From Railway Mechanical Engineer, Volume 92, No 2, February 1918, pages 87-90

date being typical, all of the 50 stalls of the engine-house were occupied by locomotives undergoing repairs. 190 of the 230 locomotives despatched were repaired on inspection pit and storage tracks where there was no shelter or protection from snow and weather. Under such conditions, and in the crowded and unheated enginehouses existing at many points, some of which are too small to accommodate the large locomotives in use today, it is not reasonable to expect that necessary work can be promptly and efficiently performed. Vigorous action must be taken to improve the condition of motive power before relief can be expected."

BLIZZARDS HANDICAP RAILROADS

Storms and continued cold weather together have made the month just past the worst January from the railroad standpoint in 50 years. The weather has prevented the realization of the relief that was hoped from the five-day closing down of industry and because of it "freight moving week" was far below expectations. Serious storms were met both in New York and Chicago; and along the Ohio river and in eastern Kentucky floods, floating ice and washouts are causing considerable damage.

The succession of blizzards and low temperatures has made it impossible to raise the embargo against general freight ordered on January 23 on the Pennsylvania, Baltimore & Ohio and Philadelphia & Reading, which it was expected would be in force but a few days. While one of the most serious conditions, the inability of ships to embark, because of the delay in obtaining bunker coal, has been remedied, many of the eastern roads have been unable to handle much new freight except food, fuel and necessary government freight for several days and most of the reports received at Mr. McAdoo's office have been discouraging, while the daily reports of the Interstate Commerce Commission's inspectors from various terminal points, received by Commissioner McChord, continue to show conditions approaching a paralysis of transportation at many points, due to weather conditions, congestion in yards, shortage of crews, and engines and cars in bad order with a shortage of labor to repair them.

A. H. Smith, regional director in charge of the eastern lines, reported on January 26 that it had been necessary to suspend operations in Northern New York on account of a heavy snow storm and that on account of a very severe snow storm at Chicago all belt roads had discontinued accepting cars. Assurances that an adequate supply of cars will be furnished for the transportation of food supplies for export to the allies was given by Director General McAdoo at a conference with commissioners representing the British, French and Italian governments on Saturday and some discussion was given to the question of diverting more export freight to gulf ports.

Director General McAdoo has instructed, in the matter of embargo on the Pennsylvania Lines east of Pittsburgh, Baltimore & Ohio east of the Ohio River, and Philadelphia & Reading, that the following exceptions be made:

(a) Food for animals.

(b) Material used in the operation and upkeep of coal mines.

To provide for the rail movement of food and supplies consigned to the French, British and Italian governments, for ports on the North Atlantic seaboard, already accepted or under permit, arrangements have been made to consolidate these shipments and move them in solid trains, or groups of cars, east from Chicago, St. Louis and intermediate terminals.

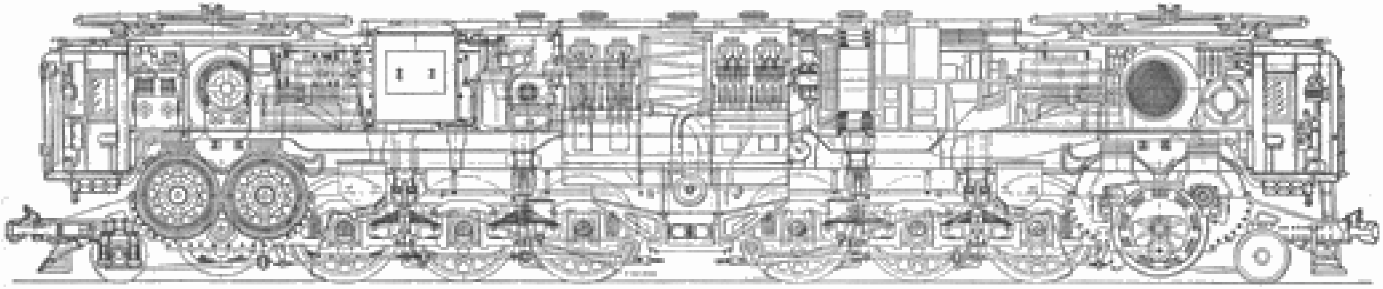
Pennsylvania Electric Locomotive

A Description of Interesting Details in the Running Gear Construction and in the Electrical Equipment

TESTS have recently been made on the Philadelphia-Paoli electrified section of the main line of the Pennsylvania Railroad, of the experimental electric locomotive which has been built for main line freight service by the Pennsylvania Railroad and the Westinghouse Electric & Manufacturing Company. A brief description of this locomotive, including the principal dimensions, was published in the July issue of the *Railway Mechanical Engineer*, page 379. It is the largest electric locomotive which has so far been built, having a starting tractive effort of 130,000 lb. and a total weight of 240 tons, of which 198 tons is carried on the drivers.

