Calculations

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Train Weight

The weight of a train in service is constantly changing. As it is being unloaded or loaded the weight changes are rapid and pronounced. The same thing happens during switching when railcars are picked-up or dropped-off. Even the burning of the fuel and the use of sanding has a small affect on the weight of the train. The motive power used must be able to move the train at an acceptable speed while safely controlling it at its maximum weight and when its weight and speed change in each application. Train weight, bearing resistance, grades, curves, track type, track conditions, temperature, and weather all affect the amount of resistance force that must be overcome in order operate the train. The train weight is the total weight of all of the elements of the train at any given point in time. The elements include the railcars, locomotives, and any mobile railcar movers that make up the train and move with the train. The maximum train weight is the first thing to consider in order to select the type and size of the motive power in any application.

Rolling Resistance

Rolling resistance is the second thing to consider in order to select the type and size of the motive power in any application. Rolling resistance is the resistance per ton of train that must be overcome by the motive power to start, accelerate, and maintain the train at an acceptable speed at each point of time over the track system where it operates. There are two basic types of rolling resistance: Starting resistance to get the train moving from a dead stop and velocity resistance to accelerate the train or keep it moving at a constant velocity. Velocity head is the negative of velocity resistance can be used to help a train climb grades. Its basically the inertia in a running start at the grade. Starting resistance and velocity resistance must both be overcome by the tractive effort and tractive-horsepower of the motive power. Tractive effort is the force that can be generated without slipping the railwheels on the motive power. Tractive-horsepower is the amount of horsepower being applied to the railwheels without exceeding the available tractive effort of the motive power. Tractive effort applied to the wheels is less than or equal to the magnitude to the rolling resistance as long as wheel slip doesn't occur; it is common in the railroad industry to simply refer to both types of these forces as tractive effort. A unit of motive power is rated at a rail speed that equates to its maximum horsepower and its maximum tractive effort for starting and running. The rating of the motive power should always be higher than the requirements of the application.

Tractive Effort

The term motive power can mean a locomotive or a mobile railcar mover like a TRACKMOBILE®. Tractive effort is the amount of force in foot-pounds that the motive power must produce to move a train without slipping the wheels. The term "drawbar pull" is seldom used when talking about motive power. It is the force required to move the entire train except for the motive power equipment being used to pull the train. Tractive effort is simply the sum of the drawbar pull plus the force required to move that motive power equipment itself; locomotive or mobile railcar mover.

To calculate the amount of tractive effort required for a locomotive or Trackmobile to start and move a train it is necessary to understand the difference between the three types of "TE" tractive effort: "STE" starting tractive effort; "CRTE" continuous running tractive effort; and "RTE-X" maximum short term running tractive effort for X minutes. The equation to calculate tractive effort is: TE = effective machine weight x adhesion coefficient. Note that horsepower isn't part of the calculation for tractive effort.

STE is the amount of tractive effort that must be produced by the motive power to start moving a train from a dead stop without slipping the wheels. CRTE is the amount of tractive effort required to keep a train in motion continuously long term without slipping the wheels or overheating the generator or traction motors. RTE-X is the amount of tractive effort required, short term, to climb a grade or move through a sharp curve. RTE-X will generally not exceed 120% of the CRTE for a short period of time; (X). The allowable time period varies depending on the type of motive power used and the type of traction motors. It is limited by overheating of the traction motors, alternator/generator, and/or engine on a locomotive. Likewise, it is limited by overheating of the transmission and/or engine on a mobile railcar mover.

Calculation of Tractive Effort (in foot-pounds per ton of train):

STE: Grade: 20 lbs. per ton of train per percent of grade

Curves: 1.25 lbs. per ton per deg. of curve in 57" gauge curves
2.50 lbs. per ton per deg. of curve in 56-1/2" gauge curves
10.00 lbs. per ton per deg. of curve in <56-1/2 inch gauge

Bearing Resistance: 10.0 lbs. per ton at 50°F
Add 0.1 lbs. per degree F below 50°F
Subtract 0.1 lbs. per degree F above 50°F

Track Resistance: For 130 lb. rail use 0 lbs. per ton
For 115 lb. rail use 1 lb. per ton
For 100 lb. rail use 2 lbs. per ton

Track Conditions: Good rail and crossties 0 lbs. per ton
Poor rail and fair crossties 2 lbs. per ton.
Poor rail and poor cross ties 7 lbs. per ton.

