½.

Performance Ratings (Room-and-entry Work)

1. Shift tonnage.......................... 412
2. No. of men in section............... 16½
3. Tons per man-shift................... 25
4. Ratio shift tons to average........ 1.00
5. Working time of loader.............. 54.9%
6. Tons per loader-hour................. 102
7. Avg. loading time per ton.......... 0.62 min.

SECTION PERSONNEL
1½ section foreman, 4 drillers, 1 cutting machine operator, 1 cutting machine helper, 1 loading machine operator, 1 loading machine helper, 2 shuttle-car operators, 1 elevator operator, 1 mechanic, 1 timberman, 1 motorman, 2 ventilation men, Total 16½.

The mine layout is based on quadruple room entries 16 feet wide on 36-foot centers.

The coal is shored by a breast machine, sideshore mounted on a caterpillar truck and equipped with a 9-foot cutter bar. A loading machine with a capacity of 5 tons per minute loads the coal into two 8-ton battery shuttle cars. The shuttle cars discharge into an elevating transfer conveyor which in turn discharges into 2-ton mine cars.

SECTION LAYOUT
Room and Entry Work
Two battery type shuttle cars
Case Study "D"

HIGH-PRODUCTIVE
SECTION NO. 051-A

Room and Pillar Work

Performance Ratings (Room Work)

1. Shift tonnage .......................... 221
2. No. of men in section ............... 8.5
3. Tons per man-shift .................... 26.0
4. Ratio shift tons to average ...... 1.34
5. Working time of loader ............. 30.7%
6. Tons per loader-hour ............... 84
7. Avg. loading time per ton ......... 0.81 min.
8. No. of trips .......................... 50
9. Tons per shuttle car ................. 221
10. Productive use of shuttle car .... 61.6%

11. Avg. distance per round trip ... 300 ft.
12. Avg. speed traveling empty ...... 258 ft./min.
13. Avg. speed traveling loaded ..... 307 ft./min.
14. Avg. discharge time per trip ... 0.90 min.
15. Avg. discharge time per ton ... 0.20 min.
16. Avg. time at loader per trip ... 3.59 min.
17. Ton-miles per shuttle-car-hour (transportation time) 704
18. Ton-miles per shuttle-car-hour (productive time) .... 140

Mounting—hand-held
Holes per cut—7
Shuttle car—1 cable-reel
Rated capacity—4 tons
Shuttle-car discharge—direct onto belt conveyor

SECTION PERSONNEL
1 section foreman, 1 driller, 1 shotfirer, 1 cutting machine operator, 1 cutting machine helper, 1 loading machine operator, 1 shuttle-car operator, \( \frac{3}{4} \) belt operator, 1 timberman. Total, 8 1/2.

Method of Travel
Room and-pillar panels are opened by driving three butt entries, 20 feet wide on 60-foot centers, for a total length of 1800 feet. Upon completion of these entries, rooms are started on the left side of the panel. Rooms are driven in sets of three, 20 feet wide on 50-foot centers, to a depth of 230 feet. Each panel consists of two units, one engaged in room development and the other in pillar recovery.

Both cable-reel shuttle cars in the section transport the coal to a 30-inch belt conveyor. This belt is advanced and withdrawn in 150-foot sections.
If you want more information

Here is a selected list of publications covering mechanical mining and the Combined Study Method. Many of the publications contain actual case studies.


We want more information

and will appreciate receiving copies of combined studies you make, to more accurately determine averages and to chart trends. Such information will be considered confidential and will not be used at any time in a manner to reveal the names of mines or cooperating companies.
MAIN BUILDING of the School of Mineral Industries houses the various departments of the school. Its 80,000 square feet of floor space contain one of the world's greatest collections of minerals, ceramic objects, paleontological specimens, metallurgical samples and mining equipment. In an art gallery on the main floor hang paintings representing every phase of the mineral industries.