The locomotive has a nominal one hour rating of 4,800 hp. at 20.8 miles an hour, which is equivalent to a tractive effort of approximately 87,000 lb. The continuous rating is 4,000 hp. or 72,000 lb. tractive effort at a speed of 20.85 miles an hour, with the motors connected in parallel. For starting and slow speed operation, a "cascade" connection of the two motors on each truck unit is provided. When regenerating at continuous capacity, the locomotive is capable of returning to the trolley system 4,400 hp. at a speed of 21 miles an hour.

In service between Altoona and Johnstown, where it is the intention eventually to use locomotives of this type, it is proposed to operate trains with one locomotive at the head end and one pushing. The continuous capacity at a speed of 20.85 miles an hour enables a trailing load of 2,300 tons to be hauled up a one per cent grade, 4,100 tons up a .5 per



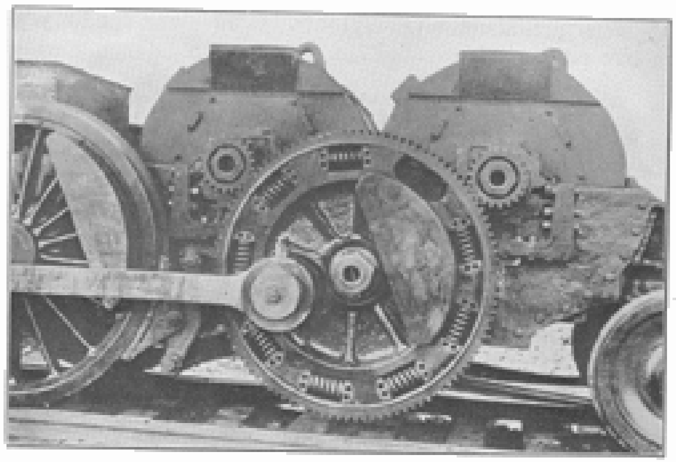
Longitudinal Section of the Pennsylvania Electric Locomotive cent grade, or 11,000 tons on level track. Two locomotives operating under the proposed plan are expected to handle 3,900 tons westbound, where the ruling grade is 2 per cent, and to handle 6,300 tons eastbound over a ruling grade of 1.33 per cent. The speed chosen is considered to be about the maximum desirable for the operation contemplated and is governed by the size of trains as well as the characteristics of profile and alinement.

In the previous article was given a general description of the construction of the locomotive, but there are a number of features of the locomotive, both mechanical and electrical, which are worthy of more detailed consideration.

The method of securing a rigidly maintained gear center distance may be seen in the illustration showing the flexible jack shaft gear and motor pinions with the casing removed. The jack shaft bearing brass consists of a solid bronze bushing pressed into an eye in the side frame. The removal of this brass involves the removal of the main gear center from the jack shaft. The armature bearings are contained in housings which are fitted into pockets 27 in. wide by 14⅜ in. deep in the top of the frame casting. These pockets depart from the rectangular in that the sides are tapered 1 in. in 16 in., the housing being forced into the pockets under a pressure sufficient to produce local stresses in excess of any that will be imposed in service. The housings are then bolted in place both horizontally and vertically. The center distances between the gear and the motor pinions are, therefore, as securely fixed as if all three bearings were in an integral casting.

