
LASH
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SEATTLE

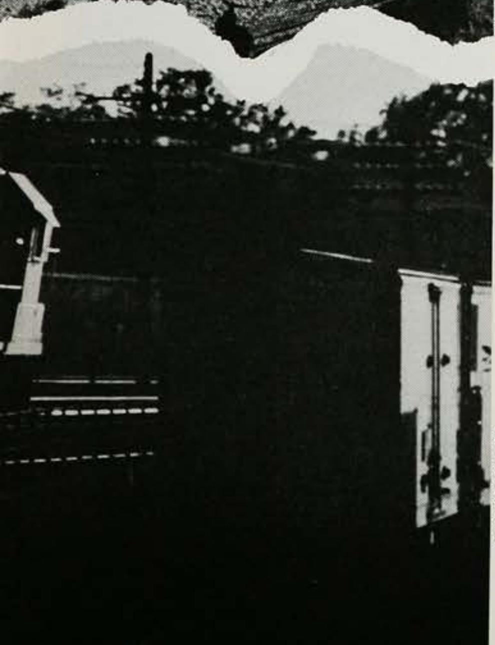
J. P. Lamb Jr.

'EM UP!

How to mate miscellaneous makes and models

JERRY A. PINKEPANK

Richard Steinheimer.



J. J. Young Jr.

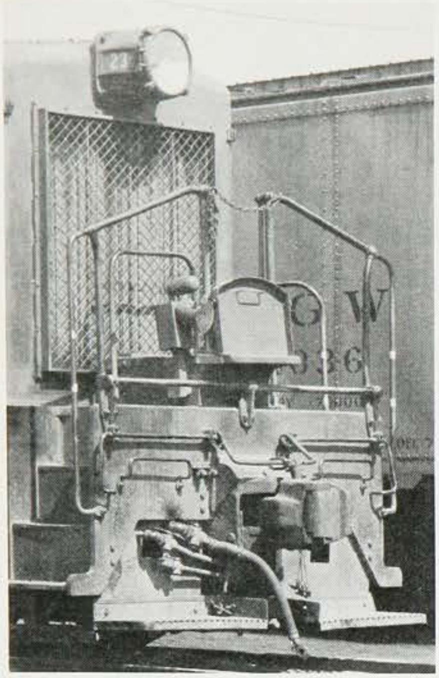
I TROLLEY ENTHUSIASTS trace the concept of multiple-unit operation to Frank Sprague, the streetcar pioneer who held a patent on an electric M.U. system. Actually, diesel M.U. so differs from the Sprague concept that the former represents an entirely new art. The essence of diesel M.U. is remote, unified control of *engine speed*, whether by electric signal, air pressure, or even coupler strain or radio signal. Supplementing the control of engine speed is remote control of the independent brake, sanders, steam generators, air compressors, transition, forward and reverse movements, and trainlined alarm circuits. Parallels to these supplemental functions exist in electric operation, but the main function of engine speed control is unique to the diesel.

HISTORY is not clear as to where, when, and by whom the idea of diesel M.U. was developed. Theoretically it became practicable as soon as gas-electric cars discontinued use of straight mechanical linkage to regulate fuel input to the carburetor and began to control through a governor. Even pre-World War I General Electric cars had Woodward governors which would have made M.U. possible. The 1923 Lemp control, invented at GE, made practical the gas-electric cars and early box-cab diesels of the 1920's. It relied on electric control of engine speed and therefore was a natural for M.U. operation. In fact, this was advertised as a feature of the 1924 box-cab switchers of Jersey Central 1000 fame. However, there was no demand in America for M.U. gas-electric cars, and no instances of Alco-GE-Ingersoll-Rand box-cabs with M.U. applied can be documented. Apparently the first diesel M.U. set recorded in America was Long Island Rail Road's "Mike & Ike" of 1927, although purists may object that the semipermanent coupling of these units excludes them. (They were later run separately, but whether they could have been rejoined by a simple jumper cable and gladhands, or would have required major rewiring and repiping, is hard to say.) If Mike & Ike are disallowed, then Electro-Motive demonstrators 511-512 would be this author's nomination for the distinction of first. Of course, if all North America is included in the inquiry, Canada's 9000 of 1929 could be interposed.