Weather Resistance: Wet rail 2 lbs. per ton
Ice/snow on the rails 10 lbs. per ton

Foreign Materials: Examples: oil, grease, mud, standing water, etc.
This has to be evaluated on a case by case basis
with an on site track survey.

It may be necessary to calculate the STE for each element of the train individually if the calculation is required to be as accurate as possible. It is important to note that these calculations are most often conservative so as to insure that the motive power will be sufficient in all anticipated conditions.

CRTE: Grade: 20 lbs. per ton of train per percent of grade

Curves: 0.50 lbs. per ton per deg. of curve in 57" gauge curves
1.75 lbs. per ton per deg. of curve in 56-1/2" gauge curves
7.00 lbs. per ton per deg. of curve in <56-1/2 inch gauge

Bearing Resistance: 3.0 per ton at 50°F

Track Resistance: For 130 lb. rail use 0 lbs. per ton
For 115 lb. rail use 1 lb. per ton
For 100 lb. rail use 2 lbs. per ton

Track Conditions: Good rail and crossties 0 lbs. per ton
Poor rail and fair crossties 2 lbs. per ton.
Poor rail and poor crossties 5 lbs. per ton.

Weather Resistance: Wet rail 1 lbs. per ton
Ice/snow on the rails 5 lbs. per ton

Foreign Materials: Examples: oil, grease, mud, standing water, etc.
This has to be evaluated on a case by case basis
with an on site track survey.

RTE-X: This will vary from CRTE up to 1.20 x CRTE depending on the type of motive power used. The time period "X" will vary depending on the amp load, the type/size of the traction motors, and the traction motor cooling capacity.

Four Axles vs. Two Axles

Switcher and road switcher locomotives have two trucks that swivel and each truck has two axles. The axles on AAR switchers trucks are on 8 ft. centers. The axles on Blomberg road switcher trucks are on 9 ft. centers. The distance between the truck centers is the primary consideration in what radius curves a locomotive can handle. Only switcher locomotives should be used on curves of 100 ft. to 400 ft. radius. Both switcher and road switcher locomotives can be used on curves greater than 400 ft. radius. Road switcher locomotives can be used most efficiently on curves of more than 750 ft. radius. Using road switchers on curves of less than 750 ft. radius can result in excessive wheel flange wear and rail head damage.

Some industrial switchers only have two fixed axles that don't pivot. In that case the distance between the axle centers and the movement of the couplers is critical in handling tight curves. Trackmobile solved this problem by having couplers that roll from side to side by up 12.5 inches from the center line as a Trackmobile moves through curves. Industrial switchers don't have any side to side movement but the coupler will pivot from side to side by up to 8 inches. They also have short axle centers from 10 to 12.5 ft. On the other hand, a small two axle industrial switcher can have axle centers of 25 ft or more. That can make handling tight curves much more difficult, with the fixed axles with the longer distance between axle centers, than by using a switcher locomotive with trucks that pivot. The pivoting trucks are also limited by the axle centers. This is why the switcher trucks have 8 ft. axle centers and the road switcher trucks have 9 ft. axle centers. The closer the axles centers and the more side to side movement in the couplers then the tighter radius curves that the motive power can handle.

Four axle switchers have a big advantage over two axle switchers in that move wheels provide more surface area contact between the wheel and the rail for traction and for braking. This makes it much easier to maintain wheel contact on uneven rail. With two axles if one slips then tractive effort drops by 50%. With four axles if one slips then tractive effort need only drop by 25% or less; depending on the traction control system.

The maximum that a two axle switcher can weigh is 160,000 lbs. because the AAR limits wheel loading to 40,000 lbs. maximum for safety and to reduce track damage. A model Titan Trackmobile has a maximum operating weight, with weight transfer, of 99,300 lbs. with a maximum wheel loading of 24,825 lbs. Some small two-axle industrial switchers weigh up to 80-tons and have a 40,000 lb. wheel load. A model PL850:4S Process Locomotive weighs 270,000 lbs. and has a wheel loading of 33,750 lbs. A model PL850:4RS can weigh up to 300,000 lbs. and has a wheel loading of 37,500 lbs. A 150-ton model PL850:4RS has a starting tractive effort of up to 114,000 lbs. on dry rail.

