

Copyright 1915. By A. I. E. E.
(Subject to final revision for the Transactions.)

THE MODERN ELECTRIC MINE LOCOMOTIVE

BY GRAHAM BRIGHT

ABSTRACT OF PAPER

The day of the small mine with small equipment is passing, and in the future most of the bituminous coal mining will be accomplished in larger mines using heavy equipment. The demand for larger capacity in equipment has been increasing rapidly of late, and owing to the restricted space available for the equipment on a mine locomotive, difficulty is being experienced in designing equipment to meet the conditions. A possible solution of the problem is in providing forced ventilation for the motors which are of a type that require very little ventilation to produce a large increase in the continuous rating. This scheme has been tried out on a large locomotive and the results indicate that forced ventilation will play a prominent part in meeting the extreme severe conditions that are frequently arising in the mine locomotive field.

THIS paper will deal with a particular phase toward which some of the new mine locomotives are tending.

Motors for mine locomotives are rated in the same manner as the railway motor, that is, the one hour rating with a rise of 75 deg. cent. This rating unfortunately does not determine the fitness of the motor to meet a certain set of conditions in mine service. The mine motor is essentially an entirely enclosed motor so that the losses must be dissipated by conduction through the casing. In a locomotive with a box type frame, the air about the motor is trapped in, so that very little ventilation is obtained. With the open bar type frame the conditions are not so bad, as considerable ventilation is obtained around the motor.

The continuous rating of a mine motor is generally given at a reduced voltage since the average voltage applied to the motor in service is considerably below normal. This rating will be found to range from 35 per cent to 50 per cent of the hour rating of the motor depending upon the capacity, speed and design. It is a much simpler proposition to design a motor to give a high one hour rating than it is a high continuous rating. The hour rating depends largely upon the amount of material in the

Manuscript of this paper was received July 22, 1915.

motor and consequently its thermal capacity. The continuous rating, however, depends upon the distribution of the material, the distribution of the losses and the ventilation. The majority of mine operators buy motors on the one hour rating, while the real capacity of a locomotive for all day service depends upon the continuous rating of its motors. For a given set of conditions the root-mean-squared current can be readily determined from a characteristic motor curve and this root-mean-squared current should not exceed the continuous capacity of the motor if the motor is not to be overloaded.

A number of operators and some engineers advocate a rating of so many horse power per ton weight of locomotive. This method may meet a great many conditions, but at times fails utterly. Unless the speed is high, a high horse power per ton cannot be utilized owing to the limited adhesion of the wheels.

The limiting dimensions, weight, gage, and rail, greatly handicap the design of a mine locomotive, and in the last few years the operating conditions have become difficult to meet owing to the increase in length of haul, weight of cars, and number of cars to be handled per trip. Some manufacturers have endeavored to meet these conditions by increasing the one hour rating of the motor while manifestly the proper thing to do is to increase the continuous rating.

About a year ago the author had occasion to estimate on a 24-ton locomotive to meet some very severe conditions. The haul was long and the grade against the loads. One manufacturer had three 85-h.p. motors as the maximum available for the equipment. According to calculations this equipment was not large enough although on a horse power per ton basis it seemed amply large (a little over 10 h.p. per ton). A second manufacturer offered a 25-ton locomotive equipped with three 115-h.p. motors.

The customer decided to try out both kinds and two locomotives of each make were installed.

The following tests made some time after the locomotives were installed clearly indicate that the high one hour rating of 115 h.p. was obtained at the expense of the continuous rating so that the 85 h.p. motor is really the larger of the two.

Both locomotives were operated in all day service and a complete record kept of the cars handled, the grades, the distances and the weights. This service was, however, much lighter than was originally specified. Table I shows the results of the

test made with the locomotive equipped with three 85-h.p. motors.

