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PROPOSED CLASS 5AT HIGH PERFORMANCE 4-6-0 STEAM LOCOMOTIVE ENGINEERING SPECIFICATION

1. Contents

1.1. This specification lists the major component parts and assemblies which will make up the proposed Class 5AT high performance 4-6-0 locomotive. Its purpose is to set down in one document the design's most important constructional features.

1.2. This specification is based on engineering considerations that are not necessarily given here.

1.3. At this stage the specification cannot be definitive, as the optimum form of components and assemblies may only become known as the detail design process evolves. All items listed in this specification are therefore subject to revision during the detail design stage. In some cases the final choice from alternative designs will best be made during detail design when the alternatives can be considered in depth, or it may be dictated by manufacturing considerations. Such alternatives are given either in the body of the specification or at the end, in the latter case being referred to by numbers in superscript brackets ( ).

1.4. Where appropriate, the Fundamental Design Calculation (FDC) referring to the item concerned is given.

2. General Considerations (refer to FDC's 1.1, 1.2, 1.3.F, 1.4, and 16)

2.1. The locomotive, excluding the tender, shall be based on the size and format of the British Railways Standard Class 5MT 4-6-0 design of 1951, this being a type and size of locomotive most suited to the intended duty of main line leisure train service. A characteristic of this type is the deep narrow firebox, which is most suited to high combustion rates (see Chapelon, *La Locomotive a Vapeur*, English Edition, pages 36 - 37). In particular, in order to facilitate certification to run on Network Rail controlled infrastructure and give a wide route availability, it shall conform to this former design in respect of:

2.1.1. Maximum axle load (20 metric tons)

2.1.2. Axle spacing and lateral movement

2.1.3. Coupled wheel diameter (1 880 mm)

2.1.4. All overall dimensions constrained by the moving structure gauge

2.2. The locomotive is to be capable of a continuous drawbar power on level tangent track of 1 890 kW (2535 hp) at 113 km/h (71 mph), requiring a cylinder power at that speed of some 2 380 kW (3 200 hp). The maximum sustainable cylinder power shall be approximately 2 580 kW (3 460 hp) at approximately 170 km/h (106 mph).

2.3. Component design, brake performance, balancing and the stability of the locomotive as a vehicle are to be suitable for 200 km/h (125 mph) with a view to a continuous operating speed of 180 km/h (112,5 mph).

2.4. The adhesive weight is to be 60 metric tons.

2.5. The nominal starting tractive effort at the wheel rims is to be 146 kN (32 830 lbf).

2.6. To give a large operating range without need to replenish fuel or water supplies (approximately 600 km under representative average main line operating conditions) the locomotive is to be coupled to a high capacity double-bogie tender carrying a total of approximately 53 metric tons of supplies.

2.7. The design shall meet the requirements of Network Rail, Railway Safety and HM Railway Inspectorate for high-speed running to the maximum extent possible within the format of a conventional steam locomotive. The extent of conformance with Network Rail's *Railway Group Standards* is not covered by this specification, but it is expected to be comprehensive. Derogation shall be sought for any items where non-conformance is unavoidable due to the inherent nature of steam traction.

2.7.1. The locomotive shall be fitted with the type of train protection system (ATP/TPWS/ETCS) required for a double-manned locomotive running at up to 180 km/h.

3. Mainframe and Associated Components (refer to FDC 14)

3.1. Welded plate frames shall be used, with the main longitudinals spaced as far apart as possible to allow the maximum width of firebox.

3.2. The mainframe longitudinals, particularly between the cylinders and driving axle, shall be well braced laterally by welded-on cross-members. The frame braces shall *as far as possible* be opposite points of maximum loading, and their design and placing shall give maximum lateral stiffness to the complete

structure and maximum resistance to the bending effect on the frame of the cylinder steam pressure forces. In particular a continuous horizontal cross-member, lying immediately over the horn gaps, shall extend from the back of the cylinder block to the back of the driving axle horn gaps. The welded H-section frame design developed in France and post-1950 German welded frame practice shall be taken as guides to mainframe design.

3.3. The horn stays are to be as robust and securely fitted as possible.

3.4. The cylinder block, rear dragbox, horn blocks, horn stay brackets, spring hanger and equalizer brackets, motion brackets, etc., shall be welded to the mainframe longitudinals.