Briefly, control of engine speed through a governor works this way: A governor with a fixed setting senses engine overspeed and cuts back on fuel, or senses underspeed and increases fuel. It does this through direct coupling to the mechanical linkage on the injection pumps, which are known as the fuel rack. The fuel rack determines how much fuel oil is metered into the pumps for each piston power stroke. The governor may read engine speed by the old flyball method, by measurement of electric current put out by a small tachometer generator geared to the engine drive shaft, or by some other means. All that is necessary to change engine speed, then, is to change the governor setting — which is done through the throttle control.

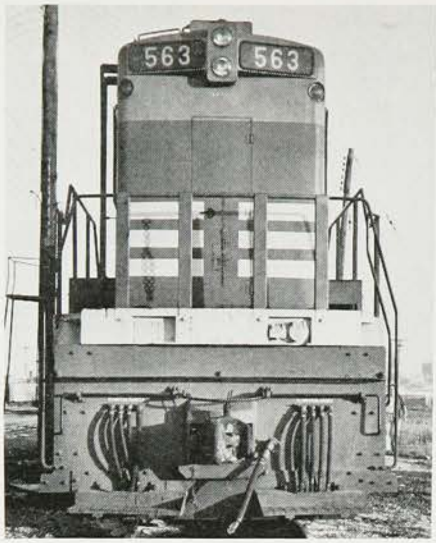
A diesel fuel-injection pump and nozzle work in two stages which we will call "fill" and "squirt." In the fill stage, an amount of fuel, determined exactly by the position of the fuel rack at that moment, is taken into a "ready room." In the squirt stage, the entire amount of fuel apportioned to this ready room is then sprayed into the cylinder when the piston reaches the top of the cylinder preparatory to a power stroke. It is the governor that decides, on the basis of its reading of engine speed, how much fuel should go into the ready rooms of the pumps and nozzles at a given moment. Assuming air supply keeps pace, the more fuel that goes into the cylinder, the more power is released by the burning of the fuel, and the faster the engine runs. The governor of an eight-notch throttle actually has seven different speed settings (the first notch merely energizes the generator field).

Those hoses



Marre-Mott collection.

THE simplest air-hose arrangement for the 14EL, 6SL, or 6BL brake in M.U. operation is displayed by this CGW unit. The large hose is the standard automatic trainline brake pipe, which would be present on a non-M.U. unit. The other two hoses are the main-reservoir and the cylinder-equalizing hoses of the 14EL, 6BL, and 6SL systems. Cutout cocks and piping for these hoses are exposed above the footboard; on most units they are concealed and only the hoses are visible. Sand control is electrical, through the 27-point receptacle.



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THIS is the standard four-hose arrangement for the 24RL or 26L brake and air sanding control. The two inside hoses — one on each side of the coupler — are the main-reservoir-equalizing hoses, which tie together air-compressor capacity on all units in the lash-up. Next are the actuating hoses, followed by the application/release hoses of the 24RL or 26L brake system (independent brake). The left outside hose is linked to the forward sand control; the right outside hose, to the reverse sand control. With forward sand control on one side and reverse on the other, the sander is automatically reversed on the trailing unit when locomotives are coupled back to back, so that sand is always applied in front of the unit's wheels in the direction of travel.

Marre-Mott collection.

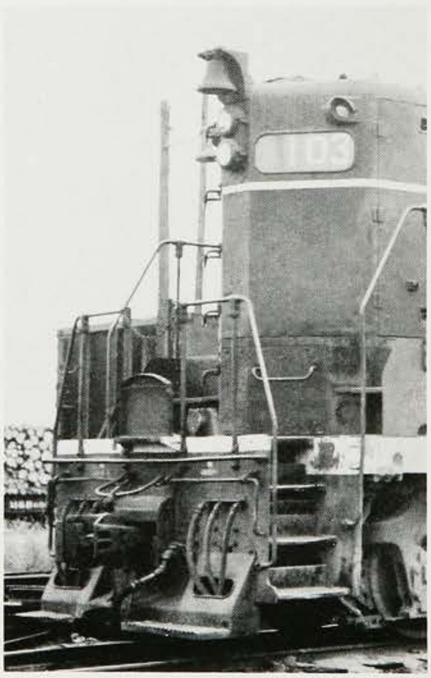
THE formidable array of six hoses per side on this DT&I locomotive depicts the compromise 6BLC brake plus air sanding control. The hoses are "duplexed" — an identical set is on each side of the coupler. The two outside positions on each set are for forward and reverse sanding (in the photo, hoses are attached to only one of these connections). The thick main-reservoir-equalizing hose is fourth from the outside. Of the three remaining hoses, two are the actuating and application/release hoses used in M.U.'ing with a 24RL or 26L engine, and the third is a cylinder-equalizing hose used in M.U.'ing with a 14EL, 6SL, or 6BL engine. Without this compromise, units with 14- and 6-series brakes would not multiple with diesels having 24- or 26-series brakes.