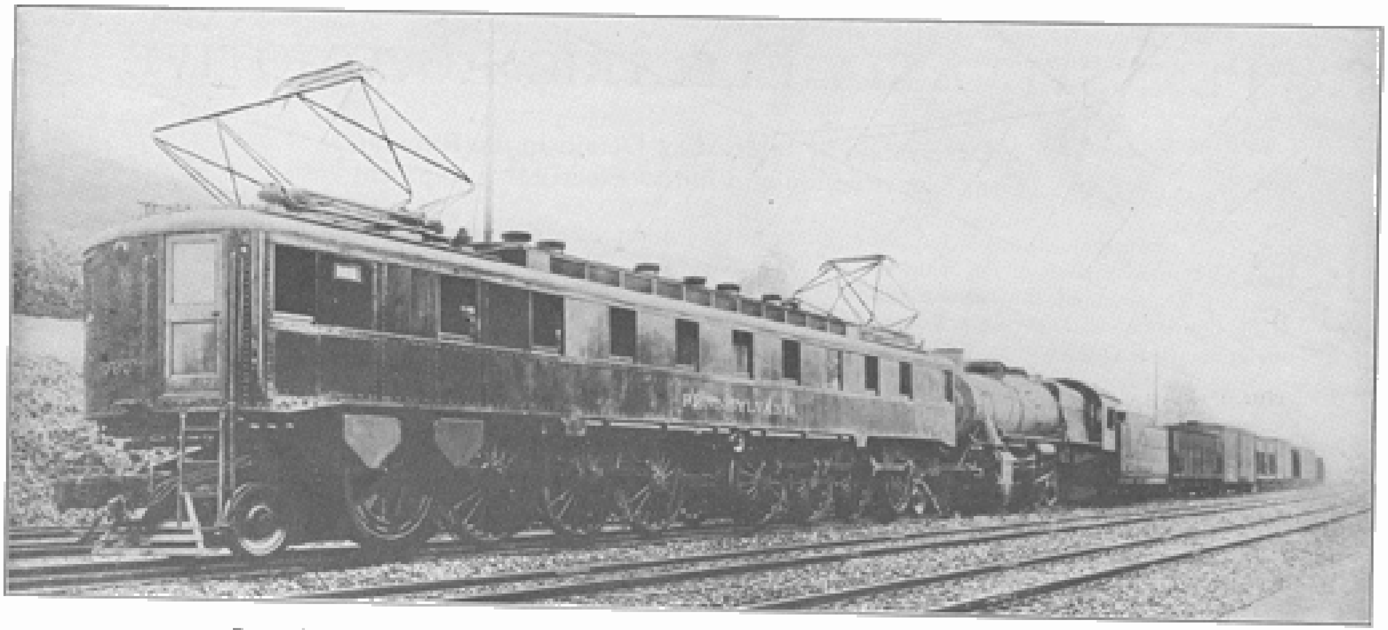
The active iron of both motor stators on each truck is mounted in a unit motor frame and locomotive cross-tie casting, which also surrounds the jack shaft. The armature bearings are arranged for oil ring lubrication, while the jack shaft is fitted with oil and waste lubrication, a large which is located in a counterbore in the outer face of the gear center. A heavy key in the taper fit insures the proper quarter of the crank pin. The crank pin is 8¼ in. in diameter and has a throw of 30 in. Opposite its center is a lead filled counterbalance with proper angular offset to compensate for transverse unbalance. A complete counterbalance is thus secured for all operating speeds.

The flexible gear is of the Westinghouse type which was



Motor and Jack Shaft Mounting

developed for railroad service and has previously received wide application both on cars and locomotives. This, however, is the first commercial application in connection with rod drive and no other railroad application approaches it in the amount of power transmitted. The gear has a face 10 in. in width which is a radical departure from previous

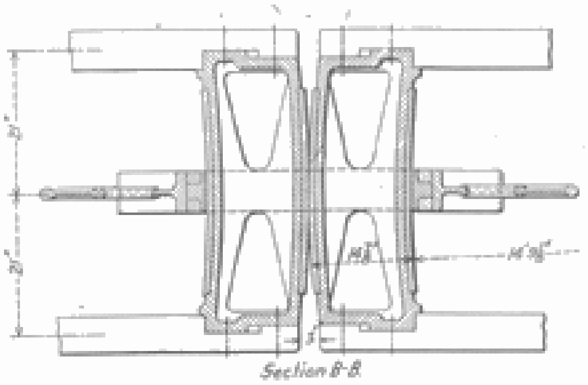


Pennsylvania Electric Locomotive Hauling an Idle Steam Locomotive and Freight Train

waste cavity being provided in the side frame casting above the jack shaft bearing.