The temperatures given are actual temperatures, so that the rise indicates that the equipment is working right up to the limit and any further load added would shorten the life of the motors so that satisfactory service could not be obtained. The actual number of cars handled was about 75 per cent of the number originally specified.

Table II shows the results with the 25-ton locomotive using three 115-h.p. motors. It will be noted from this table that the work done by the 24 ton locomotive was 42 per cent greater than the 25 ton locomotive equipped with the larger motors.

TABLE I—24-TON LOCOMOTIVE
Equipment, three 85-h.p. 500-volt motors

Distance	Grade	Pull in lbs. per car.	Work done in lb-ft.
700	0	47.5	33,300
1400	2.5	142.5	200,000
1800	1.0	85.5	153,000
1600	0.425	63.5	101,100
2400	2.5	142.5	342,000
1450	1.1	89.5	130,000
1750	2.5	142.5	249,000
1880	1.06	88.0	165,500
600	3.3	173.0	104,000
Total.....			1,477,900
Total pound miles per car....			279
Total pound miles for 725 cars			202,300

AIR TEMPERATURE 20 DEG. CENT.

	Armature	Commutator
No. 1 motor	95 deg.	97 deg.
No. 3 motor	92 deg.	97 deg.

The temperature of the motors on the 25-ton locomotive will average but two degrees lower than that of the motors on the 24-ton locomotive, showing that although the latter was doing 42 per cent more work, the temperature of its motor was practically the same as on the 25-ton locomotive, whose motors are supposed to have 37 per cent greater capacity. No doubt some of the increase in actual capacity of the 85-h.p. over the 115-h.p. motor is due to the fact that the 24-ton locomotive is equipped with the open steel bar frame which allows considerable ventilation around the motor frames, while the 25-ton locomotive is equipped with a slab steel frame which pockets the air and permits of very little ventilation. The temperature of one

motor of a second 24-ton locomotive, operating at the same time and doing about 10 per cent more work than the first, was found to have practically the same rise.

As before stated, the service conditions are becoming more severe each year until conditions are sometimes submitted that cannot be met with by any of the standard equipments from a heating standpoint. The author has had in mind for the last few years that the time is coming when forced ventilation would be necessary to meet such cases. Forced ventilation has been used very successfully for the last nine or ten years on large main line locomotives. As this particular in-

TABLE II—25-TON LOCOMOTIVE
Equipment, three 115-h.p. 550-volt motors

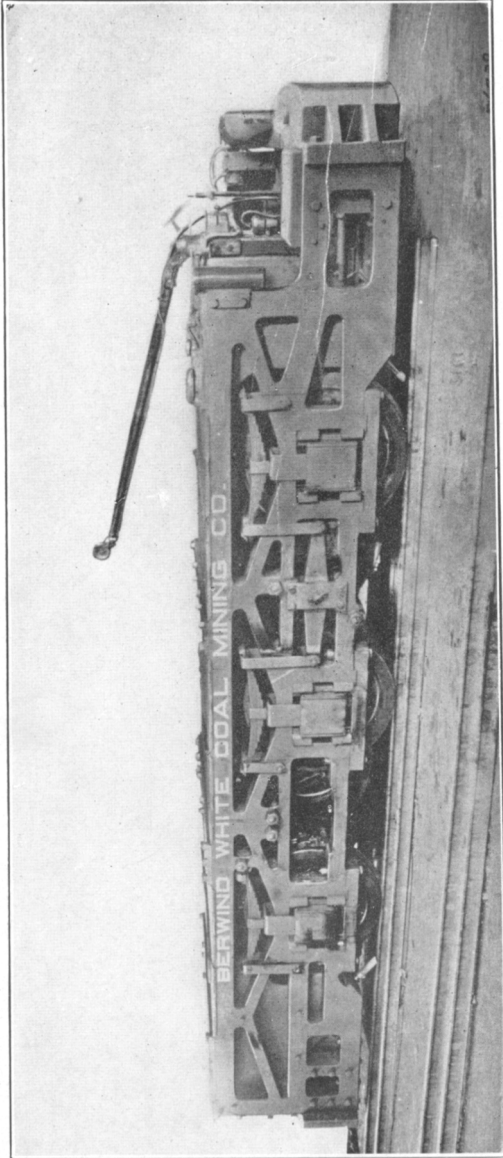
Distance	Grade	Pull in lb. per car.	Work done in lb.-ft.
700	0	47.5	33,300
1400	2.5	142.5	200,000
1800	1.0	85.5	153,000
1600	0.425	63.5	101,000
2400	2.5	142.5	342,000
600	1.1	89.5	54,000
Total.....			883,300
Total pound miles per car.....			167
Total pound miles for 851 cars.....			142,000