David Ingles.

THIS PHOTO shows a conventional five-hose setup for 24RL or 26L brake and air-controlled sanding. From the outside, or left, the first two hoses are forward and reverse sand control; the next two are the actuating and application/release hoses of the 24RL or 26L independent brake. The fifth, and thicker, hose is the main-reservoir-equalizing hose. On the other side of the diesel's coupler, along with a duplicate five-hose set, is the large regular automatic brake-pipe hose which carries trainline air.

Marre-Mott collection.

B&O BALDWIN 2249, which features an air throttle, electric sanding control, and 24RL brake, has a rather fearsome triplexed hose arrangement. The four hose connections are for throttle, main reservoir, actuating, and application/release hoses. Control of sanding is accomplished through the Baldwin 16-point electrical receptacle located under the catwalk step.



Marre-Mott collection.

THE three-hose arrangement is used in conjunction with the 24RL or 26L brake and electric sanding control. The sanding control is conveyed through the 27-point electrical receptacle. The three hoses are the main reservoir hose and the actuating and application/release hoses of the 24RL or 26L independent brake system.

At any one of these seven settings, the governor will add or subtract fuel to reach, and then to hold, the engine rpm represented by that throttle setting.

By a lucky historical accident, most American diesels use this eight-notch system. This means that even when engines with diverse ranges of rpm's, from Baldwin's 625 maximum to Alco's 1100, are M.U.'d, it is possible to control them from one throttle and expect each to maintain its share of the load through the entire range of throttle positions. In the eight-notch system the throttle "talks" to the governors through four electric wires commonly designated A, B, C, and D. The table on this page indicates which wires are energized by each throttle position and the engine rpm's that result for two typical locomotives, an Alco RS-3 and an EMD F3. The four wires produce seven different combinations of energized and de-energized relays that control engine speed — a method common to GE, GM, and Alco control systems, and often installed on other makes as well. It is a simple matter to carry four wires between diesel units. General Electric invented this control in the 1930's, at a time when GE was supplying most of the diesel locomotive electric drives and controls in the U. S. When GM ceased to purchase its electrical equipment from GE in 1938 and began to make its own, GM continued the GE-invented throttle control. Alco, of course, went on relying on GE's system, so it turned out that all three of the biggest builders spoke the same "governor language."

When American railroads began to freely mix various makes and models of diesels about 10 years ago, all the roads had to do was to change a small amount of wiring at the jumper cable receptacle. Had this not been the case, intermake M.U. would have required completely new governor systems and control stands, including rewired electrical cabinets. This work has been done on a few Fairbanks-Morse units originally built with the incompatible Westinghouse control. The job runs upwards of $12,000 per unit just for parts and materials. This is why Baldwin units constructed with air throttles and accompanying governors have not joined the great mating game. Incidentally, the 16-position GE throttle introduced with the U25B does not break the pattern of compatibility. The throttle still has only seven engine speeds above idle, with every other notch merely providing more finely gradated generator field excitation. Eight-position-throttle engines M.U.'-ing with the GE's disregard these excitation-only stages.

This happy accident of compatibility is all the more remarkable because only in relatively recent years have different models, let alone makes, been mixed extensively (remember when an F/GP lashup was worthy of comment?). The builders did not encourage mixing. Their service representatives talked darkly of possible damage to electrical equipment when units of different ratings worked together, partly on the theory that because of differences in transition and generator field excitation, some trailing unit could be carrying an excess load while the ammeter in the controlling unit showed normal. The danger seems to have been exaggerated; to the extent it does exist, it can largely be eliminated by letting the units with the most vulnerable electrical equipment lead the consist, with the weakest unit of all doing the controlling. Early examples of this practice were the "sandwich" consists, such as the "Perlman Mallet" on the Rio Grande, A-B-B-A sets of F's spliced by an SD9, or sets of F7's spliced by Wabash Train Masters. A sandwich could be kept together and run for weeks without being turned or broken up, and the weak units would always control the strong.