The body of the jack shaft is 11⅛ in. in diameter with a long taper on each end to receive the gear center. The shaft is hollow, a hole 3 in. in diameter extending through from end to end. The gear center is of cast steel with a long hub which extends through the bearing brass and forms the running surface of the journal. The bore of the gear is tapered throughout its length and fits the taper on the end of the jack shaft. The gear center is pulled home to its seat on the shaft by a heavy nut on the end of the shaft, railroad practice with overhung gearing. This width is made practicable by dividing the gear rim at its midwidth into two rings, independent flexibility being provided for each ring relative to the gear center. The gear pinions are integral and each meshes with both rings, the independent flexibility of which insures an approximately equal division of the maximum load. The pinions and gear rims were manufactured by the R. D. Nuttall Company and are of heat treated steel.

The foundation of the cab structure consists of two built-up Z-shaped girders 26 in. deep, which are spaced 6 ft. 1⅛ in. apart. To the top of these girders is riveted a cover plate upon which the electrical apparatus is secured. At the mid-length of the cab is a built-in well 15 in. deep by about 3 ft. in width, containing the electrolyte supply from the liquid rheostat, the sides of which are supported from the center girder. To the bottom of this tank is secured the articulating device, which is of unique construction; in effect it is a link by means of which the inner bumper beams of the two truck units are held in contact, and by means of which all traction stresses are transmitted from the frames of one truck unit to those of the other through the bumper beams, without imposing any stresses upon the cab structure other than those due to its own inertia.



Section Plan of the Curved Bumper Castings and Articulating Link

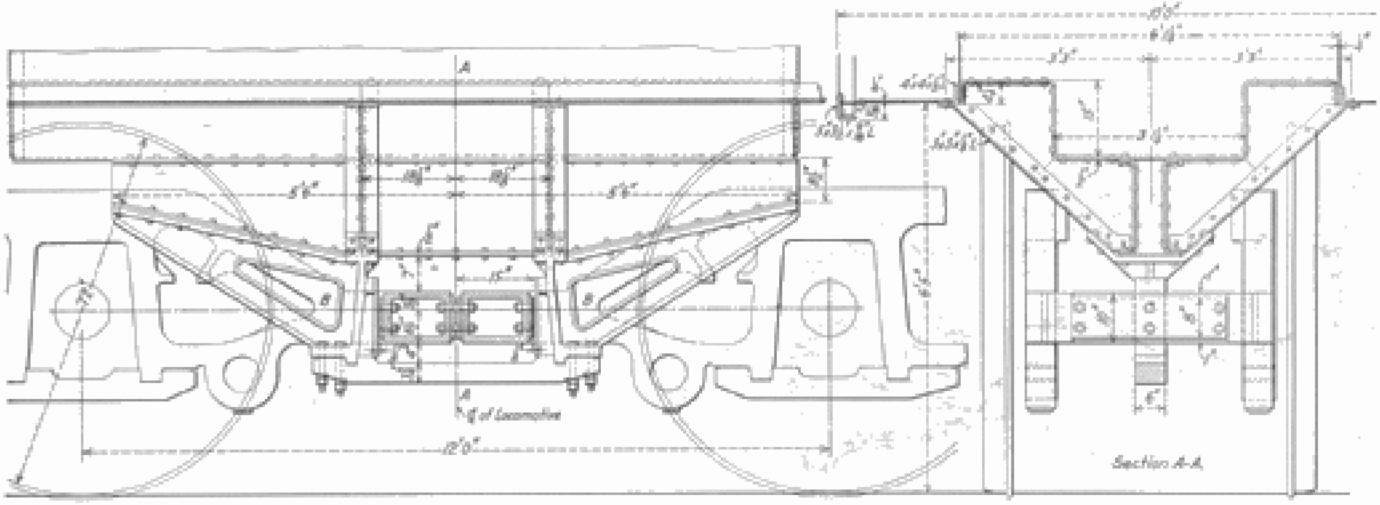
The inner bumper beam of each truck unit is a steel casting of box section, the vertical faces of which are circular arcs with radii equal to the distances from the center of the cab center pin bearing. The two castings are thus in rolling contact with each other as the angularity of the center lines of the two trucks changes, due to track curvature. Supported from the bottom of the electrolyte well by means of pressed steel channels are two steel castings, each of which forms one jaw of a longitudinal pedestal spanning the two bumper beams. This pedestal is closed by a binder generally similar to the usual type of locomotive driving box pedestal binder. The faces of the cast steel jaws are tapered and are covered by long vertical extensions on the binder to which are bolted steel wearing plates. When the locomotive is in operation the inner face of each bumper beam is in sliding contact with one of these plates. Both the inner and outer surfaces of the steel bumper beams are protected by steel wearing plates one inch thick, and held in place by countersunk bolts.

