Chapter 7. Shuttle Cars

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INTRODUCTION

A shuttle car is a self-propelled rubber-tired haulage vehicle designed specifically for underground mining, primarily in coal mines (see Figs. 1 and 2). The drive mechanism is located on the sides of the vehicle, and the load is carried in the center. A chain-and-flight conveyor distributes the load when the car is being loaded by a loading machine or continuous miner and also discharges the load onto a conveyor belt or into a mine car. As the name implies, the shuttle car shuttles back and forth between the working face and the unloading point and is not required to turn around. Shuttle cars have served as primary haulage in this country since 1940 and still perform this function in most coal mines today.

TYPES OF SHUTTLE CARS

Shuttle cars may be battery-powered, diesel-powered, or cable-reel electric powered. Battery-powered cars were used between 1940 and 1950, but are almost out of existence today because of their limited power. Diesel cars have been used in coal mines, but are used mostly in noncoal mines where rules and regulations are not as stringent. Also, objections by organized labor have limited the use of diesel-powered shuttle cars in coal mines. Today, the largest number of shuttle cars are cable-reel cars. Electric power is fed through a cable stored on a cable reel that may have a capacity from 152 to 244 m (500 to 800 ft), depending upon the size of the cable and the cable reel (see Table 1). This, of course, limits the travel of a shuttle car. However, time studies have shown that for the most efficient haulage cycle, the length of haulage should not exceed 91 m (300 ft). As haulage distance increases, the waiting time for the loader or miner becomes longer, and haulage efficiency suffers. Cable-reel cars are manufactured in standard hand and opposite standard hand models. A standard car has the operator's control on the left front side and the opposite standard car has the operator's controls on the right front. Generally a loader or miner operates with two shuttle cars, one of each type. This allows the trailing cable to lie on either side of the entry and prevents the cables from fouling each other.

Shuttle cars are designed to operate with either dc or ac power. Cars using dc power are designed for 250-v supply and ac cars are designed for either 440, 550, or 950 v, three-phase voltage. Most coal mines that are relatively level can use dc cars where dynamic braking is not required. For mines having steep grades (in excess of 15%) ac cars are used because ac traction motors have inherent dynamic braking and are safer when tramming downgrade.

A recent innovation in shuttle car design in the last five years has been the introduction of an ac/dc car. This design utilizes ac input power through the cable, and the power is rectified on the car to 250-v dc for traction motors. The pump motor and conveyor motor are powered by ac voltage. The main advantage of this design is efficiency—a much smaller cable may be used and the smooth operating characteristics of the dc traction motor is obtained. This prevents shock loading on the traction drive train, which is an undesirable feature of ac traction motors.

SHUTTLE CAR FEATURES

Elevating Discharge

Today, all shuttle cars are equipped with an elevating front conveyor that allows the shuttle car to discharge into a mine car or belt feeder without the use of ramps.

Hydraulic Power System

Today, all shuttle cars are equipped with an hydraulic power system. An hydraulic pump is driven by an electric motor which provides hydraulic power for steering, elevating the front conveyor, and powering the