3.5. The front buffer beam and dragbox may be bolted to the mainframe by shear bolts as part of the required energy-absorbing crumple zone at the front of the locomotive.

4. <u>Boiler, Superheater and Smokebox (refer to FDC's 9, 10, 11.1, 11.2, 11.3, and 12)</u>

4.1. The basis of the boiler design, with respect to satisfying current certification and insurance requirements, shall be subject to prior agreement between the designer and the regulating and insurance bodies. A suitable basis is outlined in FDC 11.1. item [2]. Provisionally, the boiler shall be of all-steel welded construction, built to standards of construction which comply with either (i) the current boiler code(s) in force in the user country or (ii) any acceptable former locomotive boiler code, *whichever is the more stringent*. In this way current industrial boiler design rules and the former design rules particularly applicable to locomotive boilers are both satisfied.

4.1.1. Depending on an acceptable method of construction being available, the boiler shall have a Belpaire firebox.(1)

4.2. The boiler shall have a normal maximum working pressure of 2 100 kPa. It shall be designed for, and the safety valves set to, a slightly higher figure, i.e. 2 130 kPa, = the authorized maximum working pressure, for ease of keeping the normal working pressure at 2 100 kPa during service without the 'pop' type safety valves lifting. The maximum permitted pressure during safety valve discharge = 2 170 kPa.

4.3. The boiler shall be capable of an actual evaporation of not less than 17 000 kg/h (heat transfer rate = 49,0 GJ/h, giving an <u>*equivalent*</u> evaporation of 21 700 kg/h) at an overall efficiency ≈ 82%.

4.4. The principal overall dimensions of the BR Class 5MT boiler and smokebox shall be retained.

4.4.1. The front part of the boiler barrel shall be arranged as a 'Chapelon type' pre-heater.

4.5. The preferred fuel shall be diesel fuel/gas oil.(2) The burner and associated equipment is to be 'state of the art' for a narrow firebox and is required to handle a heat release rate per unit of firebox volume of up to 12 GJ/m^3-h with high combustion efficiency.

4.5.1. The oil burning equipment must prevent any undue concentration of heat flux through any part of the firebox heat transfer surfaces.

4.5.2. The completeness of combustion achieved by the oil burning equipment must prevent any undue build up of oily deposits on any boiler, superheater or smokebox surfaces.

4.5.3. The oil burning equipment shall allow the combustion rate to be readily adjusted to match the steam demand over the boiler's full load range. A pilot light is to be provided to keep the boiler in steam when the locomotive is not being used and to provide a source of ignition for the main burner(s).

4.5.4. Atomizing steam is to be superheated.

4.6. The combustion air is to be preheated by exhaust steam in a heat exchanger, situated immediately upstream of the firepan, to a temperature of not less than 100°C. The combustion air intake is to face forward to take advantage of the "ram effect" when the locomotive is travelling forward.

4.7. The firebox crown shall be protected against overheating due to low water by 'drop' type fusible plugs.

4.8. The firebox arch, which is to be long, may be either of refractory brick or heat resisting steel.

4.9. Type E superheater elements shall be used.

4.10. The small and large boiler tubes shall have a length : equivalent diameter ratio of 104 : 1 and approximately 158 : 1 respectively.

4.11. The dry pipe intake shall be set high up in the dome.

4.12. A multiple valve throttle shall be incorporated in the saturated side of the superheater header, for convenience of controlling valve liner cooling steam flow. Its camshaft crank shall be connected by external rodding to a pull-out type throttle lever in the cab, the throttle valves being designed to shut automatically in case of broken or uncoupled linkage.

4.13. The superheater shall be designed to give a steam temperature at inlet to the cylinders of 450°C at the maximum rated evaporation, together with minimum steam flow pressure drop.

4.14. The type E superheater elements shall be of plain tubing, with the addition of welded-on fins to increase heat transfer.

4.14.1. The superheater elements are to be bolted to the superheater header, the necessary bolt elasticity being achieved by disc springs.

4.14.2. The superheater header is to be designed to minimize heat transfer between the saturated and superheated compartments.