The longitudinal cross section of the locomotive shows in detail the arrangement of the apparatus in the cab. Single-phase current at a potential of 11,000 volts is collected by a pantagraph trolley, thence following a path through an oil circuit breaker to the primary of the transformer from which it is led to the framework of the locomotive, the circuit being completed through the rails to the substation. The secondary of the transformer supplies power to the phase converter, which may be considered as a combined motor generator, transposing a portion of the power to a phase displacement of 90 deg. from that of the transformer secondary voltage. This, together with the direct supply from the secondary of the transformer, forms a two-phase source of power which is combined by means of a Scott connection to give virtually three-phase energy.

A small single-phase motor which is mounted on the shaft of the phase converter is used in starting to bring the phase converter up to synchronous speed. It is then automatically cut out and used as a direct current generator to excite a winding on the rotor of the phase converter, to obtain a power factor of unity.

A series of taps is used on the main transformer partly to regulate the drop in the secondary voltage of the phase converter through its impedance when operating under heavy loads, and the rise in voltage when regenerating; also to correct the distortion of the phase of the secondary voltage under varying loads. Electro-pneumatically operated unit switches are used to change the various taps on the transformer in such a way as to enable the change to be made from one tap to another without disconnecting the phase converter from the secondary of the transformer, or momentarily short circuiting the transformer coils.

Three-phase power is supplied to each of the four motors through a set of five electro-pneumatically operated unit switches. These motor primary switches are also used as reversing switches. One is used commonly for both forward and reverse operation, and the other four switches are used in pairs to interchange the connection of two of the phases for obtaining forward or reverse rotation of the motors.



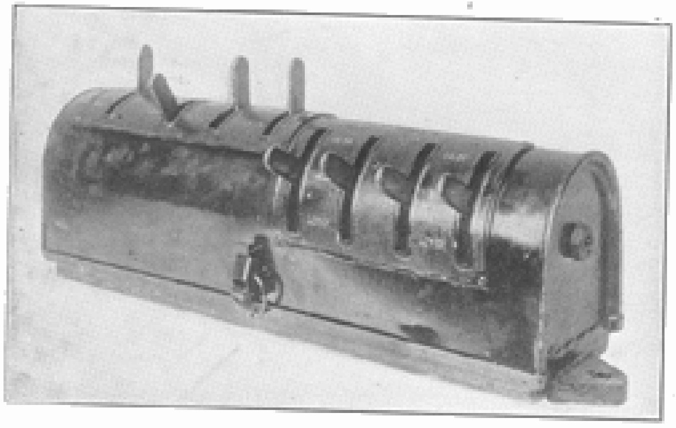
The Articulating Device—Pennsylvania Electric Locomotive

The motors are arranged for two-speed combinations, or normal regenerating positions, corresponding to approximately 10 and 20 miles per hour. On the low speed, each pair of motors is connected in cascade; on the high speed, the motor primaries are connected to the three-phase supply in parallel, each secondary being connected to a regulating liquid rheostat. The control is arranged so that the change from one speed to another is made without losing more than half the accelerating or regenerating torque, this being accomplished by a progressive transition of the pairs of motors.

The liquid rheostats, which govern the acceleration of the driving motors, are located in two separate tanks, the castings of which are built as a part of the cab frame. Each tank contains two sets of electrodes. The liquid is circulated continuously through each of the tanks by centrifugal pumps. The level of the liquid in each tank may be varied independently by means of tubular overflow valves, which are controlled by differential air engines of the Westinghouse PK type. The rheostats are located in the center of the locomotive, one pair at each end of a cooling tower compartment containing two cooling towers. A small percentage of the liquid is by-passed to the top of the cooling towers and flows over the surface of the cooling trays back into the main tank. Air is blown over the trays in a direction opposite to that of the liquid. In this way the body of the electrolyte in the main supply tank is sufficiently cooled by the expenditure of a relatively small amount of energy for pump operation, and the sacrifice of but a small quantity of electrolyte through evaporation.