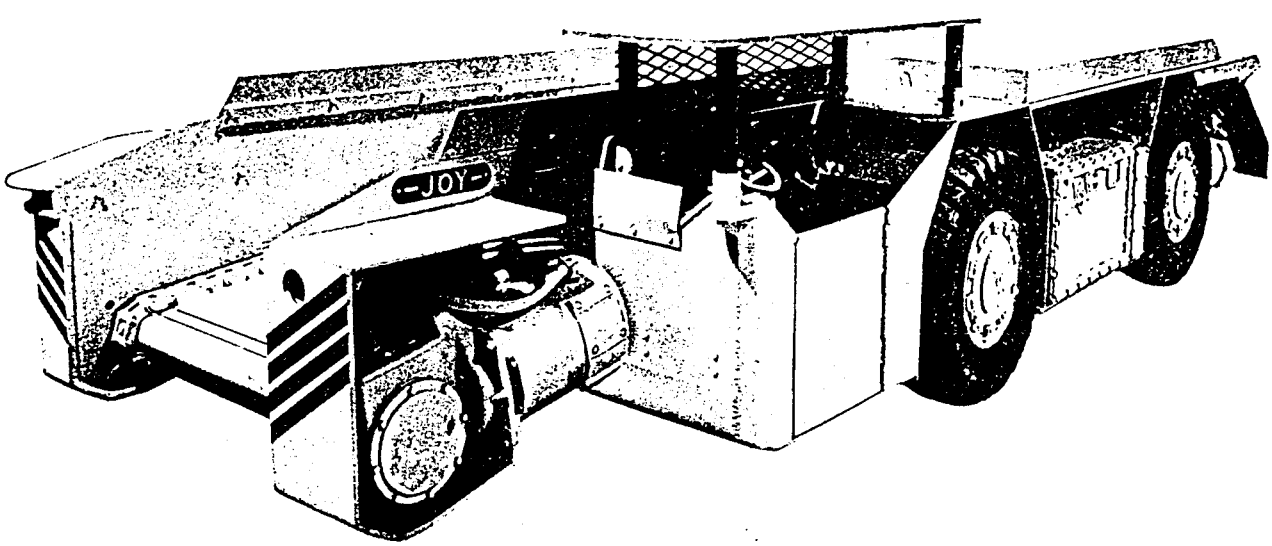

Fig. 1. One type of shuttle car (Model 10SC22B, Joy Manufacturing Co.).

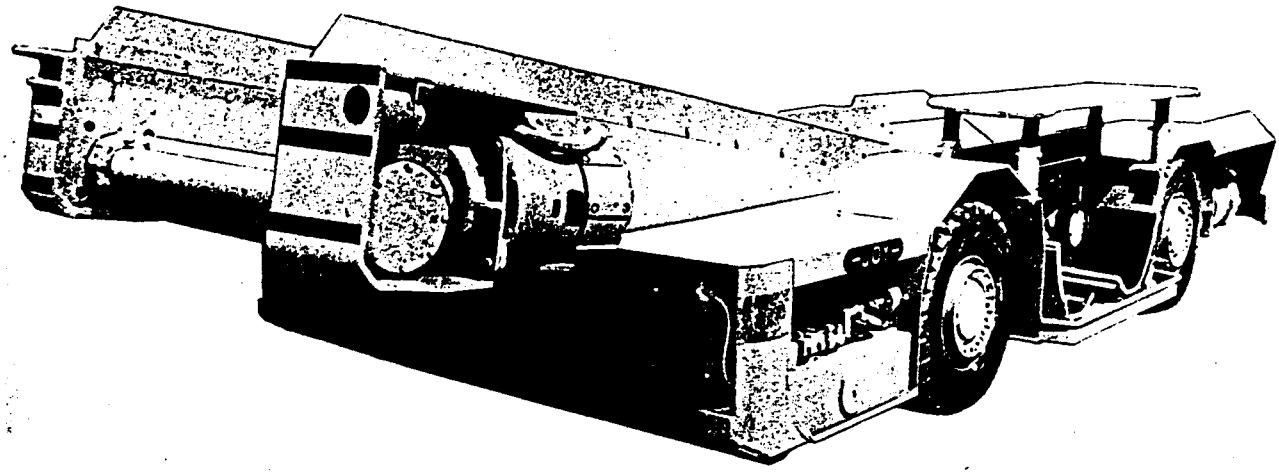

Fig. 2. Another type of shuttle car (Model 21SCB, Joy Manufacturing Co.).

cable reel, which automatically reels the trailing cable as required.

Brakes

Disk brakes are used on all modern shuttle cars. They are hydraulically operated and are designed to provide safe operation in the conditions found in underground mines. Automatic emergency brakes are a recent improvement. These are spring-loaded, hydraulically released brakes energized automatically if power is cut off or if failure of the service brakes should occur.

Models

Shuttle cars are available in different sizes and types to fit various mining conditions. Most cars today use four-wheel drive and four-wheel steering. The lowest models may be used for coal seams as low as 664 mm (34 in.), and the larger models may be used in the highest seams found in this country. All models built today are permissible, and all electrical components are enclosed in explosion-proof compartments that have been tested by the Mine Safety and Health Administration (MSHA). Each carries a permissible plate, and the purchaser must maintain the permissible features throughout the life of the car.

Table 2 gives the specifications for cars manufactured by one major company in 1976.

OPERATION

Shuttle cars generally are used in pairs on either a conventional section or a continuous-miner section. Fig. 3 shows shuttle cars on a continuous miner three-entry section, and Fig. 4 shows a conventional five-entry section. Each shuttle car follows a different route from the face to the belt feeder to increase the haulage efficiency. Cycle times vary according to mine conditions and length of haul, but a typical haulage cycle on a 91 to 122 m (300 to 400 ft) haul would be:

Loading time	60 sec
Hauling to feeder	75 sec
Unloading time	30 sec
Tramming to face	75 sec

This gives a total cycle time of 4 min, providing a theoretical 15 trips per hr. In seams 1.8 m (6 ft) and higher, the maximum haulage capacity would be from 91 to 136 t (100 to 150 st) per hr.