Four axle Process Locomotives have much more capacity in the traction motors than two-axle industrial switchers. For example a PL850:4S or PL850:4RS has traction motors sized for up to 3,600 HP while the total power available to all four motors is only about 900 HP. However, horsepower or KW is not the limiting factor it is amp loading. Amps are power and it takes a lot of amps to handle heavy trains. The four EMD D78 traction motors can take a total of up to 6,400 amps continuously for up to 20-minutes. Thus the motors can operate at very high amp loads with little problem of overheating. This makes it easy to do traction control without losing momentum or velocity head.

Braking is much easier with heavier motive power with more wheels in contact with the rail. When changing direction on a grade it is necessary to fully release the brakes on the railcars and the motive power must be able to safely hold the train at full stop when that is required. If the motive power is too light then it will not be able to hold the train and that can result in the weight of the train pushing it back down grade. This should never occur; but, it sometimes does. An inexperienced locomotive operator may couple to a heavy train and start moving it down grade. He can stop it with the railcar brakes; but, when he stops and releases those brake then the motive power must be able to hold the train and then move it back up grade. Many an operator has gotten into trouble by coupling to more than his motive power could handle.

DC Traction vs. AC Traction

The amount of running tractive effort required to move a train is always significantly less than the starting tractive effort required to get it moving from a dead stop. As soon as the train is rolling the tractive effort required drops of with regard to curve resistance, bearing resistance, track resistance, weather resistance, and foreign materials resistance. Grade resistance is unaffected except for the negative resistance factor of the velocity head. That can be helpful in climbing grades as rail speed drops. For a typical switching application the difference between the required starting tractive effort and the required running tractive effort can be up to 60% on level grade in poor weather.

It doesn't do much good to have the running tractive effort equal to the starting tractive effort; because, the motive power can't effectively move a train that it can't start, and by the laws of physics, the starting tractive effort required is going to be significantly higher than the running tractive effort required. This applies to any train and to any type of motive power. Starting tractive effort is limited by the amount of force that can be applied at the wheels without slipping them.

That is calculated by simply taking the effective weight of the motive power and multiplying it by the adhesion (friction) coefficient. It is irrespective of the type of motive power being used. Running tractive effort is limited to how many amps can put to the traction motors without overheating them. This is why CLCX Process Locomotive have continuous duty constant flow rate traction motor blowers so that a constant amount of air flow is achieved anytime that the engine on the locomotive is running. A typical model PL850:4S can handle about 1,530 amps for up to about 20-minutes to climb steep grades; even though the continuous duty rating of the D78 traction motors is 1,176 amps.

Some manufacturers claim that one of their locomotives can produce as much continuous running tractive effort as it can starting tractive effort. The reason is that they are using AC drive motors with inverters. A design D AC traction motor can handle high starting torque but at 10% to 13% slip it is an inefficient motor. The torque curve drops off significantly as motor speed increases. As a rule of thumb; it can handle about 10% more starting current than its rated continuous running current without rapid overheating. A DC traction motor with sufficient cooling can handle up to 30% more starting current than its continuous running current without rapid overheating. The current used by the traction motors is directly proportional to the amount of tractive effort produced at the wheels.

AC drive systems often use inverters and choppers with IGBT resisters for traction control. Those components often require special cooling systems to keep them from overheating. Overheating of those type components has been known to result in fires and/or explosions. Much care must be taken when using those type devices in locomotive service.

AC traction motors are useful for dynamic braking for Class I and II mainline operations depending on the terrain. However, in switching operations where operations are start-stop, over and over, dynamic braking is of little use. The reason is that for quick stopping and accurate spotting of heavy loads it is necessary to use the train air brakes. To do all of the braking with the motive power can cause damage to the motive power and to the track system. Wheel sliding creating flat spots on the wheels and gouges into the top of the rail are commonly found on facilities where the railcar air brakes are not used.

Some manufacturers offer regenerative braking to charge battery packs. This is not efficient either if you use the train air brake system. The momentum lost in using the railcar brakes can't be recovered. That can be up to 90% of the total energy involved in braking. So having regenerative braking to recover 10% to charge a battery pack that is more than 10% inefficient can be a waste of money and huge maintenance headache. Granted on mainline service that may all work well; but for yard and industrial switching it can be more trouble than it is worth.