FROM the relatively static sandwich consist, the railroads pushed on to free assembly of building blocks. The building-block idea came from the builders, and it was an argument formerly used to defend lower-horsepower units. If one small unit was laid up for maintenance, said the builders, the remaining units could be mixed with others *of the same make and model* and kept out on the road. The theory was fine, but in practice, a spare F3, for example, could not always be found to replace an ailing F3. The roads were not able to mix the F3 with a GP7 or an Alco that might be available. Sometimes even units of the same make and model were incompatible because of minor differences in gear ratio, M.U. wiring, and so forth. To solve this problem and to get full mileage out of the building-block principle, railroads about 10 years ago began freely using all types of road engines together, making whatever minor modifications were required, and creating power consists simply by adding up horsepower or tractive effort. The resulting "lash-ups," or "dog's breakfasts," may not look pretty, but they keep utilization figures high. The advent of high-horsepower locomotives and "unit reduction" has eliminated most of the more outlandish strings of locomotives one saw at the onset of the horsepower race, but make-mixing is here to stay, and is all the more necessary now that the big units have tightened power pools. Furthermore, the advent of mergers en masse and widespread power pooling underlines the need to eliminate remaining minor incompatibilities among units. The trade publication *Railway Locomotives & Cars* is calling editorially for locomotives that can be interchanged as freely as freight cars.

ALTHOUGH common control of engine speed is about 90 per cent of the battle, it is not quite enough to bring about M.U. operation of diesel loco-

Synchronizing engine rpm's

Throttle setting	Wires energized	Alco RS-3 engine (rpm)	EMD F3 engine (rpm)
Idle	None	350	275
Run 1	None	350 (Excitation only)	275
Run 2	A	450	350
Run 3	C	550	425
Run 4	A, C	655	500
Run 5	B, C, D	765	575
Run 6	A, B, C, D	860	650
Run 7	B, C	920	725
Run 8	A, B, C	1000	800

Because the Alco is a four-cycle engine, it uses larger cylinders and a higher rpm to reach the same horsepower as the two-cycle EMD. However, the governors on both units are set to divide the total range of power output into eight increments. If the two units are so rated as to divide the horsepower load at maximum output (55-45 per cent at Run 8), they will maintain approximately that load-sharing relationship at the other throttle settings. In practice, a little shifting back and forth of load shares between the units takes place as throttle position varies, but this does not prevent effective performance of the hauling job. Notice that this maintaining-share-relationship feature would apply even if a 3600 h.p. SD-45 were multipled with a 1500 h.p. F3 or Alco RS-2. The throttle does not equalize the horsepower outputs — it equalizes the *share* of the output (about 25-75 per cent in this case) at all throttle settings. I motives. There must be common control of basic generator field excitation. This has followed the same historical pattern as engine speed control and is not a problem. There also must be a connection for forward and reverse controls so that regardless of which way a unit faces in a consist, it will respond to a command to go "forward" in the right direction. A simple two-position relay does the job. Two wires connect this relay to the outside world, and when one is energized it snaps to "forward"; when current flows in the other, it snaps to "reverse." If the locomotive runs backwards in the consist, a switch must be thrown that reverses these wires. This is done at the enginehouse before the units are dispatched; if someone forgets, much spinning of wheels will ensue the first time the throttle is opened. Improper operation of the forward-reverse control in large motive-power consists can also lead to jackknifing in attempted reverse movements. For this reason most roads caution their engineers to open out slowly in reverse moves with four or more units.

Transition control could have been a big problem in American M.U. practice, but rapid adoption of automatic transition forestalled potential difficulties. Transition is the method of changing the traction-motor connection or field excitation in order to counter the buildup of "resistance" in traction motors as they revolve at faster and faster speeds during acceleration. It is not really resistance but counterelectromotive force. Electrically this force is the same as resistance as far as the generator is concerned. Without transition, as the traction motors turned faster, more and more generator output would be used up overcoming resistance and less would reach the wheels for useful work. With manual transition, the engineer determines when motor connections are changed by means of a lever at his control stand. That lever is still present today, but unless the engineer uses it to override the automatic transition, it performs no function. Newer locomotives often have no provision for trainlining manual transition, and thus they cannot operate with manual transition units trailing. Automatic transition has been a standard item since before 1950, so few manual-transition units remain to cause problems in this respect. No difficulty arises in operating automatic transition units without a transition train line. Each unit takes care of its own transition, and if a trailing unit does not make transition, the engine overload trip protects it.