4.15. The boiler shall have 70 small tubes of 44,5 mm o/d x 2,6 mm wall thickness and 96 large tubes of 88,9 mm o/d x 3,6 mm wall thickness.

4.15.1. The boiler tubes are to be welded to the firebox tubeplate and expanded in the smokebox tubeplate.

4.16. Two independent boiler feed systems shall be fitted, each with a capacity of not less than the boiler's rated maximum evaporation (≈ 17 000 kg/h): (i) a live steam injector, preferably with single-lever control, and (ii) a steam-operated reciprocating feedpump delivering via two cylindrical closed type (shell and tube) feedwater heaters situated on either side of the top of the boiler barrel immediately behind the chimney and giving a feed temperature of not less than 100 °C over a wide range of evaporations (≈ 110 °C at maximum rated evaporation with clean heat transfer surfaces). Condensate from the feedwater heaters and (possibly) exhaust steam from the feedwater pump and are to be piped to the tender tank.

4.17. All boiler feed controls are to be conveniently grouped on the fireman's side of the cab.

4.18. The cylindrical smokebox shell, of corrosion resistant steel, shall be long enough to accommodate all items within it without detrimental compromises in their design.

4.18.1. The smokebox door shall be similar to that of the BR Class 5MT, except that it may be arranged to close against a resilient seal and/or be tightened by peripheral dogs to better guarantee air-tightness.

4.18.2. Inspection openings and associated covers may be fitted to the smokebox shell approximately level with the bottom of the superheater header.

4.19. The smokebox saddle shall be integral with the cylinder block and shall be of the 'high saddle' type with integral steam passages from the smokebox to the steam chests, these passages tapering outwards towards the steam chests and forming part of the steam chest volume.

4.20. The branch steam pipes from the superheater header shall be 139,7 mm o/d x 4,5 mm wall thickness. If bolted on, the necessary bolt elasticity shall be obtained by disc springs.

4.21. The smokebox shall be bolted or welded to the smokebox saddle, the back of the firebox supported on the hind dragbox by an expansion plate, and a single slide bearing shall provide an intermediate boiler barrel – frame connection, all connections being designed to minimize boiler-mainframe heat transfer.

4.22. The locomotive shall be fitted with a double exhaust of the type detailed in FDC 12, incorporating a co-axial Kordina upstream of the blast nozzles.

4.22.1. The double chimney shall be secured to the smokebox shell by the usual curved flange.

4.23. The whole of the boiler shall be extremely well insulated. The insulation shall be as thick as possible, whilst allowing good forward visibility from the cab and without taking up space necessary for other equipment, up to a maximum thickness, where space permits, of 150 mm. Reduced thickness insulation is to be applied to the lower firebox sides lying between the mainframes, to minimize mainframe longitudinal expansion due to radiation from the firebox.

4.23.1. The insulating material shall satisfy all criteria that shall be specified in terms of such parameters as thermal conductivity, density, mechanical strength, long life, etc.

4.23.2. The clothing shall be such as to provide adequate support and protection for the insulation and guarantee its long-term effectiveness.

4.23.3. Pars. 4.23.1. and 4.23.2. apply to all thermally insulated surfaces throughout the locomotive.

5. <u>Cylinders and Driving Gear (refer to FDC's 2.1, 2.2, 2.3, 3, 4, 5, 6, 7, 8, 13 and 17)</u>

5.1. The engine shall be of 2-cylinder simple expansion type, with cranks set at 90º, r.h. cranks leading.(3)

5.2. The piston stroke shall be 800 mm and the cylinder bore diameter 450 mm.

5.3. The cylinders shall be of steel. The cylinder block, comprising both cylinders and steam chests, etc., frame stretcher and smokebox saddle, shall preferably be cast as a single piece, or alternatively may be fabricated (welded) or of part cast / part fabricated construction. It shall be welded to the mainframe longitudinals immediately behind the cylinders (as, for example, on the DB 10 Class 4-6-2's), and bolted to the front frame extensions immediately ahead of the cylinders by shear bolts, to satisfy the requirement for an energy-absorbing 'crumple zone' at the front of the locomotive.

5.4. Liners of pearlitic cast iron (diesel quality) shall be fitted to the cylinders. These liners shall be supported in the cylinder bore at the ends and centre only and the annular spaces around the liners shall be filled with insulating material and / or the liner o/d coated with a thermal barrier coating.