Computer controlled train air brakes or manual 26L train air brakes are the best options for yard and industrial switching.

DC traction can be more economical in short line and industrial service. For example, compare a 600-BHP/475-THP 80-ton industrial switcher with AC traction and up to 35% adhesion vs. a 1005-BHP/850-THP 130-ton model PL850:4S Process Locomotive with DC traction and up to 38% adhesion vs. a 1200-HP/950-THP 124-ton EMD SW1200 with DC traction and up to 25% adhesion.

At 80-tons and 35% adhesion that is 56,000 lbs. of starting tractive effort. Assume that the Traction motors are also sized for 56,000 lbs. of continuous running tractive effort. Maximum rail speed at 56,000 lbs. of TE would be about 3.2 MPH. The cost of replacement AC traction motors can be double that of DC traction motors and the lead time for delivery can be several months instead of a few days for the DC traction motors.

At 130-tons and 38% adhesion that is 98,800 lbs. of starting tractive effort. The EMD D78 traction motors are sized for 62,000 lbs. of continuous running tractive effort and for up to 82,500 lbs. of running tractive effort for up to 20-minutes at a time. Maximum rail speed at 62,000 lbs. of TE would be about 5.1 MPH. At 55,400 lbs. of TE it would be about 5.8 MPH.

At 124-tons and 25% adhesion that is 62,000 lbs. of starting tractive effort. The EMD D77 traction motors are sized for 55,400 lbs. of continuous running tractive effort. Maximum rail speed at 55,400 lbs. of TE would be about 6.4 MPH.

It should be noted that some manufacturers have claimed adhesion levels of up to 50%. This can only be done with sanding on dry track and also by slipping the rail wheels at a speed of about 1 MPH faster than the ground speed. This tends to distort the wheels and can damage the wheels and the track.

According to physics text books the maximum friction coefficient of smooth steel on smooth steel is about 42% under laboratory conditions. Railroad tracks are generally a long way from being smooth. Achieving anything above 40% adhesion on short line or industrial track is very unlikely.

For medium to heavy duty switching service a model PL850:4S Process Locomotive can replace an EMD SW1200, SW1500, MP15, GP10, and GP18 in most applications while providing improved performance.

Real Locomotives

"REAL LOCOMOTIVES" are locomotives that can comply with FRA Blue Card requirements to operate on a Class III or higher railroad. Real locomotives look and function like the standard diesel electric locomotives. They have standard locomotive trucks, traction motors, couplers with draft gear, and brake systems that are rebuilt to OEM and FRA standards. They can be moved anywhere by Class I, II, or III railroads on standard gauge track.

Process Locomotives are "REAL LOCOMOTIVES". Most industrial switchers that may look similar to locomotives are not built to be "real locomotives". The deck down equipment on a Process Locomotive is the same, as built by EMD, GE, ALCO, etc., as are used or have been used in Class I, II, or III railroad service. The deck down equipment on Process Locomotives are rebuilt to OEM standards or better. The above deck equipment is mostly new. They have standard AAR trucks, braking, and type-E alignment couplers. They can be moved anywhere in North America that has standard 56-1/2" rail gauge.

For example, the trucks under a model PL850:4S are the same type as used on an EMD SW1200. The model PL850:4RS has the same Blomberg trucks that were used on the EMD GP38 and GP40. Process Locomotives are remanufactured units that use older locomotive cores for the frame, truck frames, traction motors, fuel and air tanks, coupler, and some sheet metal. The traction motors are normally rebuilt and rewound to EMD D78 OEM specifications.

When railroads and persons with railroad working experience look at a Process Locomotive they see it as a "real locomotive" rather than just an industrial switcher. They also have much higher resale values than industrial switchers. A typical resale valve of a remanufactured Process Locomotive after 10-years of service is in the range of 60% of the original purchase price. An industrial switcher is more likely to bring less than 10% of the original purchase price. If the unit is for a lease then there would be a huge difference in the residual value and thus the lease rate per $100,000 of the sales price.

Rail Speed

The operating rail speed of a given train is a function of the tractive effort (CRTE or RTE-X)and the traction-horsepower being produced at that same instant in time. The "AREA" American Railroad Engineering Association equation relates these variables as follows:

Rail speed in MPH = (THP x 375)/(CRTE or RTE)

Note: At any given instant in time the rail-speed is inversely proportional to the tractive effort produced and directly proportional to the tractive-horsepower produced. This equation applies to both locomotives and mobile railcar movers; however, the efficiency is different for each type of motive power.