LET'S EXAMINE the M.U. jumper cable — the device which carries all of these electrical signals between units.

By far the most prevalent jumper is the 27-wire type first standardized by GM in the 1940's. The 27-point receptacle succeeded the 17-point jumper originally used for FT units and the 16-point jumper still used by some roads for E units. It is now the Association of American Railroads recommended standard, but since locomotives are not interchange equipment, the AAR standard is not binding. The most notable dissenter from the 27-point receptacle is Union Pacific, which uses the old Alco dual jumper with 12 and 21 points. Furthermore, the fact that a unit is equipped with a 27-point receptacle is no assurance it is compatible with another unit so equipped. Although there are few variations on the pin numbers used for the A, B, C, and D engine-speed control wires and the forward and reverse control, many other pins of the 27-point receptacle have been used for a variety of conflicting functions. When EMD and non-EMD units are mated, pins used for transition will cause trouble unless they meet on blind "spare" pins. On some units various alarm circuits may or may not be trainlined, or may be trainlined on different pins, with the result that the hot-water alarm on a trailing unit may sound the low oil-pressure alarm on the leading one. One case is documented in which the trainlined ground light switch of one class of Alco RS-3's could operate — as the unintentional result of modification in the road's own shop — the dynamic brake control on another class of RS-3's.

Since most of these supplementary functions are not really necessary to M.U. operation, on many roads a quick cure has been simply to cut the wires leading to the conflicting pins and to tape them to prevent grounding. A 27-point receptacle may get along on about 10 functioning pins. This follows the philosophy of those who think trainlining of alarms is a waste of effort, since most alarm functions announce themselves by shutting down the engine. When a locomotive leaves the line, the effect is instantly apparent to the head-end crew; if the alarm circuit rings on only one unit, the trouble is localized more rapidly than if the alarm rings in all units in the consist. One alarm which does not shut down the engine is the hot-water warning, and for this reason it is often trainlined. Obviously, lead-unit control of the headlights, ground lights, and indicators of the trailing units is not vital to operations. If the cut-and-tape method is unappealing, though, it is relatively simple for a road to publish a standard 27-point receptacle chart and have its shops move the wires around the pins as needed. Usually the only work required is on the receptacle itself, not inside the unit.

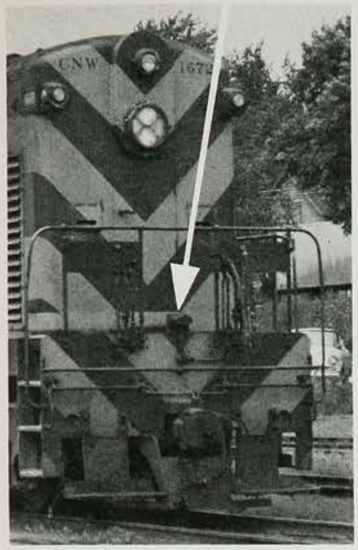
Another cure for nonmatching 27-point receptacles is a special jumper in which a wire connected to pin 7, for example, on the "A" end is connected to pin 5 on the "B" end. Such jumpers must be carefully labeled and segregated from regular jumpers, but still the day will come when someone sticks the green end in the blue receptacle or uses the jumper on some incompatible third-party unit, with the result that ground relay action on a trailing unit will turn out the headlight on the leading one, or perform some other mischief. Special jumpers of this type are sometimes used for pool arrangements in which power of two different railroads with differing 27-point receptacles must multiple. Union Pacific and Burlington have cooked up a special V-shape jumper that connects UP's 12- and 21-point twin receptacles to CB&Q's 27-pointers for the roads' long-standing pool arrangements.

The AAR has tried for the past 12 years to settle on a standard 27-point receptacle for adoption by all railroads, but the recommended standard has been changed so often that any road which attempted to keep up with it would have spent a fortune by now in electrician man-hours.

Until recently GM units with dynamic braking required an extra jumper for the field loop — a feature of GM dynamic braking not used by other systems — in addition to the normal electric jumpers between units. As a result, some non-GM units have been built with field loop conductors to make full dynamic braking possible in mixed-make power consists. GM is not using the field loop on its present models. In place of the 27-point receptacles, a few other varieties can be found on units not required to mix with other types. The old E-unit 16-point jumper is often paired with another 16-point jumper for carrying additional functions. The old Alco 12 and 21 pairs survive in a few enclaves other than UP. The special Baldwin, Alco switcher, and Fairbanks-Morse receptacles occasionally are seen.