5.4.1. The cylinder liners (and valve liners and cast iron piston and valve rings, as appropriate) may be surface treated for wear resistance, e.g. Sulfinuz or Tufftride processes or hard chromium plating.

5.5. The steel front and back cylinder covers shall be bolted on, and a suitable thermal barrier coating is to be applied to their inside surfaces (and also where possible to all other non-rubbing cylinder surfaces directly exposed to high-temperature steam).

5.5.1. The cylinder covers shall be fitted with fracture discs or spring-loaded relief valves (whichever is better) to prevent damage from excess pressure due to water ingress.

5.6. Twin piston valves are to be fitted to each cylinder, operated by a single set of Walschaerts valve gear on each side of the locomotive, to provide large steam flow areas yet minimize cylinder clearance volume (calculated value 10,6%).

5.6.1. Piston valves shall be of Porta type and 'state of the art'.

5.7. The pearlitic cast iron (diesel quality) valve liners, two per valve, shall incorporate all proven thermal and tribological refinements, to include rubbing surface cooling. With oil firing, steam ports of trapezoidal shape to improve the regularity of boiler combustion air flow shall be used only if specifically recommended by oil-firing specialists.

5.8. The steam chests shall have an internal volume = the piston swept volume.

5.9. The various cylinder steam ports and passages shall be designed for optimum steam flow.

5.10. The cylinders and steam chests shall be provided with air operated drain valves, controlled by a hand operated valve in the cab.

5.11. The cylinder block shall be thoroughly insulated, using welded-on clothings to seal the insulation in place wherever possible (no pipe couplings shall be made under any clothings). Exposed surfaces of the smokebox saddle and, if practical, those parts of the mainframes next to the cylinders, shall also be insulated by the same means.

5.12. No snifting or by-pass valves shall be fitted.

5.12.1. Drifting shall be in mid-gear with a very small amount of drifting steam supplied by putting the throttle lever against a drifting stop.

5.13. All reciprocating components shall be carefully designed for minimum mass: *this is of the utmost importance for a high-speed 2-cylinder locomotive.*

5.14. Lightweight fabricated pistons of high-strength (SAE 4340) steel, each carrying 6 diesel-quality rings, shall be used. Each piston head shall be welded to a hollow piston rod and fitted with a hollow tail rod.

5.15. Piston rod, tail rod, & valve spindle packings shall be of metallic multiple-element fully-floating type.

5.16. The Timken-type split crossheads with taper roller bearing gudgeon pins shall be as light as possible, each having two white-metalled aluminium alloy shoes sliding on 'alligator' slidebars.

5.17. The connecting rods shall be of lightweight I-section type in high-strength (SAE 4340) steel with a spherical roller bearing at the crankpin end.

5.18. The coupling rods of I-section and SAE 4340 steel shall be fitted with a spherical roller bearing at each crankpin. The knuckle joints behind the main crankpins may be of the Fischer type.

5.19. The connecting and coupling rod roller bearings shall be mounted on the crankpins by taper adapter sleeves. They shall be grease lubricated. Particular attention shall be paid to all crankpin roller bearing seals, and in liaison with the roller bearing suppliers a more effective alternative to the normal labyrinth seal found to eliminate grease throwing, if possible.

5.20. The driving and coupled wheel centres shall be of the BFB type.[(4)] The rim section should be the absolute maximum allowed by the axle load / unsprung mass.

5.20.1. The shrink fit of the driving and coupled wheel tyres to the wheel centres must guarantee that the tyres will not loosen during severe braking, in which case they may be shrunk on the BFB wheel centres without retaining rings. The tyre profile shall be as mandated by Network Rail (e.g. Heumann type), if possible altered at the outer part of the tread to improve adhesion.