Example Calculation: Assume a 1000-BHP locomotive switching a string of loaded railcars pulling a train weighing 1,000 tons with a running tractive effort requirement of 40,000 lbs. "THP" traction horsepower is assumed to be 81% of rated horsepower.

Rail speed in MPH = ((1000 x 0.81) x 375)/(40,000) = 7.6 MPH

Rail Speed Comparison

NOTCH	EMD SW1200 with EMD 12-567C 1200 Rated HP BHP Power in Notch Estimated From 12-645E data	EMD SW1500 or EMD MP15 with EMD 12-645E 1500 Rated HP BHP Power in Notch Per EPA	EMD GP9, GP10, with EMD 16-567C 1750 Rated HP BHP Power in Notch Per EPA	EMD GP20, with EMD 16-645E 2000 Rated HP BHP Power in Notch Per EPA		CLCX PL850 CUMMINS QST-30 Tier-3 Switcher Duty Service BHP Power in Notch Per CLCX
1	70	72	80	98		267
2	185	233	181	333		419
3	350	440	431	589		685
4	535	669	666	871		845
5	710	885	960	1161		884
6	885	1108	1231	1465		919
7	1100	1372	1528	1810		950
8	1260	1586	1820	2124		1000

This comparison shows that a CLCX model PL850:4S or PL850:4RS Process Locomotive can produce sufficient horsepower to replace an EMD SW900, NW2, SW1000, SW1001, SW1200, SW1500, MP15, GP7, GP8, GP9, GP10, GP15, GP18, or GP20.

Maximum top speeds will be slower with the PL850 Process Locomotive series; but normal switching speeds should be affected very little if any. This should not be a problem. When you consider that notch 8 on the SW, MP, and GP units is rated for up to 65 MPH. That said look at the AAR equation for calculating the top rail speed.

Speed in MPH = (HP x 375 x efficiency) / Tractive Effort

Let the required tractive effort to move a string of railcars be a constant for all six types of EMD locomotives and for a PL850:4S Process Locomotive. Also let the efficiency is 82% in all seven cases. The equation becomes:

Speed in MPH = HP x (307.5/TE) = HP x Constant

I.e.: double the HP to double the rail speed or cut the HP to cut the rail speed.

The worse case reduction in the top rail speed from the chart above would be the comparison of the EMD GP9/GP10 to the CLCX model PL850 series.

Maximum Speed of PL850:4S is (1000/1820 = 55%) x maximum speed of GP9. That is the maximum difference in notch 8. When you compare notch 5 on the GP9 to notch 8 on the PL850:4S there is no loss in the top rail speed. It the standard locomotive normally operates in notches 6, 7, or 8 then the repowered Process Locomotive can still move the same train; but just not as fast as the standard locomotive can in those top three notches. In fact the Process Locomotive can more likely move more railcars in one string that the standard locomotive. The Process Locomotive is heavier; it has high adhesion traction control; it has larger D78 traction motors; and it can produce more tractive effort.

In most switching operations an EMD SW1200 will seldom operate above notch 5 so there should be little to no lost time in replacing any EMD SW Series with a CLCX Process Locomotive or with a CLCX repower conversion kit. The CLCX standard is the 1000 BHP engine to replace a locomotive with a 900 HP thru a 1800 HP engine; but, in some lighter duty applications lower horsepower engines can work.

Repower Engine Horsepower Comparison: EMD SW1200 to CLCX Repowered Locomotive

NOTCH	EMD SW1200 with EMD 12-567C 1200 Rated HP BHP Power in Notch Estimated From 12-645E data	CLCX PL400:4S CUMMINS QSX-15 Tier-3 Off-Road 600 BHP rated BHP Power in Notch Per CLCX	CLCX PL600:4S CUMMINS QSK-19 Tier-3 Off-Road 700 BHP rated BHP Power in Notch Per CLCX	CLCX PL850 CUMMINS QST-30 Tier-3 Switcher Duty Service BHP Power in Notch Per CLCX
1	70	114	171	267
2	185	190	300	419
3	350	286	457	685
4	535	388	586	845
5	710	500	628	884
6	885	555	654	919
7	1100	600	678	950
8	1260	600	700	1000

When replacing or repowering a standard locomotive like an EMD SW1200 it is a good idea to know how the standard locomotive has been operated. For example if the locomotive seldom is operated above notch 5 then it is only producing about 710 BHP. A 1000 BHP repower engine can easily handle the application. A 700 BHP engine can also probably handle the application as long as the standard locomotive only operates above notch 4 less than about 20% of the time.