WE now reach the subject of M.U. air hoses. These air hoses, which range from 2 to 10 or more in number, perform three main functions.

First, they tie together the independent brake on all units (*i.e.*, the separate brake system of the locomotive which applies or releases locomotive brakes independently of the automatic brakes on the train). The trailing locomotives would, of course, respond to the automatic brake through the normal brake-pipe hose,



Jerry A. Pinkepank.

HOW do you tell if a diesel has a standard 27-point receptacle or one of the variants? Without lifting the lid to count the points, it is difficult indeed. An easily recognizable exception is the old oblong Fairbanks-Morse 12-point receptacle photographed in 1958 on this Chicago & North Western road-switcher.

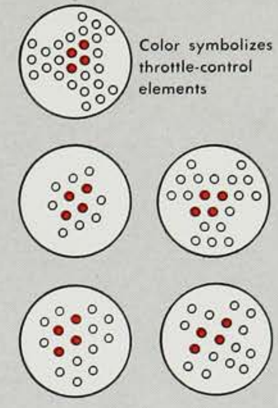
Marre-Mott collection.

UNION PACIFIC is the last major holdout from the 27-point receptacle. UP has standardized instead on a dual receptacle — one 12-point and one 21-point. On EMD dynamic-brake-equipped units, as shown, a field loop receptacle is situated between the dual receptacle. Originally an Alco system, dual receptacles came to UP on the road's first large order of freight diesels in 1946. Some UP SD40's that run almost exclusively in pool freight service have 27-point receptacles.

Throttles and jumpers

THE 16-point receptacle was original equipment on most early E units, although many 16-pointers have been replaced by 27-point receptacles. They are located behind the door at the left of the headlight. Another compartment to the right of the headlight originally contained a different type of 16-point receptacle which carried, among other things, the electropneumatic HSC brake signal used on early streamliners to supplement the normal air brake. Since the HSC brake operated only if the entire train was equipped, it went out of use when early trains were broken up. Some roads still carry steam generator controls on this cable.

Four-solenoid throttle control



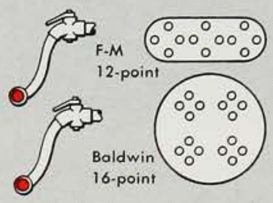
The 27-point jumper, with four-solenoid throttle control to provide seven engine speeds above idle, is the most widely used electrical M.U. connection.

The 12-point and 21-point receptacles are used by Union Pacific. Throttle control is compatible with other four-solenoid arrangements if pin wires are matched.

The 16-point and 17-point receptacles are used by older E and FT units respectively. Since the four-solenoid throttle is employed, units can be made compatible easily and inexpensively by matching of pins.

Drawings are stylized and do not show actual pin layout.

Air throttle for road engines



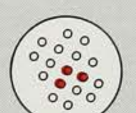
WABCO (Westinghouse Air Brake Company) air throttle for road locomotives formerly was used on Baldwin and on some Fairbanks-Morse units. A new governor, a new control stand, and electrical-cabinet changes are required to make such units compatible with units in other throttle groups. Each builder used its own electrical receptacle.

Air throttle for yard engines

Non-throttle electrical jumper to suit builder

WABCO air throttle for yard engines was employed on some Baldwin, Fairbanks-Morse, and Lima locomotives. This throttle does not M.U. with other types, and requires change of governor, control stand, and electrical cabinet for compatibility.

Three-solenoid throttle control



A simplified three-solenoid throttle control, which is not compatible with other arrangements, is used by Alco switchers and RS-1's. A 17-point jumper that is not compatible with the EMD FT 17-point M.U. jumper is employed.

Non-M.U. throttles

Governors controlled directly by mechanical linkage from the throttle handle are found on many early yard engines. These engines must have new control stands and governors, as well as electrical cabinet changes, before they can M.U. with other groups.

The author acknowledges with appreciation the research on this subject provided by Kenneth L. Douglas.

Marre-Mott collection.

Charles K. Marsh Jr.

just like the trailing cars, but universal practice is to M.U. the independent brake (and most people feel this is required by the ICC's Delphic pronouncements on the subject — page 51). Therefore, the 6-series (such as the 6BL used on yard engines) and 14-series brakes have one hose called the application and release, or cylinder equalizing, hose. The 24RL and 26L road-engine brake schedules use one additional hose called the actuating hose.