5.21. The rotating masses on each wheel, including those of the eccentric crank and eccentric rod, shall be precisely dynamically balanced on the same wheel. The percentage of the reciprocating masses on each side of the locomotive which is balanced shall be worked out in agreement with Network Rail. With a 'solid' (unsprung) engine-tender drawgear, no reciprocating balance is required, however balancing approximately 7,65% of the reciprocating masses per side on each coupled wheel and 4,4% on the main driving wheels, total = 19,7%, will give a smoother-riding locomotive without the dynamic augment due to reciprocating balance at 200 km/h exceeding that of the BR 5MT at its present maximum permitted speed of 120 km/h, by whichever criterion dynamic augment is measured, whilst at the same time the main driving wheel reciprocating balance reduces the dynamic augment due to connecting rod angularity to a minimum. The dynamic augment per axle and for the whole locomotive at 200 km/h (9,41 Hz) is less than allowed by the 1928 Bridge Stress Committee at 5 Hz.

5.22. The driving and coupled axles shall run in sealed grease-lubricated spherical roller bearings mounted in one-piece or split cannon type axleboxes.

5.23. The driving and coupled wheel axleboxes shall be provided with wedges as follows: driving axlebox; parallel guides at the rear and spring-loaded wedges at the front: leading coupled axlebox; fixed wedges at the rear and spring-loaded wedges at the front: trailing coupled axlebox; spring-loaded wedges at both front and rear (to allow for mainframe expansion between the driving and trailing

coupled axles due to radiation from the firebox). The position of the fixed wedges shall accord with the exact leading coupling rod lengths between bearing centres, and shall be lockable. The spring loading of the wedges shall be of the Franklin lever type, mounted transversely on frame cross-stays, as necessary to clear the underhung springs.

5.23.1. Where appropriate, rubbing surfaces of the axleboxes and their guides/wedges shall be fitted with wearing plates of wear-resistant material (e.g. 11-14% Mn. steel or non-metallic 'dry' materials).

5.24. The underhung driving and coupled axle springs on each side of the locomotive shall be compensated, giving, together with the bogie, 3-point suspension of the sprung masses of the engine as a whole.

5.25. The Walschaerts valve gear shall be designed to give the required valve events, priority being given to obtaining good valve events in the most frequent running cut-offs, taken as from mid-gear to 30% in forward gear. Equal front port and back port cut-offs at 25% forward gear cut-off are aimed at. The full forward gear cut-off shall be 75% and full reverse gear 69% (average of front and back ports in each case). The valve gear shall be as light as possible. The eccentric rods shall be fitted with sealed grease-lubricated spherical roller bearings at the eccentric crank ends, and other joints throughout the gear with sealed grease-lubricated (full complement) cylindrical roller or needle roller bearings, as appropriate. The expansion links shall be of the box design (CSD type, but with two trunnions), and the dieblock-link rubbing surfaces (and possibly the dieblock bearings) shall be mechanically lubricated with machine oil fed via flexible hoses to the radius rods. The manual screw reverser shall be power assisted if possible.

6. Leading Bogie (refer to FDC 16)

6.1. The leading bogie frame shall be of cast or fabricated (welded) steel.

6.2. The maximum lateral displacement of the bogie shall not be less than that of the BR Class 5MT (± 101,6 mm at the pivot).

6.3. Geared roller centring shall be used, the centring force - displacement relationship being arranged to give maximum stability during running together with ease of negotiating small-radius curves.

6.4. Inboard axle bearings shall be used. The bogie wheelsets shall run in sealed grease-lubricated spherical roller bearings mounted in one-piece cannon-type axleboxes. Axlebox details shall, where appropriate, be similar to those of the driving and coupled wheel axleboxes.

6.5. The bogie wheels shall be of solid disc type, and shall, if appropriate, conform to general current practice for non-powered railway vehicle wheels.

6.6. If a conventional steam locomotive bogie suspension is considered acceptable for the locomotive's maximum permitted speed, weight transfer shall be via a combination of semi-elliptic + coil springs on each side of the bogie to equalizing beams distributing the load equally to the two axles, with disc springs between each equalizing beam and axlebox (as on the DB 10 Class). The semi-elliptic, coil and disc springs are all in series, giving soft springing.

7. Brake Gear (refer to FDC 15)

7.1. The locomotive itself shall be fitted with air brakes and shall be equipped to work air braked stock and, only if necessary, vacuum braked stock, the vacuum train pipe pressure then being controlled by an air/vacuum proportional valve. Brake operation and performance shall be, as far as is possible, 'state of the art', and the stopping distance – speed curve shall satisfy Network Rail's requirements at all speeds up to and including the locomotive's maximum permitted speed.