The length of haul is governed by the length of cable that can be stowed on the cable reel. In the lower seam models, the capacity of the reels is less than 152 m (500 ft). In larger models, cable reels are capable of stowing up to 244 m (800 ft) of cable. However, the length of cable is governed by rules and regulations set forth by MSHA. The maximum length of cable allowed depends upon the size of cable used. Table 1 shows the maximum allowable length of cable according to cable size.

Larger cars obviously require larger cable sizes. A car using 37 kW (50 hp) traction motors requires a No. 1/0 cable to handle the required current and to prevent cable overheating. Smaller cars with 15 kW (20 hp) traction motors may require only a No. 6 ac cable or No. 3 dc cable.

Table 1. Allowable Cable Length According to Cable Size (per MSHA Regulations)

Cable size	Length of cable, m (ft)
AWG No. 6	168 (550)
AWG No. 4	183 (600)
AWG No. 3	198 (650)
AWG No. 2	213 (700)
AWG No. 1	229 (750)
AWG No. 1/0	244 (800)

SELECTION FACTORS

In applying shuttle cars to a particular mine, it is judicious to consider a number of points. Obviously, the largest car that can be used safely is the first point to consider. Room layouts are available from all manufacturers to help select a particular model for the required mine or section of mine. Grade conditions and the electrical power system of the mine determine the type of power supply to the car. For level mines, 250-v dc or 440-550-v ac for ac/dc models are the best selection. For steep grade operation, 440-550-v ac with ac traction motors is the best selection. Power requirements for the traction motors can be calculated rather

Table 2. Specifications for Typical Shuttle Cars *

	Model A	Model B	Model C	Model D	Model E
Height, in.	28.5	34	40	50	52.5
Length, ft-in.	25-0	25-6	26-9	26-9	26-9
Conveyor width, in.	48,56,64	48,56,64	40,48,56,64	40,48,56,64	40,48,56,64
Overall width, in.	110-126	104-120	96-120	96-120	96-120
Capacity, cu ft	105-220	140-255	140-285	230-410	230-410
Max rating, st	7.5	7.5	12	12	12
Traction motors (dc)	20	20	30	30	35
Traction motors (ac)	n.a.	n.a.	40	40	50
Conveyor motor (dc)	20	20	30	30	30
Conveyor motor (ac)	25	25	25	25	30
Total horsepower (dc)	60	60	100	100	110
Total horsepower (ac)	65	65	115	115	140
Tire size	8.25 x 15	10.00 x 15	12.00 x 20	12.00 x 20	12.00 x 24
Ground clearance, in.	6.5	8	10	10	12.5
Weight, lb	24,500	26,500	32,000	33,000	34,000
Approx. cost	$100,000	$108,000	$114,000	$114,000	$131,500

* Metric equivalents: in. × 25.4 = mm; ft × 0.304 8 = m; cu ft × 0.028 316 8 = m³; st × 0.907 184 7 = t; hp × 0.746 = kW; lb × 0.453 592 4 = kg.

easily using the following formulas and sample calculations.

Tractive Factors

Rolling Resistance (RR): For most mine conditions, a factor of 50 kg/t (100 lb per st) may be used as the rolling resistance for a shuttle car.

Grade Resistance (GR): The grade resistance is the force required to overcome the gravitational force of a shuttle car when operating on grades. Grade resistance is equal to 10 kg/t (20 lb per st) for each percent of grade.

Tractive Effort (TE): Tractive effort is the total force delivered by the traction motors and drive line to the wheels of the shuttle car. When this force is greater than the sum of rolling resistance plus grade resistance the car will move. When the TE force becomes greater than the product of the weight of the shuttle car and the coefficient of adhesion between the tires and the ground, the wheels will slip. Drive lines for shuttle cars are designed for 100% adhesion, although in mining conditions, it generally is not possible to have more than 60%

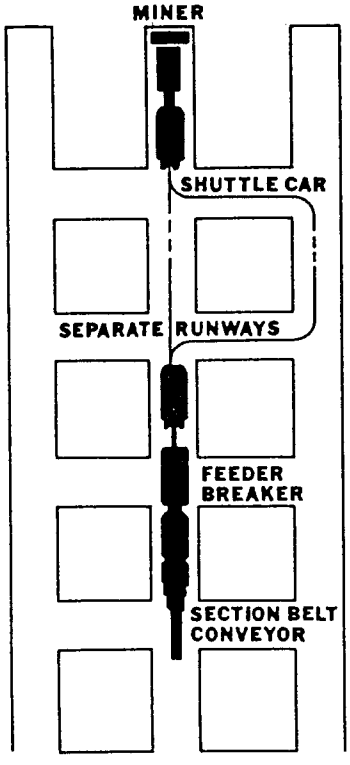

Fig. 3. Three-entry continuous miner section.