When the liquid level in the rheostats has reached its maximum height, which occurs when the overflow valves occupy their uppermost position, a set of switches is automatically closed to short circuit the secondary motor winding and cut out the rheostats. A small motor generator set, the motor of which is of the three-phase induction type, provides a source of direct current for energizing the field of the phase-converter motor when it is operating as a direct-current generator to excite the phase converter motor winding. Power to operate the control circuits and marker lights is also obtained from this set.

One of the illustrations shows the master controller with the case removed. The upper handle, which is designated the "speed" handle, has three positions, one each for the 10 and 20 mile per hour combinations, and one midway between these two which is used as the transition position to enable one pair of motors to be changed over to a new combination without losing the accelerating or regenerating torque of the other pair. The center handle on the master controller controls the acceleration of the locomotive. It has three positions, marked "raise," "hold" and "lower." A movement of the handle to the "raise" position and then



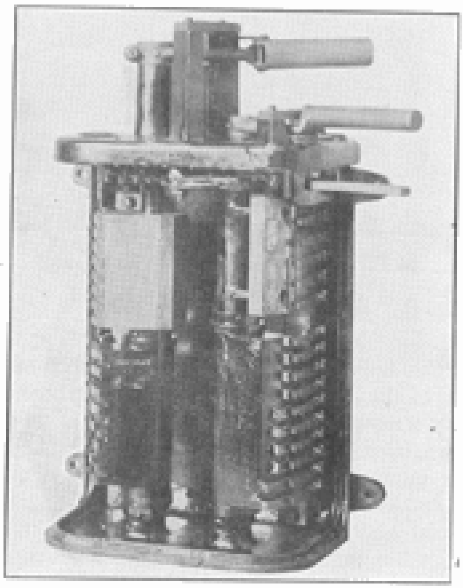
The Auxiliary Controller

back to the "hold" position gives a positive increment of rise in the liquid level of the rheostats. Moving the lever to the lower position and then back to the hold position results in a lowering of the level of the liquid in the rheostats. In this way the speed of the locomotive is controlled during either the cascade or parallel connections.

Overload protection is obtained by a current limit relay. This has the advantage of not opening the circuit, but operates first to arrest the rise of the liquid level in the rheostats and then to lower the level if the accelerating current goes beyond a certain fixed maximum value.

The liquid rheostats may be operated independently of each other by means of levers located in an auxiliary controller. This provides a means of equalizing the load on the different pairs of motors and of reducing the current supply to one pair, without affecting the other pair. Other levers are provided in the auxiliary controller for raising and lowering the trolley, starting and cutting out the phase converter, and operating the phase converter voltage and phase balancing switches.

Due to the inherent characteristics of the induction motor regeneration requires no extra control equipment. Manipulation of the master controller is exactly the same for re-



Master Controller with Case Removed

generation as it is for running. The manipulation of this type of locomotive is extremely simple for both running and braking, requiring no special knowledge other than the manipulation of the air brakes when handling heavy trains.

There are two compressor sets on the locomotive, each a four-cylinder, two-stage balanced compressor having a capacity of 150 cu. ft. These are manufactured by the Westinghouse Air Brake Company. The armature of the motor is fitted on the overhung shaft of the compressor. The motor is a Westinghouse four-pole commutator type for alternating current, and at 150 volts on each circuit develops 35 hp. continuous rating at 1,200 r. p.m. By making use of a single-phase commutator motor, the compressor set can be operated independently of the phase converter, the only other apparatus needed being the transformer. This motor has characteristics similar to a series motor and gives a high torque at starting. The compressor sets are controlled automatically by electro-pneumatic governors.

There are two sets of motor driven blowers on the locomotive. These blowers force air through ducts to the main motors, phase converter and main transformer. They are mounted one at each end of the cab. In the event of failure of one set, the air ducts and dampers are so arranged as to supply air to all the apparatus in the cab from the other set.

This feature also makes it possible to shut down one blower set while switching, and also to reduce stand-by losses. Although normally operating three-phase, the blower motor will run single-phase and act as a phase converter for the circulating pump motors. After a run, the phase converter may therefore be shut down and the blower motors will continue to run on single phase after having been brought up to speed on three-phase while the phase converter was in operation. This makes possible a further reduction in stand-by losses.