7.2. A reciprocating steam-driven air compressor of adequate capacity, bracketed from the left side mainframe longitudinal, shall be fitted for supplying compressed air for braking and air-operated auxiliaries. Its steam exhaust shall be piped back to the tender tank via an oil separator.

7.3. Clasp brakes, with brake blocks acting on the wheel tread, shall be fitted to all wheels, with the exception of the rear wheels of the leading bogie where space limitations permit braking at the front of the wheels only. The line of action of clasp brake forces shall pass through the axle centre line. DR-type double brake blocks shall be used on the coupled and tender wheels and possibly the leading bogie wheels.

7.3.1. As an alternative to tread brakes, disc brakes, either wheel or axle mounted, may be considered for non-powered axles.

7.4. The engine and tender brake force shall be regulated by a (centrifugal) pressure regulator so as to be a function of the locomotive's speed (higher at high speed).

7.4.1. The maximum brake force at the rail on the engine and tender, as a percentage of the locomotive weight at average supplies, shall be approximately 5,5% up to 60 km/h and 13,6% for speeds > 60 km/h and up to 200 km/h. The former is superior to the brake force of the BR 5MT and the latter to that of modern high-speed traction in the UK.

7.4.2. The tender shall be fitted with axle load monitors and a brake pressure regulating valve to

automatically regulate the maximum brake force according to the actual tender weight as supplies are used up.

7.5. For slip control there shall be an independent anti-slip brake (which may be hand operated or foot pedal controlled) supplying air to the brake cylinders braking the driving and coupled wheels only. This may also function as a low-speed independent engine brake.

7.6. The brakes shall be arranged so that full sanding is automatically applied during an emergency brake application.

7.7. The parking brake, to be spring applied and air released, shall act on the tender wheels only.

8. Sanding Gear

8.1. 'State of the art' foot pedal operated air sanding shall be fitted. All powered wheels shall be sanded for forward running and the trailing coupled and driving wheels for reverse running. In addition an extra independent sand supply shall be fitted for semi-continuous light sanding ahead of the leading bogie front wheels when long stretches of bad rail are encountered. All sand nozzles shall be bracketed from the axleboxes for optimum alignment. The large capacity sandboxes shall be located under the running boards/boiler/cab, and for the semi-continuous sanding inside the front streamlined cover behind the buffer beam.

8.2. A rail washer, using boiler water, may be fitted to clear sand from the rails behind the trailing coupled wheels during normal (non-emergency brake) sanding.

9. Lubrication Equipment (refer to FDC 17)

9.1. It is intended that the locomotive shall require lubricating only by servicing staff, i.e. that locomotive crews shall have no lubrication duties.

9.2. Cylinder oil, which may be of synthetic type suitable for the envisaged rubbing surface temperatures, shall be used for pistons; valves; piston rod, tail rod and valve spindle packings; piston tail rod bearings; slidebars; and reciprocating steam-driven auxiliaries. Except for auxiliaries fitted with their own lubricator, cylinder oil is to be fed to all these parts by a single mechanical lubricator supplied by a large capacity (approximately 100 litre) oil reservoir mounted under one running board. This lubricator may be driven from a point in the valve gear such that the oil feeds are a function of the engine cut-off. The valve oil feeds are to be direct to the valve liner rubbing surfaces, in such a way as to guarantee 'through the rings' oiling of the piston valves.

9.3. Machine oil with E.P. capability shall be used for all other oil-lubricated components, which may include all engine axlebox guides (if not of 'dry' material), the driving and coupled axlebox spring-loaded wedges, spring equalizing beam pivots, bogie pivot, engine-tender radial buffer, and expansion link dieblocks. Machine oil is to be fed to all such parts by a single mechanical lubricator supplied by a large capacity (approximately 100 litre) oil reservoir mounted under one running board.

9.4. Roller bearing grease is to be used for all roller bearings.

9.5. Soft grease is to be used for all rubbing surfaces not fitted with 'dry' materials which see little movement, such as the boiler slide bearing. It may also be used for any pin joints not fitted with roller bearings.

9.6. For mechanically lubricated items, an appropriate check valve is to be placed in the oil pipe as close as possible to the item concerned, and drip trays shall be fitted where necessary and possible, to prevent spent oil contaminating the tyres and rails.