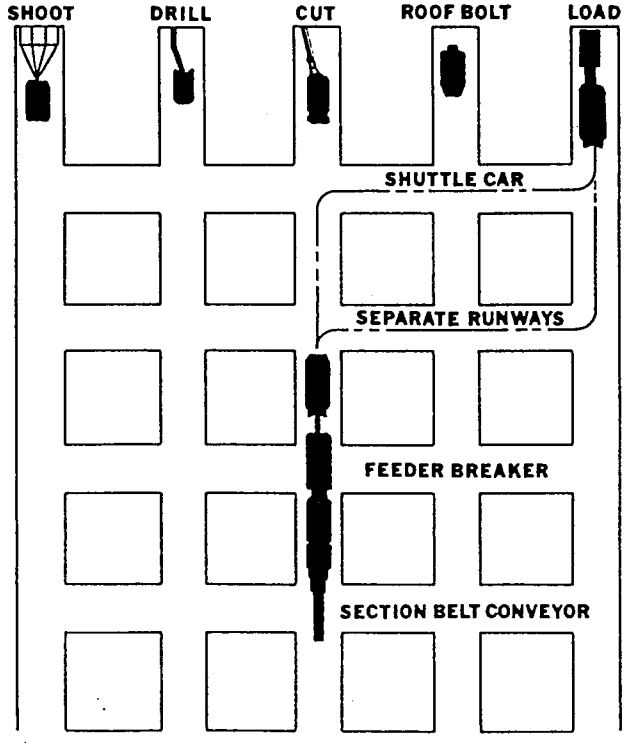

Fig. 4. Five-entry conventional section.

adhesion. This becomes a safety factor that generally takes care of the shock loading and abuse in operation.

Efficiency: The efficiency of shuttle-car drive lines usually is around 85%. This factor must be allowed for in determining power requirements of traction motors.

The following example shows how power requirements may be determined for a hypothetical application:

Loaded weight of car (W) = 27.2 t (30 st)
Speed desired (km/h) = 4.00 km/h
(mph) = 2.5 mph
Grade (G) = 10%
Rolling resistance (RR) = 50.0 kg/t (100 lb per st)
Efficiency (E) = 85%

$$kW = \frac{TE \times km/h}{367 \times E}$$

$$hp = \left(\frac{TE \times mph}{375 \times E} \right)$$

$TE = RR + GR = 50\ kg/t \times 27.2\ t + 10\ kg/t \times 10\% \times 27.2\ t$
$TE = RR + GR = 100\ lb\ per\ st \times 30\ st + 20\ lb\ per\ st \times 10\% \times 30\ st$
$TE = 1360\ kg + 2720\ kg = 4080\ kg$
$TE = 300\ lb + 6000\ lb = 9000\ lb$

$$hp = \left(\frac{9000 \times 2.5}{375 \times 0.85} \right) = 70.6$$

$$kW = \frac{4080 \times 4.0}{367 \times 0.85} = 52.7$$

For a shuttle car having two traction motors, this means that each traction motor is required to produce 25 kW (35 hp) for this particular condition. It should be kept in mind that the maximum energy a motor can produce is several times the nameplate rating. Motor ratings are based on the thermal capacity of any given motor, and mine rated motors generally are rated on a 1-hr basis without exceeding a certain temperature rise. Most dc traction motors can produce up to three to four times their nameplate rating for short periods of time. Alternating-current traction motors are a special design, and they also can produce much more energy for short periods than what is indicated on their nameplates. For specific applications, the user should consult with the manufacturer to choose the traction motors for a particular model.

New Mandatory Safety Standards

Mandatory safety standards for shuttle cars in underground coal mines have been imposed under the authority of the Federal Coal Mine and Safety Act of 1969.

Major safety standards encompass fire suppression, cabs and canopies, panic bars, and emergency brakes. The new law stipulates that shuttle cars must be equipped with automatic fire suppression systems such as carbon dioxide, water, or dry-powder systems. Nearly all manufacturers have chosen the dry-powder system to be the most practical for underground use. The law offers the option of using fire-resistant hydraulic fluid in lieu of a fire-suppression system. Cabs and canopies also must be attached to the frame of the shuttle car to protect the operator in case of roof falls. These cabs or canopies must withstand a uniform load of 8 t (9 st) without failure of the structure.

Panic bars must be included as a safety stop switch to cut the power to the traction motors in case of an emergency.

Emergency brakes must be included in the braking system. These generally are integrated with the panic bars so that when the power to the traction motors is interrupted, the emergency brakes actuate and stop the car in a short distance. Most brakes are hydraulically released and spring actuated.

Explicit details for these provisions are included in the Mine Safety Act and further information can be requested from MSHA.