AIR TEMPERATURE 20 DEG. CENT.

	Armature	Commutator
No. 1 motor	92 deg.	95 deg.
No. 3 motor	92 deg.	95 deg.
Rating of 25-ton locomotive.....		345 h.p.
Rating of 24-ton locomotive.....		252 h.p.
Work done by 25-ton locomotive.....		142,000 pound-miles
Work done by 24-ton locomotive.....		202,300 pound-miles

stallation seemed to be such a case, permission was requested of the operating company to allow the manufacturer to install a small fan at one end of the locomotives to blow air through a duct to be so mounted that air could be delivered to the rear end of each motor. The commutator lid was raised around the edges a small amount to permit the air to escape. From 200 to 300 cu.ft. of air per minute was supplied to each motor. The motor driving the fan required about one h.p.

Before installing the fan in the locomotive a test was made on a single motor mounted on the test floor at the factory. The result of the test showed that with about 300 cu. ft. of



[BRIGHT]

FIG. 1—MINE LOCOMOTIVE WITH FORCED VENTILATION

air per minute passing through the motor the continuous rating could be nearly doubled. Since the continuous rating of a large slow-speed motor of this type without ventilation is only about 40 per cent of the one hour rating it will be seen that with ventilation this continuous rating is still considerably below the one hour rating.

Owing to the dusty condition of the mine it was thought that trouble would be experienced by the motors being filled with dirt. During the heavy pull when bringing the trip out a great deal of dust is raised and the operators decided to run the fan only while the locomotive was going in with the empty trip.

The results have been surprising both in regard to temperature rise and the condition of the motors.

Table III shows the result of a test made by the operating

TABLE III

	Three 85-h.p. motors	Three 115-h.p. motors
Mine air at beginning of test.....	25 deg. cent.	25 deg. cent.
Motor frame.....	35 "	35 "
Motor armature.....	42 "	42 "
Mine air at end of day.....	25 "	25 "
Motor frame at end of day.....	75 "	93 "
Motor armature at end of day.....	97 "	121 "

company on the locomotive with blower, and a locomotive equipped with 115-h.p. motors without a blower. The load conditions were much more severe than on the original test and the latter locomotive was doing about 5 per cent more work than the former.

The results shown in Table III were obtained with the fan on the 24-ton locomotive operating considerably less than 50 per cent of the time. An inspection of the inside of the motors showed that they were much cleaner than the ones not using forced ventilation. The results of the tests show conclusively that the increased capacities that are being demanded can be economically met by the use of forced ventilation with standard motors if these motors are properly designed. This will prove quite a saving to the operators, since without forced ventilation new and expensive motors would have to be signed.

It is the intention now to install a blowing equipment on the other 24-ton locomotive and on both locomotives equipped with 115-h.p. motors. It is not probable that the 115-h.p. motor will receive as much benefit from forced ventilation as the 85-h.p. motor, due to the fact that the armature of the 85-h.p. motor is furnished with ventilating slots while the 115-h.p. motor is not.

Fig. 1 is an illustration of the 24-ton locomotive, and with its ventilating equipment it has a greater capacity than any other mine locomotive yet built.