10. Cab (refer to FDC 17)

10.1. The cab shall comply with health and safety features required by the controlling authorities.

10.2. Cab fittings shall, as far as possible, be of readily available proprietary type.

10.3. The cab shall be fully enclosed with a lockable access door on each side.

10.4. Windows for good visibility shall be provided at the front, sides and back of the cab, the last being placed in line with the inset in the tender sides.

10.4.1. The front and possibly the rear windows shall be provided with pneumatically or electrically operated wipers. A window washing spray, to clean (oily) dirt from the glass, shall be fitted.

10.4.2. The side windows shall slide open to allow easy vision ahead from a sitting position through a safety glass placed outside the cab, and to allow easy cleaning of the outside of the front windows from within the cab.

10.5. The cab front shall be inclined vertically and horizontally (similar to the Milwaukee F7 Class 4-6-4's) and the cab roof shall be extended forwards to provide a shield over the cab front windows.

10.6. The cab may (optionally) be steam heated using radiators, the radiator condensate being returned to the tender.

10.7. The cab shall be provided with ergonomically designed and located seats for the driver and fireman.

10.8. The respective controls for the driver and fireman shall be ergonomically arranged to be within convenient reach from a sitting position.

10.9. Foot pedal controls shall be provided for the sanding and (optionally) anti-slip brake (driver's side only) and the audible warning device (whistle / horn) (both sides).

10.10. The throttle lever (regulator handle) shall be of the pull-out type, its position lockable at the full open and shut positions only, and with a stop locating the drifting position.

10.11. The boiler gauge glasses shall be of the type most suited to the boiler's authorized maximum working pressure and alkaline boiler water (the tubular type is preferred if acceptable by these criteria). Their steam and water connections shall be provided with extension tubes of suitable length inside the boiler, to avoid false water level readings.

11. Electrical Equipment (refer to FDC 17)

11.1. A steam turbine driven electrical generator or generators, charging a battery system if necessary, shall be fitted, the whole system being of sufficient capacity to power all electrical equipment on the locomotive. The generator exhaust shall be piped back to the tender tank.

11.2. Lights for both directions of running shall be fitted which comply with the relevant Network Rail *Railway Group Standard.*

11.3. Suitable cab lighting shall be fitted, including an illumination of all gauges, which does not detract from the crews' vision ahead.

11.4. Other electrical equipment shall be fitted as required.

12. Tender

12.1. A tender with large fuel and (especially) water capacities is necessary to allow for the absence of replenishing facilities. The capacities shall be at least 7 metric tons of diesel fuel/gas oil and 46 metric tons of water, giving operating ranges under representative average main line service conditions of approximately 940 km and 615 km respectively.

12.2. The tender shall be of modern welded monocoque construction (i.e. no mainframe) in corrosion resistant steel. A gross : tare weight ratio of at least 3:1 shall be designed for, so that for a gross tender weight not exceeding 80 metric tons and an axleload not exceeding 20 metric tons the maximum quantity of supplies can be carried.

12.3. The tender shall be mounted on two 2-axle bogies of any suitable modern design (reconditioned bogies from existing stock may be used). The axles shall preferably be mounted on AP (rotating end cap) taper roller bearings.

12.3.1. Clasp brakes acting on the wheel treads or disc brakes may be used.

12.3.2. The locomotive's speedometer shall be driven from the leading tender axle.

12.4. The tender tank shall be extended down between the tender bogies in the form of a well, and shall be set inwards level with the bottom of the cab rear windows to provide backward vision from the cab.

12.5. Part of the tender tank may be partitioned off to provide a hot well for maximum heat recovery from condensate returned to the tender and for pre-precipitation of feedwater salts.

12.6. Effective dispensing apparatus for boiler water treatment chemicals shall be fitted in the tender tank.

12.7. Accurate fuel and water gauges, visible from the cab, shall be fitted to the tender front.

12.8. Fuel and water filling points shall be sited at a convenient position accessible from ground level, and shall have couplings compatible with those of delivery hoses. The fuel and water gauges shall be duplicated at the filling points.

12.8.1. A tender water filler hole may also be provided in the conventional position, at the top rear of the tender, if required (e.g. for operation on preserved railways). It shall be of large longitudinal dimension, to minimize the difficulty of "spotting" under water columns, and its cover door(s) may be pneumatically operated using a control valve accessible from ground level.