Fuel Efficiency

Fuel efficiency is stated in "BHP-hrs/gal." or in "Gal./BHP-hr" That means an engine can develop that much brake-horsepower continuously for one hour by burning one gallon of diesel fuel.

Examples For Locomotives in Switcher Service:

EMD Locomotives with 16-567/645 engines average: 12 to 14 BHP-hrs/gal.
0.0714 gal./BHP-hr.

EMD Locomotives with 12-567/645 engines average: 13 to 15 BHP-hrs/gal.
0.0667 gal./BHP-hr.
In both cases they average 435.5 HP when running
When idling 12-567/645 avg. 49.5 HP and 16-567/645 avg. 63 HP

According to published US EPA data these engines can produce as little as 4.0 & 3.3 BHP-hrs/gal. respectively at idle in test-cell conditions.

CLCX model PL850:4S Process Locomotive with a Tier-2 DDC-MTU model 12V2000 engine, US EPA certified for Tier-2 off-road, average: 20.6 BHP-hrs/gal. or 0.0486 gal./BHP-hr.

By repowering an EMD GP9 in switcher service, that is averaging about 212 BHP 24/7 and running on low sulfur diesel, with a CLCX PL850RK Tier-2 conversion kit, running on ultra low sulfur diesel, under the same load and running the same amount of operating hours the fuel savings calculation is as follows:

0.0714 – 0.0486/0.0714 = 31.93% less fuel/BHP-hr for the repower engine.
Or that it takes 46.9% more fuel/BHP-hr for to run the older engine.

The above calculation assumes that the repowered locomotive engine will run as much as the standard locomotive engine. That is generally not the case. In many cold weather climates the owner will leave a standard locomotive running 24/7 in order to keep it warm. Standard locomotive engines are difficult to start when they are cold.

In warmer climates the owner may leave a locomotive running whenever it will be needed within a four hour period of time. It is often too much trouble to restart a standard locomotive engine more than once or twice per shift. The US EPA and many States are pushing locomotive owners and builders to install "idle timeout". That means that the locomotive will shutdown automatically anytime it idles for more than 30-minutes. The idea is to reduce stack emissions; because all diesel engines produce the highest amount of emissions as measured in "g/BHP-hr" grams per brake-horsepower hour when they are idling.

Idle timeout can require restarting a standard engine as many as 8 to 24 times per day in some applications. Those engines are not designed for that nor do their battery packs have that much starting power. Idle timeout can lead to big problems with large standard locomotive engines; including having sufficient battery capacity. The repower engines are designed for multiple starts per shift.

If the locomotive is not needed for more than 20-minutes at a time then it should be turned off. The battery packs on the repowered locomotives are anywhere from 2 to 4 times that size required to start the engine. Idle timeout works very well on locomotives that are repowered with smaller 1800-RPM engines.

According to the US EPA the average standard switcher locomotive idles 59.8% of the time that is it running. A CLCX Process Locomotive can reduce idling down to about 10% of the time or less. Given a 24/7 operation (1440 minutes per day) that would save 717 minutes per day of idle time. That is 49.8% of the day that the Process Locomotive's engine would be turned off. Given that a typical standard switcher locomotive idles at about 4.5 gal./hr (or 0.075 gal./min). That is a savings of (717 min./day x 0.075 gal./min =)54.8 gal./day of fuel just due to turning the locomotive off when it is not needed. At $3.00/gal. that equates to a savings of about $164.40 per day. That is in addition to the fuel efficiency savings listed above.

There is a third method of fuel savings by down sizing the horsepower. In many cases a Process Locomotive with less horsepower, but with more tractive effort, (like a model PL850:4RS) can out work a larger locomotive like an EMD GP9, GP10, GP16, or GP18. For example in June, 2009 a model PL850:4RS with 1005 BHP replaced a GE U18B with 1800 HP. The model PL850:4RS out-pushed the U18B by approximately 60%. It easily handled 35-each 143-ton coal cars while the U18B could only handle 22 of the same 143-ton coal cars in the same application. Horsepower is for speed not necessarily for additional capacity in moving more railcars.