Second, air hoses tie together the air compressor capacity of all the units in a consist. If the compressor capacity of only the lead unit were used to pump off the train at initial terminals not equipped with yard air, or after stops, serious delays would occur. A main-reservoir-equalizing hose ties all the main reservoirs together. Pressure then falls off at the same rate in the main reservoirs of all units, automatically bringing their air compressors on the line.

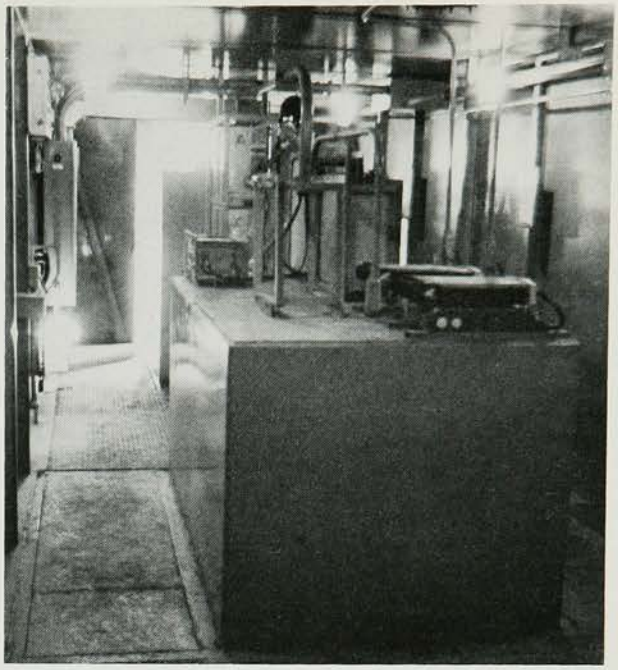
Third, air hoses are used in sanding, both forward and reverse. Several roads prefer not to trainline the sand air lines, however, and instead use electric sanding signals on the 27-point jumper. The individual air system of each unit then takes care of the sanding.

Westinghouse Air Brake Company formerly furnished an air throttle which was used on Baldwin units (unless the customer ordered otherwise), on some FM units, and on yard engine versions by Baldwin, Lima, and Fairbanks-Morse. This air throttle has no notches as such. The position of the throttle handle regulates air pressure to create infinite variations between idle and full rpm's. The road version of the air throttle, however, has three running positions on which the handle can be rested when the engineer's hands are busy elsewhere. Operating practice revealed that changes in air pressure made this throttle unreliable with more than four units. (EMD at one time advised that the electric M.U. throttle should not be trusted when power exceeded eight units, but a number of railroads have used it in this manner with impunity. The engineman must exercise care with so many units under one throttle, in case all units do not respond to a sudden throttle change and jackknifing threatens.) Air-throttle locomotives are linked with a special hose resembling a brake-pipe hose, but mounted high.

The latest wrinkle in M.U. operation is the remote control of slave units by coupler strain or radio. The coupler-strain-gauge version was put into practice experimentally by the Louisville & Nashville using a strain-gauge-equipped F7 to pilot the slave, but the result was not complete success. Today, the rapidly spreading method of slave operation employs the Locotrol system of Radiation, Inc., a subsidiary of General Signal Corporation. Much of the pioneering in this area was performed by the Southern Railway, which now has slave-unit operation everywhere on its system as an everyday matter. A Southern operating man holds some of the patents relating to the slave-brake system used by Locotrol. The system is the radio equivalent of a 36-wire jumper that carries all the M.U. functions normally handled on the 27-point jumper plus the air systems.

The electronics are conventional by modern communications standards. Each of the 36 functions has a "code" consisting of 50 "bits" (*i.e.*, 50 "mark" and "space" signals such as those used for modern teletype). A mark is a 2500-cycles-per-second tone, and a space is a 1500-cycles-per-second tone. A "computer plus telegraph" wired into the cab of the locomotive takes readings of changes in the locomotive-control-stand switches and relays, as indicated by the energization or de-energization of circuits in the pre-existing control system. A change in the condition of one of these control circuits comes in on a particular wire to the "computer" and triggers one of the 50-bit combinations of mark and space "telegraph" signals. The frequencies of 1500 and 2500 cps are in the voice frequency range; thus they can be broadcast over an ordinary railroad radio. Two radios — including one for backup — are provided in each control unit and slave unit. All radios operate on the same frequency, transmitting and receiving simultaneously. The frequency must be different from the one used for voice operations because the Locotrol signals are in voice frequency and they are audible. The first 11 bits of the 50-bit code for each function are an identity code peculiar to that master-slave set, so that several Locotrols can operate on the same frequency without mutual interference. The slave will disregard any signal not preceded by the correct identity code. The slave unit also transmits alarm signals and acknowledgments of signals from the master, with the same identity code applying. If the slave does not receive a signal from the master for 45 seconds (as it normally would owing to a built-in continuity check signal), it

Charles K. Marsh Jr.