12.9. Any ladder provided at the rear of the tender up to the top of the tender tank shall be such as to prevent unauthorized climbing.

12.10. The length of the tender body shall be approximately 9 metres. This will give an overall length of engine and tender wheelbase of approximately 18,9 metres and an overall length over buffers of approximately 22,1 metres, slightly less than that of the largest former British steam locomotives. [The tender length must be such as to give an overall locomotive length compatible with available turning facilities and track layouts.]

13. Drawgear (refer to FDC 8)

13.1. The engine and tender buffers and drawgear shall be compatible with those of the stock to be hauled.

13.2. The engine-tender drawgear shall be of the 'solid' (unsprung) type, with a spring-loaded friction-damped intermediate radial buffer (e.g. of the Franklin type), this arrangement giving an engine-tender

coupling that allows the mass of the tender to act effectively to reduce fore-and-aft accelerations due to the unbalanced reciprocating masses.

14. External Outline

14.1. The locomotive shall have a smooth outline to minimize its rolling resistance. Partial streamlining of the front of the locomotive, similar to that of the DB 10 Class 4-6-2's, and including a streamlined cover at the front of the smokebox, hinged for access to the smokebox door, shall be used, not only to decrease frontal drag but also to improve exhaust lifting, the whole front of the locomotive being designed to maximize exhaust lifting and hence guarantee good forward visibility. The smokebox streamlined cover may also act as smokebox thermal insulation and as part of the front-end energy-absorbing zone, and if necessary may provide part of the yellow warning panel required for high-speed running. The sides of the locomotive and tender shall be as smooth and free from projecting fittings as possible.

14.2. Witte type exhaust deflectors shall be fitted.

15. Miscellaneous

15.1. All safety appliances and markings shall conform to current regulations.

15.2. The front of the locomotive, i.e. front frame extensions ahead of the cylinders, streamlined front casings of the running board and smokebox, and the exhaust deflectors, shall, if so required, be designed for energy-absorbing in case of severe impact.

15.3. Audible warning shall preferably be by chime whistle, supplemented by an air horn if mandated.

15.4. The locomotive shall be fitted for steam heating only if it will be required to work steam-heated stock.

15.5. Pipework shall be sited and supported so as to ensure accessibility and rigidity, and to minimize vibration, looseness and leaking joints. No water, steam or oil pipe connection shall lie over the coupled wheels or rails.

15.5.1. Consideration shall be given as to whether to use predominantly copper or steel piping.

16. Alternatives

1. (Par. 4.1.1.) A round-topped firebox may be used only if construction of the Belpaire type cannot be economically justified.

2. (Par. 4.5.) The boiler may be coal fired. This would require the following equipment not given in the main specification: Gas Producer firebox (restricted-free-air-area all-shaking power-operated firegrate with Hulson firebars, the shaking arranged for both automatic and manual operation; ashpan; supply of clinker control steam; secondary air intake with air preheater, and suitable air inlets in the firebox walls); mechanical stoker; coal bunker with coal pusher; means of self-cleaning and spark arresting in the smokebox. The use of coal firing may be expected to complicate the locomotive's design and cause undesirable secondary effects (such as internal smokebox plates increasing boiler gas flow resistance and interfering with the exhaust system design).

3. (Par. 5.1.) The proposed design will define 'state of the art' for 2-cylinder simple locomotives, and may serve as a reference level to which the performance of all other types of locomotive can be compared. Analysis has shown no net advantage for the 3-cylinder simple type compared to 2-cylinder simple, and whilst the 3-cylinder compound type, with one h. p. and two l. p. cylinders and with the l. p. cranks set at 90º, *might* offer slightly better thermal performance, more especially at lower speed, an overall thermal improvement sufficient to justify the extra design complexity and higher manufacturing cost is thought unlikely. The limited l. p. cylinder volume possible within the British moving structure gauge, with a conventional layout of the cylinders, is an important limiting factor on compound design and performance.

4. (Par. 5.20.) Scullin double-disc wheel centres would be preferred, but it is considered that manufacturing 'know-how' for such wheels is now probably a 'lost art'.

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