A CLCX model PL850:4RS with a 1005 BHP engine averages about 3 to 5 GPH vs. about 14 to 18 GPH for an EMD GP9 with a 1750 HP engine. At $3.50/gal. that is up to $45.50 per hour in savings when it is running. When the PL850:4RS turned of it is saving about (4.5 gal/hr x $3.50/gal =)$15.75/hr. When it is idling the savings is about (2.0 gal/hr x $3.50/gal =) $7.00/hr. Those save money and reduce emissions.

Example Of A Model PL850:4S Process Locomotive In An Actual Application

A model PL850:4S Process Locomotive with DDC-MTU 12V2000 engine powering trains of up to 10 loaded railcars plus the 130-ton locomotive operating in an industrial facility on grades of up to 3% and curves of up to 15% simultaneously. Average fuel usage 4.74 GPH with an average engine loading of 51%. Starting tractive effort up to 98,800 lbs.; RTE-20 short term running tractive effort up to 82,500 lbs.; continuous running tractive effort with EMD D78 traction motors up to 62,000 lbs.

The 4.74 GPH average fuel usage was not estimated by CLCX. It was taken directly from the DDC-MTU DDEC-IV engine control module using DDDL software to download the data. It covered more than 3-months of data.

Switching Service

Example: Assume an EMD GP9 in a typical 24/7 *light duty switching cycle* moving cars about 579 minutes and idling for about 861 minutes vs. the Process Locomotive moving cars about the same 579 minutes but only idling for about 144 minutes.

Fuel usage with the GP9 is approx. (300.2 gal. + 64.6 gal. =) 364.8 gal/day.

Fuel usage with the PL850:4RS is approx. (204.0 gal. + 7.2 gal. =) 211.2 gal/day.

That is a fuel savings of about 153.6 gal./day or 42.1% of what the GP9 uses. The fuel savings is based on producing the same average 435.5 HP when running and the respective HP when idling or turned off. At $3.00 per hour that is a savings of $460.80 per day or $168,192 annually. No matter the type or brand of standard locomotive, EMD or GE, the comparison of fuel savings would be similar.

Emissions Reductions

Less Fuel = Less Emissions

The US EPA rates engines in grams per brake-horsepower hour. That assumes that the load, the fuel efficiency, and the hours of operation are all the same. In the real world that is simply not the case; almost never. If one takes into account the lower emissions ratings, the better fuel efficiency, and greater fuel savings it is obvious that there will be even more reduction in emissions by going to a repower engine than would otherwise be indicated by simply comparing the standard and repower engines based only on their US EPA emissions ratings.
In order to quantify the amount of reduction requires a case by case evaluation; but it is sufficient here to show that all three parameters have a direct affect on reducing emissions.

The following is an extension of the above example. The object is to explain how the operating parameters can affect emissions reductions.

Assume an EMD GP9 switcher locomotive operates 24/7 in a heavy duty switching cycle and has to produce an average of 435.5 HP 40% of the time (9.65 hrs/day) and idles at an average 63 HP (with all the accessories included in the load (cooling fans, air compressor, HVAC, lights, etc.) 60% of the time (14.34 hrs/day). The fuel efficiency is 14 BHP-hrs/gal. The NOx emissions average about 14.0 g./BHP-hr.

Calculation: 435.5 HP x 9.65 hrs = 4,202.6 HP
63.0 HP x 14.34 hrs = 903.4
5,105.0 HP

5,105 HP x 14 g/BHP-hr = 71,470 grams or 157.4 lbs. of NOx
Average HP/24 hrs = 212.7 HP
Fuel burned in 24 hrs = 364.8 gallons

Assume that the replacement for the EMD GP9 is a CLCX model PL850:4S. It only operates when needed so that the idle time is reduced to 2.4 hrs. and the running time remains at 9.6 hrs. It produces 435.5 HP when running and 61.8 HP when idling. Fuel efficiency is 20.6 BHP-hrs/gal. The NOx emissions average about 4.55 g./BHP-hr.