Don Dover.

Slave units

PIONEER and chief exponent of the Locotrol slave-unit operation, Southern Railway shows how it's done by moving 11,500 tons in a 117-car coal train through Orton, Va. A four-unit master diesel is followed by slave control car 5955 and four slave units. Interior view of control car reveals that little space is consumed by slave control elements, which on some railroads are installed in the cabs of the locomotives.

sends an alarm but continues operating until an air-brake application through the trainline occurs, at which point the slave isolates itself.

The equipment on both master and slave units comprises two "logic" cabinets with circuitry set up — as in a simple computer — to translate locomotive circuit changes into mark and space codes; a power supply to convert the locomotive's auxiliary A.C. to the D.C. used in the Locotrol circuits; an air-brake manifold which reads changes in the air-brake system for translation by the logic into mark and space signals; and a relay interface cabinet. On the slave, the air-brake manifold also puts the air-brake commands into effect; on the master, an additional item — the master control console — bears the alarms and the switch for isolating the slaves by radio. Although this equipment can be set up in the cab of any locomotive, leaving sufficient room for the head-end crew, wiring the system to the locomotive is a major project. Therefore, a few particular units must be designated as Locotrol leading units and a few more as trailing units. Southern avoids the trailing-unit problem by using special cars, most of them built on old locomotive frames, as "slave drivers" for trailing slaves. Any locomotive can be connected to such a slave driver or to a slave-equipped locomotive by the usual M.U. connections.

Multiple-unit legal code

THE only published Federal regulation regarding M.U. operation is found in the Interstate Commerce Commission's *Rules of Locomotive Inspection Other Than Steam.* It reads as follows:

> When locomotive units are coupled in multiple control, all parts and components of each unit capable of providing power for propulsion or supplying the retarding effect which will enable the engineman to control the speed or stop the locomotive or train shall respond to control from the engineman's compartment of the controlling unit.
>
> Means shall be provided whereby alarms and indications of either slipping or sliding driving wheels on any unit in a locomotive used in road service will be shown in the engineman's compartment of the controlling unit.

The first paragraph has been interpreted to apply only to air brakes, meaning that presumably it is lawful to operate dynamic brakes on only a part of the power consist. It also has been construed to make M.U. operation of sanders a matter of law.

Another interpretation which has arisen out of the ICC regulations suggests that it is necessary to provide a safe passageway for traveling between M.U. units while they are in motion. This caused catwalks to be added to some road-switchers built without them, and end doors to be cut in the nose of some cab units; but not all roads accepted this as a valid interpretation. Cab units with no nose M.U. connections usually have no nose doors. I

Locotrols are also in regular service on Kansas City Southern, Canadian Pacific, and Great Northern, and have been used experimentally by Penn Central and Norfolk & Western. The idea is spreading fast, and other roads may well be on the list by the time this article is in print. The main advantage of such systems is to permit longer trains and better train handling than the strength of drawbars would otherwise allow. For the future, this method of operation can be the means of eliminating slack altogether, which is now necessary for starting heavy trains. With slack eliminated, freight cars need not be constructed with the heavy center sills essential today to withstand the buffeting and stresses of slack action at speed. With power scattered throughout a train, slack is not required to start even the heaviest consist. Recently a third such system, WABCO's remote M.U., has entered the market and is being tested by PC.

FOR those who enjoy watching operations, diesel M.U. differences are a rewarding source of interest. They explain why some locomotives are seen together and others are not. There may be other reasons, too, of course. A wide difference in gear ratios can be awkward. A unit without steam and signal trainlines cannot operate between steam-equipped units and the passenger train behind. Lack of the proper type of train-control device may prevent a given unit from leading in train-control territory. Parts warehousing and maintenance cycles can keep certain units out of the general pool. M.U. provides its share of operating puzzles, though, and one can gain some satisfaction in knowing what all those hoses are for. I