Calculation: 435.5 HP x 9.6 hrs = 4,202.6 HP
61.8 HP x 2.4 hrs = 148.3
4,350.9 HP

4,350.9 HP x 4.55 g/BHP-hr = 19,797 or 43.6 lbs. of NOx
Average HP/24 hrs = 181.28 HP
Fuel burned in 24 hrs = 211.2 gallons

Emissions Reduction in lbs/day based on operating parameters for run time and fuel efficiency:
(157.4 – 43.6)/157.4 x 100% = 72.3% reduction in NOx.

The reduction in NOx based only on the US EPA emissions ratings and ignoring the operating parameters would be:
(14.0 – 4.55)/14.0 = 67.5% reduction in NOx.

The most important factors in calculation the emissions reductions for locomotive replacement or repowers are:

1. **The type of the original engine and the type of replacement engine.**

2. **The type of the original fuel and the type of the replacement fuel.**

3. **The hours of operation per day, the amount of horsepower required to do the work, and the application as a whole. In some industrial switching operations the running time may be as little as 10% of a day. The required horsepower when running can be as little as 300 HP. However, the standard locomotive may be left running 24/7 to prevent having to restart it. The following is a rework of the above calculation based on replacing an EMD GP9 that runs 10% and idles 90% of the time.**

   Fuel usage with the GP9 is approx. (51.4 gal. + 97.2 gal. =) 148.6 gal/day.

   Fuel usage with the PL850:4RS is approx. (35.0 gal. + 7.2 gal. =) 42.2 gal/day.

That is a fuel savings of about 106.6 gal./day or 71.6% of what the GP9 uses. The fuel savings is based on producing the same average 300 HP when running and the respective HP when idling or turned off. At $3.00 per hour that is a savings of $319.80 per day or $116,727 annually.

In the above example going from a reduction of 67.5% to a reduction of 72.3% may not seem like a big improvement but it may be the difference in getting an appropriation or grant approved vs. another applicant that doesn't consider these factors.

Governmental grant programs are currently the driving force in getting "Green" locomotive projects approved. Some grants will pay up to 80% to replace an older locomotive with a "Green" locomotive. They will also pay up to 100% to repower and older locomotive with a new low emissions engine. In most cases the minimum requirement for a grant application is a reduction of more than 25% in NOx and PM emissions.

Government grants are projected to become more important in 2010 through 2018. In addition "Cap and Trade" legislation is being considered by the Congress. Reductions in locomotive emissions might be sold to others in the event that "Cap and Trade" becomes law.

Process Locomotives are an excellent method for changing over to "Green" locomotives and they add additional value by significantly reducing maintenance costs, external and cab noise, and oil leakage for more environmentally friendly "green" locomotives.

Transportation Issues

The best and easiest way to move a locomotive over long distances is to have it pulled by commercial carrier railroads. That is simpler, cheaper, and less risky than moving a locomotive by truck or on a special railcar equipped for that purpose. In order to get a Class I railroad to pull it requires that the locomotive be equipped roller bearing trucks; legal wheels, alignment couplers and draft gear; brakes that are in good condition; and the required FRA safety equipment. CLCX Process Locomotives are all equipped for shipment by commercial carrier railroads. Shipping in this manner will generally save about 50% to 75% over the other two methods. Shipping by truck requires shipping it in several pieces to stay below the weight limits of the various states. That requires disassembly and reassembly which adds costs to the move.

Some older locomotives that are otherwise in good condition but don't have alignment couplers are land locked. This significantly reduces their residual and/or resale values. The best way to move them is to replace the couplers, draft gear, and draft pockets with suitable alignment type units.

For more information on how to:

1. **size a Trackmobile or a CLCX locomotive for your application**
2. **save fuel and reduce emissions from locomotives**
3. **discuss repowering or rebuilding your locomotives or Trackmobiles**
4. **discuss how to achieve optimum locomotive/Trackmobile efficiency**

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AEA-Andress AEA@railspur.com or (800) 437-4211 for Trackmobiles

DISCLAIMER

The calculations and information in this file are for general information only and nothing listed herein is approved, certified, or in anyway verified to be correct for use in the design, construction, or sale of any motive power or other railroad related equipment. Every application is different and each piece of motive power can be different. The above listed information is only presented to give the reader a better understanding of issues and options to consider when specifying motive power as either locomotives or mobile railcar movers. Any actions taken by the reader in conjunction with the information contained in this file are purely and strictly at the risk and the liability of the reader as to the outcome of said actions.